Better Metrics for Ranking SE Researchers

George Mathew, Tim Menzies, Senior Member IEEE

Abstract—This paper studies how SE researchers are ranked using a variety of metrics and data from 35,406 authors of 35,391 papers from 34 top SE venues in the period 1992-2016. Based on that analysis, we: deprecate the widely used "h-index", favoring instead an alternate Weighted PageRank(PR_W) metric that is somewhat analogous to the PageRank(PR) metric developed at Google. Unlike the h-index, PR_W rewards not just citation counts but also how often authors collaborate. Using PR_W, we offer a ranking of the top-20 SE authors in the last decade.

Index Terms—Software Engineering, Bibliometrics, Topic Modeling, Ranking

1 INTRODUCTION

One metric that is commonly used to detect a “good” researcher is the number of articles they publish at leading venues (e.g. the h-index). Such citation-based metrics has been criticized as an incomplete summary of the value of research. Many alternative schemes have been proposed but, so far, there is little agreement on which to use.

This paper studies the rankings of the 35,406 authors of 35,391 papers from 34 top SE venues in the period 1992-2016. Various ranking schemes are proposed including one method called PR_W that rewards both citation counts and how often researchers collaborate with each other. As shown below, PR_W is more trustworthy since it is numerically stable (defined below).

Using that stable ranking, we offer a ranking of the top-20 SE authors in the last decade.

Overall, this paper makes the following contributions:
1) We define tests for a “good” metric of scholastic excellence:
   (a) it should use information from multiple sources (not merely citation counts); (b) the rankings offered by that metric are stable across minor changes to its derivation parameters.
2) We define an automatic test for metric numeric stability.
3) We show that PR_W satisfies our tests for a “good” metrics.
4) Using PR_W, we list the most high-profile SE researchers.
5) We offer at goo.gl/xn6f63 all the data and scripts required to automatically repeat this analysis.

This last point is very important. While prior studies have proposed methods to rank scholars in software engineering, those methods had repeatability issues due to the subjective nature of some of the decisions within that analysis. Here, we seek a ranking methods that is most repeatable since it is most stable across a wide range of subjective decisions.

The rest of this paper is structured as follows. After some preliminaries in the next section, we present the data used in this study. This is followed by the results from that data that make us advocate for PR_W. Finally, using PR_W, we list the top-ranked authors in SE in the last decade.

Note that this paper is an extension to a prior study [1] that looked for topic trends in software engineering. That prior work did not explore issues of author rankings, nor did it test if different ranking metrics resulted in different author rankings.

2 PRELIMINARIES

2.1 Motivation

Why is it important to study ranking metrics for software scholars?
We argue that just as software should be verified, so too should this community verify the software models that rank SE scholars. For example, ranking model includes derivation parameters which, if changed by small amounts, could potentially change the rankings of SE scholars. This paper verifies that our preferred ranking metric, PR_W, is stable across a range of derivation parameters.

But taking a step backwards, why is it important to debate how this community recognizes scholastic achievement? Researchers are often judged by their scientific contributions which helps them in their research and academic career. A recent article in the Science Magazine surveyed factors affecting tenure faculty hiring. They noted:

In the tenure-track faculty job hunt, status counts.

The survey suggests that the hiring committee at a research-intensive university valued most in an assistant professor candidate were the number of articles published in high-profile venues and the number of citations these articles receive. Teaching and service were deemed “unnecessary credentials” and more often than not did not influence tenure selection [3]. The results, though not surprising, offer a reminder that with so many people vying for a limited number of tenure-track faculty positions, “trainees need to do more self-analysis of where they are and what the realities are for them to potentially become a faculty member” [5].

Since status matters so much, it is wise to reflect on how that status is calculated and used to sort and select supposedly superior scholars. We prefer the PR_W metric, for several reasons.

Firstly, it use more information about an author; i.e. it rewards not just citation counts but also how often authors collaborate.

Secondly, how we measure our own community tells the world what we value most within this community. Measures based on just solo citations can encourage the belief that all that matters in research is individual success. However, if our community decides to endorse collaboration-aware metrics, that say that SE researcher preferentially encourages a community where researchers explore and assess and critique and improve each others’ ideas.

Thirdly, as shown in this paper, this PR_W metric is numerically stable. We say that a metric is unstable if small changes

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1. According to Fenton [2], a “measure” is some numeric value (e.g. “h-index=28”) while a “metric” is some combination of measure and threshold (e.g. “h-index over 20 is good”). Nevertheless, we use the term “metrics” for all the different indicators studied here (h-index, PR_W and two others) since once they are used to rank “N” scholars, then that “measure” becomes a “metric” since it ranks scholars into worst, better, best.

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*George Mathew is a Ph.D candidate in Computer Science at North Carolina State University. E-mail: george.meg91@gmail.com*

*Tim Menzies is a full professor in Computer Science at North Carolina State University. E-mail: timm@ieee.org*
to its derivation parameters lead to large deviations in the metric. Such instability is highly undesirable while ranking scholars, since small changes to how it is applied can lead to inappropriate changes in the final ranking. In the Monte Carlo analysis reported below, we show that PRW’s rankings are barely altered by perturbations to its derivation parameters.

Fourthly, as shown below, the rankings of scholars generated by these different metrics are not always the same. However, PRW’s rankings most overlap with those from other metrics. Hence, adopting PRW will lead to least future disputes about methods for ranking SE scholars.

2.2 Ranking Metrics

Over the years, success in SE has been defined and redefined by quite a few researchers in SE [4], [5]. A few popular metrics to evaluate the success of an author are defined below

Reputation Ranks: Proposed by Ren & Taylor [4]. Authors are assigned weights based on the reputation of their affiliated institutions and the published venues. Authors are then ranked on this score. While an insightful study, their calculations were based on some subjective decisions by Ren & Taylor. This makes it difficult to repeat, dispute, or improve on that study. Here, we seek to do better than Ren & Taylor by finding a ranking methods that is stable across a wide range of subjective decisions.

Fernandes in a 2014 article suggested four other metrics to evaluate author success

- Inf: Total citations of the authors.
- CoA: Total number of co-authored articles.
- Frac: Represents the fractional credit per author which is the cumulative citation count for each article weighted by the unit fractional credit. Unit fractional credit is the contribution of an author towards an article defined as the reciprocal of number coauthors in an article.
- Harm: Represents the harmonic credit per author which is the cumulative citation count for each article weighted by the unit harmonic credit. Unit harmonic credit(UHC) is the contribution of an author towards an article defined as follows:

\[ UHC \text{ for } i^{th} \text{ author} = \frac{1}{i + \frac{1}{2} + \ldots + \frac{1}{N}} \]

Note that some aspects of these metrics are problematic. Inf and CoA do not account for co-authors and citations respectively. As to Harm, this assumes that an author’s position in the author list precisely defines their contribution to a paper. In the SE field, this may not be case as documented in a recent debate on this point [1].

h-index: Hirsch in 2005 proposed h-index [6] which is defined as the number of papers with citations greater than or equal to h. Although, this metric is a very popular metric used to represent an author’s reputation, it fails to address some specific scenarios. For example, since h index of an author considers only the number of citations of her article, it does not account for the prior work based on which the article is developed. For example, consider the Google Scholar profile of Yann Gael Guenneneuc. This author made many highly-regarded contributions (papers over 100 citations) for different domains in SE. This work has influenced many other researchers to write their own, highly cited articles. But, based on h-index, Guenneneuc ranks 50th amongst SE researchers. Thus, h-index fails to address scenarios that lead to greater contribution by other researchers.

PR: In this metric, authors are ranked using the decreasing order of their weighted PageRank. PageRank was initially developed by Page et al. [7] in 1999.

\[ PRW(a_i) = (1 - \theta) \frac{1}{N} + \theta \sum_{k \in N(a_i)} \frac{PR(a_k)}{|N(a_k)|} \]

where \(\theta\) is the probability of collaboration set between 0 and 1 and \(N(a_i)\) represents the collaborators of an author \(a_i\). The authors of PageRank argue that PageRank is a Markov Chain algorithm trying to stabilize the probability of transition between all the nodes (in this case authors) of a weighted graph of authors. A high value of \(\theta\) leads to more faster convergence but can result in instability while a low value leads to slower convergence. For much this paper we use \(\theta = 0.5\), to allocate equal weight to both parts of PageRank (but see [4,3] for studies where other values of \(\theta\) are explored).

PRW: Ding et. al. propose a framework to modify PageRank to add a weight component [8] to account for the individual contribution of an author. The weighted PageRank of an author \(a_i\) is defined as follows.

\[ PRW(a_i) = (1 - \theta) \frac{W(a_i)}{\sum_{j=1}^{N} W(a_j)} + \theta \sum_{k \in N(a_i)} \frac{PR(a_k)}{|N(a_k)|} \]

Here, \(W(a_i)\) represents the weight assigned with an author. This weight can be number of citations, number of collaborators, h-index or any weighing factor. In our work we use either the number of publications (denoted \(PR_{publ}\)) and number of citations (denoted \(PR_{cite}\)).

Note that PR and PRW stress the value of collaborations

3 DATA

The last section listed multiple metrics for ranking SE scholars: PR, Inf, CoA, Frac, Harm, h-in, PR_{publ}, or PR_{cite}. Which should be used?

To answer that question, we computed and compared rankings for 35,406 authors over a period of 25 years between 1992-2016, from 35,391 papers seen from 34 SE conferences [4] and journal [5].

This time period (25 years) was chosen since it encompasses recent trends in software engineering such as the switch from waterfall to agile; platform migration from desktops to mobile; and the rise of cloud computing. Another reason to select this 25 year cut off was that we encountered increasingly more difficulty in accessing data prior to 1992; i.e. before the widespread use of the world-wide-web.

As to the list of venues, that was initialized using the top h5-index scores from Google Scholar, then expanded after two rounds of input from the SE community. More details on that process is extensively described by Mathew et. al. [1]. What can be said here is that this venue list was explored for conclusion stability (specifically, the venue list was expanded until the n + 1 expansion yielded the same conclusions as n). It should be noted that all the data collection method is automated. Thus, this list of venues could expanded to additional venues in the future.

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2. https://goo.gl/A7kD8y
3. scholar.google.com/citations?user=VV4cZYAAAAB
For studying and analyzing those venues we construct a database of 18 conferences, 16 journals, the papers published with the metadata, authors co-authoring the papers and the citation counts from 1992-2016. That data was collected in several stages.

Firstly, for each venue, DOI (Document Object Identifier), authors, title, venue & year for every publication between 1992-2016 is obtained by scrapping the html page of DBLP. DBLP (DataBase systems & Logic Programming) computer science bibliography is an on-line reference for bibliographic information on major computer science publications. As of Jan 2017, dblp indexes over 3.4 million publications, published by more than 1.8 million authors.

Second, for each publication, we obtain the corresponding citation counts using crossref's REST API.

Finally, since the data is acquired from three different sources, a great challenge lies in merging the documents with their citation counts. DOIs for each article can be obtained from the DBLP dump, then used to query crossref’s rest API to obtain an approximate of the citation count. Of the 35,391 articles, citation counts were retrieved for 34,015 of them.

### 4 RESULTS

Our results with this data will recommend $PR_W$, for three reasons. Firstly, as shown in Table 1, an increasing trend in the SE literature is SE collaborations between multiple authors. Further, those multiple-author papers are increasing prominent (cited most often). Hence, it is appropriate to switch from metrics like the h-index to other metrics that reward collaboration like $PR_W$.

Secondly, as shown in Figure 2, $PR_W$ agrees with the most with all the other metrics studies here. Hence, if we used anything other than $PR_W$, then that would lead to more future disagreements about what ranking metric to use.

Thirdly, as shown in Figure 3, $PR_W$ is numerical stable; i.e. perturbations in its derivation have little impact on its rankings.

#### 4.1 Results #1: Why Focus on Collaboration?

Figure 1 shows the number of authors per paper within our corpus fro 1993 to 2016. In that figure, we observe that:

- The number of single author papers in SE has plummeted from 35% (in 1993) to not much more than 10% (in 2015).
- Similarly, over the same period, the number of double author papers has nearly halved.
- On the other hand, as observed by the positive trends in the results of all other curves, the number of paper with 3 or more authors has been steadily increasing.

So, clearly, the conclusion from Figure 1 is that the SE community is collaborating more. But does that collaboration lead to more prominent papers? To answer that question, we turn to Table 1.

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7+ |
|------|---|---|---|---|---|---|----|
| 1992 | 0.08 | 0.24 | 0.20 | 0.12 | 0.12 | 0.20 | 5.48 |
| 1993 | 0 | 0.13 | 0.17 | 0.21 | 0.29 | 0.13 | - |
| 1994 | 0 | 0.17 | 0.22 | 0.35 | 0.17 | 0.65 | 0.26 |
| 1995 | 0.05 | 0.23 | 0.27 | 0.32 | 0.55 | 0.18 | 1.68 |
| 1996 | 0 | 0.10 | 0.14 | 0.24 | 0.05 | 0.57 | - |
| 1997 | 0.05 | 0.10 | 0.15 | 0.25 | 1.20 | 0.50 | - |
| 1998 | 0.05 | 0.26 | 0.26 | 0.16 | 0.21 | 0.42 | 0.21 |
| 1999 | 0 | 0.11 | 0.11 | 0.11 | 0.06 | 0.22 | - |
| 2000 | 0 | 0.18 | 0.18 | 0.18 | 0.06 | 0.12 | 0.18 |
| 2001 | 0 | 0.19 | 0.38 | 0.38 | 0.25 | 0.25 | 0.38 |
| 2002 | 0.07 | 0.33 | 0.33 | 0.47 | 0.27 | 0.67 | 0.53 |
| 2003 | 0.07 | 0.45 | 0.43 | 0.71 | 0.57 | 0.35 | 0.58 |
| 2004 | 0.08 | 0.23 | 0.38 | 0.38 | 0.54 | 0.46 | 0.71 |
| 2005 | 0.08 | 0.33 | 0.33 | 0.33 | 0.33 | 0.17 | 0.33 |
| 2006 | 0 | 0.36 | 0.36 | 0.45 | 0.55 | 0.18 | 0.27 |
| 2007 | 0.10 | 0.50 | 0.60 | 0.70 | 0.70 | 0.60 | 0.50 |
| 2008 | 0.11 | 0.56 | 0.78 | 0.56 | 0.67 | 0.89 | 1.21 |
| 2009 | 0 | 0.38 | 0.63 | 0.75 | 0.63 | 0.75 | 0.38 |
| 2010 | 0.14 | 0.57 | 0.71 | 0.86 | 1.00 | 0.71 | 1.00 |
| 2011 | 0 | 0.67 | 0.83 | 1.00 | 1.00 | 0.83 | 1.00 |
| 2012 | 0 | 0.60 | 0.80 | 1.00 | 1.40 | 1.00 | 1.20 |
| 2013 | 0 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2014 | 0 | 0.67 | 1.00 | 1.00 | 1.33 | 1.00 | 1.67 |
| 2015 | 0 | 0.50 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 |

#### TABLE 1: Median value of average cites per year for articles with different number of coauthors. Cells with the same color have similar values (as judged by an A12 test). In any row, cells with one color have a different median value to cells of any other color in that row. Pink, green blue and white denote groups of cells with values that are lowest, not-so-low, higher an highest (respectively) for any one year.
TABLE 2: Percentage of common authors in the top 1% of different ranking schemes. The best overlap for each column is shown in green.

|    | Infl | CoA  | Harm | Frac | PK   | PRpub |
|----|------|------|------|------|------|-------|
| CoA | 67   | 59   | 71   | 72   | 80   | 79    |
| Harm| 74   | 59   | 78   | 77   | 78   | 98    |
| Frac| 74   | 71   | 78   | 77   | 78   | 98    |
| PK  | 80   | 72   | 79   | 78   | 98   | 98    |
| PRpub| 80  | 72   | 79   | 78   | 98   | 98    |
| PRcite| 79 | 73   | 79   | 78   | 98   | 99    |

4.2 Results #2: Ranking Agreements

Another reason to prefer $PR_W$ it has most agreement with all the other metrics. Table 2 studies the top 1% most cited authors in our corpus (i.e. 3540 authors). The cells of Table 2 shows how often an author was ranked into group X using two different metrics. The green cells of that table show results of maximum overlap between the rankings generated by a column’s metric to a row’s metric.

The key observations from Table 2 are:

- The metrics which most agree with the other metrics are two $PR_W$ variants $PR_{cite}$ and $PR_{pub}$.
- When green cells appear in other rows, they always show a match that equals one of the $PR_W$ rows.
- Hence, when selecting a metric that offers most of the same rankings as anything else, we recommend either of the $PR_W$ metrics since this will lead to least future debates about the merits of alternate metrics.

Further to the last point, for pragmatic reasons, we recommend $PR_{cite}$ since that is closest to current practice (that is based on citation counts). Hence, $PR_{cite}$ may be least disruptive to current career paths (therefore more palatable to more academics).

4.3 Results #3: Numerical Stability

Another observation we make $PR_W$ is that there is a 98% overlap between page rank ($PR$) and the two weighted page rank measures ($PR_{pub}$ and $PR_{cite}$). This suggests that the ranked generated with this measure is insensitive to the derivation parameters of that metric. Note that such insensitivity is a highly desirable property for a ranking metric since it means that the reported ranks are not effected by minor decisions within the calculation of that metric. We say that such a metric is numerically stable.

To test is $PR_W$ is numerically stable we performed a perturbation study on Equation 1 and 2. Figure 2 visualizes the score of our top 20 most-cited authors using $PR$ and $PR_W$ for $0 \leq \theta \leq 1$. This is figure shows results from $PR$, $PR_{pub}$ and $PR_{cite}$.

The key observation from Figure 2 is that the relative ordering of the ranks are very similar. We can observe small changes at lower values($< 0.15$) of $\theta$ but at later values the ranks are almost similar.

6 Conclusion

The above discussion recommends $PR_{cite}$ since it incorporates aspects of author collaboration as well as more traditional citation counts. Also, this metric has most agreement with other metrics which means that rankings generated by this metric are less likely to be refuted by other metrics. Further, $PR_{cite}$ is numerically stable.

Table 3 uses $PR_{cite}$ to show the top authors from various SE topics, in the last decade (since 2009). The topics of that figure were discovered by a text mining methods called Latent Dirichlet Allocation that automatically discover groups of terms that cover most documents. For more details on that analysis, see [1].

Note that tables like Table 3 are not the goal of this research. Rather, our main point is that if status is so important to SE scholars, then the methods used to assess that status need to be debated by this community. Any proposal that SE scholars should be assessed using metric Weighted PageRank($PR_W$) needs to be carefully audited. More specifically, as done here, the analysis that recommends metrics $PR_W$ needs to be automatic and repeatable. To this end, we offer all our data and scripts at goo.gl/6xM6l. We strongly encourage other researchers to be as forthcoming with their assessment material.

5 Related Work

The most similar recent study to this work was performed by Fernandes in 2014 who studies authorship trends in SE [5]. That study collected 70,000 papers entries from DBLP for 122 conferences and journals, for the between 19712012 and process several bibliometric indicators like CoA, Infl, Frac, Harm. He empirically shows trends like a) the number of authors of articles in software engineering is increasing on average around 0.40 authors/decade; b) Until 1980, the majority of the articles have had single authors, while more than half of the recent articles (2000 - 2012) have 3 to 4 co-authors associated with them. This study had two limitations a) It fails to address the impact of collaboration on SE which is a major part of SE which can be seen from Figure 1 b) The study is not repeatable as data and algorithms are not made publically available.

In their 2014 Elsevier newsletter, Plume and van Weijen studied contribution of authors to SE research [10]. They show that there has been no increase in contribution per active author over the last decade. They theorize that authors use their authorship potential to become more collaborative in the way they work. We can empirically see from Figure 1 that there has been a rise in collaboration over the years in SE. This can be attributed to the reward of more citations from collaboration as seen in Table 1.

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| Object-Oriented | Testing | Source Code | Architecture | Modeling | Developer |
|----------------|---------|-------------|--------------|----------|-----------|
| J Sheffield    | M Harman| D Poshyvanyk| S Apel       | DL Moody | T Dyba    |
| PR Houser      | A Aciri  | R Oliveto   | P Avgierou   | M Dumas  | T Zimmermann |
| B Doty         | G Fraser | A de Lucia  | C Kastner    | M Chechik| T Dingsoyr |
| Y Tian         | AM Memon | M di Penta  | U Kulesza    | S Uchitel| P Runeson |
| L Lighty       | LC Briand| Y Gueheneuc| J White      | C Ouytel | M Host    |

| Program Analysis | Requirements | Metrics | Applications | Performance |
|------------------|--------------|---------|--------------|-------------|
| W Weimer         | BA Kitchenham| T Menzies| R Buyya      | C Chang     |
| A Orso           | T Gorschek   | N Nagappan| CAF De Rose  | C Tsai      |
| MD Ernst         | P Brereton   | T Zimmermann| RN Calheiros| T Mekhailov |
| A Zeller         | MP Velthius  | MJ Shepperd| R Ranjan     | T Chen      |
| S Forrest        | D Budgen     | AE Hassan | A Beloglavoz | C Yang      |

**TABLE 3:** The top 5 authors seen in 11 SE topics since 2008. Scores calculated using $PR_{cite}$. Topics determined as per [11].

| Object-Oriented | Testing | Source Code | Architecture | Modeling | Developer |
|----------------|---------|-------------|--------------|----------|-----------|
| VR Basil       | G Rothermel| F Antoniol | N Medvidovic | GJ Holzmann| JD Herbleb |
| MV Zelkowitz   | MJ Harrold| A DeLucia  | R Taylor     | J Kramer  | BA Kitchenham |
| O Laitenberger | M Harman | A Marcus   | D Garlan     | LC Briand | T Dyva    |
| RL Glass       | J Offutt  | D Poshyvanyk| J Bosch      | S Uchitel | T Zimmermann |
| F Shull         | LC Briand | GC Murphy  | J OckerBloom | B Nuseibeh|

| Program Analysis | Requirements | Metrics | Applications | Performance |
|------------------|--------------|---------|--------------|-------------|
| MD Ernst         | CF Kezerer   | LC Briand| R Buyya      | TMJ Fruchterman |
| A Zeller         | SR Chidamber | MJ Shepperd| B Benatallah | EM Reingold |
| A Orso           | BA Kitchenham| NE Fenton | M Dumas      | C Chang     |
| MJ Harrold       | BW Boehm    | T Menzies| J Kalagnamun | T Chen      |
| K Sen            | AL Anton   | BA Kitchenham| H Chang      | M Hwang     |

**TABLE 4:** The top 5 authors seen in 11 SE topics in the corpus. Scores calculated using $PR_{cite}$. Topics determined as per [11].

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