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# Impact of mutual influence while ranking authors in a co-authorship network

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## Abstract

Online bibliographic databases are providing significant resources to conduct analysis of academic social networks. We believe that work of an author is always influenced by work of his or her co-authors. In this study, we investigate the impact of productivity and quality of work of an author's co-authors on his or her ranking along with his own contribution. We propose mutual influence (MI) based ranking method, which ranks authors based on (1) Publications of an author, along with impact of publications of his or her co-authors, (2) Normalized author position based Citations weight, which is calculated from the citations received by an author with respect to position of his or her name in the co-authors list, (3) MINCC that combines the impact of both factors. A series of experiments has been conducted and results show that proposed approach has capability to ranks authors in a significant way.

**Keywords:** Academic networks; impact of authors; mutual influence (MI); PageRank; ranking of authors.

## 1. Introduction

Academic social networks came into existence due to collaboration of authors, who work together as co-authors and cite each other's work. These networks are being immensely studied in recent times because of their significant applications for academic recommendation tasks. The ranking of authors in citation based networks or co-authorship based networks (Ding *et al*., 2009; Yan & Ding, 2011), finding the rising stars (Daud *et al.,* 2013; L*i et al.,* 2009), ranking of academic entities in heterogeneous networks (Amjad *et al.,* 2015; Sun *et al.,* 2011; Tang *et al.,* 2011; Yan *et al.,* 2011; Yan & Ding, 2010; Zhou *et al.,* 2007), expert finding (Balog *et al.,* 2006; Balog & de Rijke, 2008; Tang *et al.,* 2011), topic based ranking of academic entities (Ding, 2011a; Gollapalli *et al.,* 2013; Tang *et al.,* 2008a) and time weighted ranking of authors (Daud, 2012; Daud *et al*., 2010; Fiala, 2012; Wang *et al.,* 2013) are some of the examples of the general tasks in academic social networks. The methods that exist in literature to rank authors generally consider the publications count and citations count as the ranking criteria. We believe that these simple metrics are not sufficient enough to find the standing of an author. When authors work in collaboration with each other, they share the part of their rank with their co-workers. If the authors are senior, they impart more influence on the co-workers, while on the other hand if they are junior they impact others with a smaller weight. This concept was first studied and introduced by Li *et al.* (2009) for searching of rising stars in a bibliographic network and they call it MI of scholars upon each other. In this study, we use the concept of MI for ranking of researchers, along with the impact of their productivity and the citations that are normalized according to author's name's position in co-authors list. The existing methods that use the citations as a weighing metric for ranking of authors give full weight of citations of a paper to all authors of that paper. Generally, the first author is believed to be main contributor of the paper, hence allocating full weight of citations to all authors of a paper is not justified. Some methods have been introduced in literature to divide the weights with respect to author's name's position (Chai *et al.,* 2008; Sekercioglu, 2008; Wan *et al.,* 2013, 2007). This study normalizes the citations for all authors of a paper according to the position of their name in a publication in an innovative way. The main contribution of this research are abridged as follows: (1) showing the importance of MI of researchers upon each other while working in collaboration and proposing a method to incorporate this influence, (2) finding normalized weight of citations for all authors of an article according to their name's position in that article and finally (3) proposing a method for ranking of authors in a co-authorship network based on MI of authors along with normalized citations count (MINCC).

## 2. Related work

PageRank (Page *et al.,* 1999; Brin & Page, 1998) is a trend setting method that provides basis for ranking of web pages. It distributes the rank of a page uniformly amongst all the pages it links to. It considers a page to be important, if there are many other important pages pointing towards it. PageRank provides basis for many author ranking methods, considering the authors as nodes and their collaborations as the edges between them. This collaboration can be co-authorship, citations or co-citations.

Author-Rank, a weighted version of PageRank, was presented by Liu *et al*. (2005) for the ranking of authors in digital library research community. They used the co-authorship frequency and their exclusivity as the weighting measure. They studied the prominence of authors by determining the centrality of an author in a co-authorship network. Yan & Ding (2009) studied the centrality measures like closeness, betweenness, degrees and PageRank in co-authorship networks and they found these measures to be very significant for impact analysis. Author collaboration and citation networks were studied for the ranking researchers by using their publications and citations as weights in the standard PageRank algorithm (Ding, 2011b; Yan & Ding, 2009).

RareRank ranks the documents semantically by modelling the actions of a researcher as a replacement of an arbitrary web surfer (Wei *et al.,* 2011). It is an extension of PageRank and it involves a knowledge base that contains scholastic objects like scholars, publication venues and papers and a terminological topic ontology. Gollapalli *et al.* (2011) used PageRank for expert finding from electronic collections to accommodate multiple obtainable evidences from academic entities and their relationships. Umagandhi & Kumar (2014) presented a time heuristic based ranking approach for query recommendation task, which also ranks the recommended queries based on preferences and access time of the query.

In bibliometrics, we found methods that calculate the individual contribution of the authors in multi-authored publications for their ranking. It is not fair to give equal credit to all co-authors of an article equally as in general, the co-authors contribute differently. These days, the practice in use is to list the authors of a publication according to their contribution, instead of doing it alphabetically (Hu *et al.,* 2010). Sekercioglu (2008) presented $k^{th}$-rank index to measure the contribution of co-authors instead of giving an equal contribution to all authors in a multi-authored paper. According to $k^{th}$-rank index, every co-author contributes 1/k of the first author. Egghe (2008) has also presented fractional h and g indices. The study calculates h-index (Hirsch, 2005) and g-index (Egghe, 2006) of authors in a fractional way (Egghe, 2008). Liu & Fang (2011) presented an h-index and g-index based method to give fair credit to authors according to their contribution in a research.

The academic social networks not only include the authors, but their papers and publication venues are also important constituent parts. Ranking of authors, papers and the journals was presented in which the citations from prestigious scientists were considered to be more important rather than only summing up the citations (Zhou *et al.,* 2012). Hence, the popular and prestigious authors, papers and journals were distinguished from each other while ranking. For ranking of scientific articles in a publications network, a network centred approach was introduced, which involves authors, venues, citations and time information (Wang *et al.,* 2013). Amjad *et al.* (2015) presented a method for topic based ranking of author, papers and journals simultaneously, considering the effect of all these academic entities on each other in a heterogeneous network. Existing methods do not consider the impact of MI of researchers upon each other while they work in collaboration. This motivates us to present the Mutual Influence and Normalized Citations Count (MINCC) based Rank. The upcoming section provides the details of proposed MINCC Rank.

## 3. Mutual influence and normalized citations count based ranking of authors (MINCC rank)

Concept of MI was introduced by Li *et al.* (2009) for finding the rising stars. Later, Daud *et al.* (2013) have also used this concept for the same purpose. In this study, our main purpose of using concept of MI, is to include not only the work of a researcher, but also taking into account the impact of his or her co-researchers on their rank. A scholar who collaborates with more number of researchers, receives influence from more researchers and vice versa.

The proposed methods assimilate the MI based weight in the network topology section of the standard PageRank formula, while at the same time integrates publications, and normalized author position based citations in the first part of PageRank formula.

### 3.1. MI with respect to the publications count (MIP)

In this approach, we consider the MI of authors among themselves considering the sum of their published papers. The quantity of publications is representation of productivity of an author. The authors receive more influence if they co-author with more productive researchers. In the co-authorship graph under consideration, the authors represent the nodes of the network and their co-authorship relationship represent the edges between them. Suppose that we have two authors, *X* and *Y*, with different number of publications. The weight with which *X* influences *Y* is different from the weight with which *Y* influences *X*. These weights, as a result make a weighted co-authorship graph. Let author *X* has 12 publications and author *Y* has 8 publications. While they have co-authored each other in 4 papers. Weight $W_{XY}$ is the weight with which *X* influences *Y* and it can be calculated as $W_{XY} = \frac{4}{8} = 0.5$. While $W_{YX}$ represents the weight with which *Y* influences *X* and it can be calculated as $W_{YX} = \frac{4}{12} = 0.33$. We can observe that as *X* has more publications so *X* is influencing *Y* with a greater value and vice versa.

The equation of the MI approach with respect to the count of published articles is as follows:

$$MIP(A_i) = (1-d)\frac{WP(p_i)}{\sum_{p_j \in M(p_i)} WP(p_j)}$$

$$+d \sum_{A_j \in M(A_i)} \frac{W_{ji} * MIP(A_j)}{\sum_{A_k \in M(A_i)} W_{jk}} \quad (1)$$

Where $MIP(A_i)$ stands for rank of author $A_i$, $M(A_i)$ demonstrates the group of authors who cite author $A_i$, $W_{ji}$ is influence of $A_j$ on $A_i$, $WP(p_i)$ is sum of publications of author *i*, $\sum_{p_j \in M(p_i)} WP(p_j)$ are the sum of publications of all authors in dataset and *d* is the damping factor.

### 3.2. Normalized author position based citations (NAPC)

In this section, we introduce the concept of assigning the weight of citations to each author of a publication corresponding to the rank of author's name in the co-author's list of that paper. Here, by rank of author's name, we mean the position of author's name among co-authors of an article. Consider a simple example of a paper *P* that has four authors *L, M, N* and *O* and their name's positions are 1, 2, 3 and 4 respectively. Let *P* has received 20 citations. *L* being the first author of *P* receives most weightage from the received citations and *O* receives the least weightage. The formula for the calculation of *NAPC* is given as follows:

$$NAPC_i = \frac{N-i+1}{\sum_{i=1}^{n} i} \times c \quad (2)$$

Where *i* represents the rank of researcher's name in paper *P*, total number of authors of that paper is represented by *N* and *c* reflects the quantity of citations received by *P*. Using equation 2, we can calculate the *NAPC* for the authors *L*, *M*, *N* and *O* as under:

$$NAPC_L = \frac{4-1+1}{10} \times 20 = 8$$

$$NAPC_M = \frac{4-2+1}{10} \times 20 = 6$$

$$NAPC_N = \frac{4-3+1}{10} \times 20 = 4$$

$$NAPC_O = \frac{4-4+1}{10} \times 20 = 2$$

We can notice that author *L* has received the maximum weightage of the citations, while *O* being $4^{th}$ author of the paper has received minimum weightage of the citations.

### 3.3. MI and normalized citations count based rank (MINCC)

This section brings forward a cumulative formula for Mutual Influence and Normalized Citations Count based Rank. We introduce the normalized author position based ranking weight into equation 1 of proposed method to get our final MINCC rank as follows:

$$MINCC(A_i) = (1-d)\left(\frac{WP(p_i)}{\sum_{p_j \in M(p_i)} WP(p_j)} + \frac{NAPC_i}{\sum_{p_j \in M(p_i)} NAPC_i}\right)$$

$$+ d \sum_{A_j \in M(A_i)} \frac{W_{ji} MIP(A_j)}{\sum_{A_k \in M(A_i)} W_{jk}} \quad (3)$$

Equation 3 shows that considering only the citations count for ranking a researcher is not adequate enough. Adaptation of MI of authors results in producing valuable outcomes.

## 4. Experiments

### 4.1. Dataset

AMiner[1] dataset (version 5) has been utilized for examining the results of the proposed method. This dataset is publically available for the scholars and researchers

[1]https://aminer.org/billboard/citation

and is a part of AMiner project byTang *et al.* (2008b). It encompasses all publications from DBLP along with references relations among them. The dataset includes 117,676 papers ranging from 1960 to 2011 containing 988,030 citation relationships and 128,778 authors.

### 4.2. Performance measurement and parameters

Absence of ground truth values in field of ranking makes the process of performance evaluation a very challenging task. We have compared the results of our proposed method with weighted versions of standard PageRank algorithm introduced by Yan & Ding (2011) considering it as a baseline (BL) method. The features that we have selected for comparison of proposed and BL methods are the sum of publications of a researcher, the sum of citations earned by him or her and the number of collaborators he or she has in network. The impact of these features is discussed in section 5. In standard PageRank the d =0.85 is considered, which shows that there is 85% chance that user on a given webpage will follow one of the links provided on that webpage. Considering the arguments provided by Maslov & Redner (2008) we used d=0.5 for the representing the results in this research. They suggested that in case of citations d=0.5 is the most suitable choice to represent a researcher's behaviour, as researchers usually follow a citation chain up till two links.

## 5. Results and discussion

In this section, we compared and discussed MIP and BL methods. In tables, "Cits" represents the sum of citations, "Pubs" stands for the sum of publications "Socio" stands for the total collaborators of a researcher representing the sociability. We have rounded the averages to nearest decimal places.

Table 1 shows the top 20 authors positioned by the BL and the proposed MIP method. For purpose of comparison and evaluation we computed the average of the publications, citations and sociability of the authors. Both techniques involve the number publications of an author as a ranking criterion. However, the proposed method involves the impression of MI of all the collaborators of an author according to their productivity. As a result of this criterion, the authors that appeared in top 20 list of MIP method have higher average number of publications, citations and sociability. Top two authors that appeared in results of both methods are same, i.e., P. S. Yu and M. T. Kandemir are on positions 1 and 2 respectively in both methods. A. L. Sangiovanni, who is on 3$^{rd}$ position in BL method, has moved to position 15 in MIP method and J. Han has replaced his position. We observed from the results of proposed method that itis not only the sum of publications and citations which is important but the sociability of an author is also a very imperative factor to determine an author's ranking. More social authors receive impact from more number of authors. We traversed the co-author lists of the authors who have appeared in among top 20 authors of MIP method and we found that it is not only the number of co-authors that is making a difference in results of two methods, but presence of a prestigious author among the co-authors list is also imparting value to rank of an author. For example, P. S. Yu is appears in co-authors list of C. Faloutsos, J. Han and M. S. Chen. Similarly, existence of M. T. Kandemir in collaborators of M. J. Irwin, D. Blaauw, F. Catthoor and L. Benini, and appearance of J. Hanamong collaborators of M. S. Chen was the reason behind increase in their ranking positions as compared to their positions in BL.

**Table 1.** The top 20 authors ranked by BL and MIP

| | BL | | | | MIP | | | |
|---|---|---|---|---|---|---|---|---|
| **Rank** | **Authors** | Cits | Pubs | Socio | Authors | Cits | Pubs | Socio |
| 1 | P. S. Yu | 3154 | 205 | 160 | P. S. Yu | 3154 | 205 | 160 |
| 2 | M. T. Kandemir | 1355 | 165 | 117 | M. T. Kandemir | 1355 | 165 | 117 |
| 3 | A. L. Sangiovanni | 1114 | 116 | 146 | J. Han | 3046 | 152 | 150 |
| 4 | W. B. Croft | 1861 | 93 | 108 | L. Benini | 1609 | 145 | 160 |
| 5 | N. R. Jennings | 1364 | 107 | 106 | K. G. Shin | 1390 | 143 | 109 |
| 6 | Q. Yang | 644 | 78 | 116 | H. G. Molina | 3187 | 139 | 155 |
| 7 | L. Zhang | 307 | 56 | 109 | E. Bertino | 1469 | 137 | 126 |
| 8 | M. Sharir | 540 | 81 | 80 | J. Cong | 1428 | 127 | 104 |
| 9 | J. Cong | 428 | 127 | 104 | M. Pedram | 872 | 125 | 68 |
| 10 | A. B. Kahng | 950 | 102 | 106 | D. Blaauw | 1581 | 117 | 110 |
| 11 | M. Li | 281 | 54 | 83 | M. S. Chen | 1028 | 84 | 42 |
| 12 | K. Roy | 824 | 110 | 95 | C. Faloutsos | 2655 | 116 | 145 |
| 13 | C. L. Giles | 878 | 85 | 101 | G. D. Micheli | 1629 | 94 | 85 |
| 14 | W.Nejdl | 422 | 42 | 82 | N. R. Jennings | 1364 | 107 | 106 |
| 15 | M. Pedram | 872 | 125 | 68 | A. L. Sangiovanni | 1114 | 116 | 146 |
| 16 | B. A. Myers | 1259 | 96 | 103 | M. J. Irwin | 886 | 94 | 92 |
| 17 | D. Srivastava | 1361 | 81 | 110 | F. Catthoor | 666 | 113 | 164 |
| 18 | S.Shenker | 2701 | 79 | 148 | D. F. Towsley | 1576 | 109 | 133 |
| 19 | P. Stone | 356 | 52 | 52 | K. Roy | 824 | 110 | 95 |
| 20 | E. A. Rundensteiner | 503 | 80 | 84 | M. F. Kaashoek | 2867 | 60 | 80 |
| | **Average** | **1001** | **91** | **101** | | **1685** | **123** | **117** |

Table 2 represents the results obtained by the MINCC rank method that involves the normalized author position based citation along with the impact of MI. We can notice that R. Agrawal attains the top position in proposed method as compare to his 43rd position in MIP method and 73rd position in BL. The reason behind is that out of 59, 41 of his publications are as "first author" hence, he receive more weight of the received citations as compared to his co-authors. P. S. Yu and M. T. Kandemir have moved down a few positions. To further verify results, we traversed the profile of R. Agrawal from the web and found him to be a winner of many prestigious awards. Similarly, C. L. Giles is also a well-known professor for Search engines, information retrieval, digital libraries, information extraction and data mining.

The applications are usually interested in finding the top few retrieved results. Figure 1 shows the average of citations received by top 10, 20 and 30 authors using BL, MIP and MINCC methods.  It can be noticed form the figure that the proposed methods have retrieved the authors as top authors, who have received more citations. Similarly, Figure 2 shows the average publications of top 10, 20 and 30 authors for all three methods.

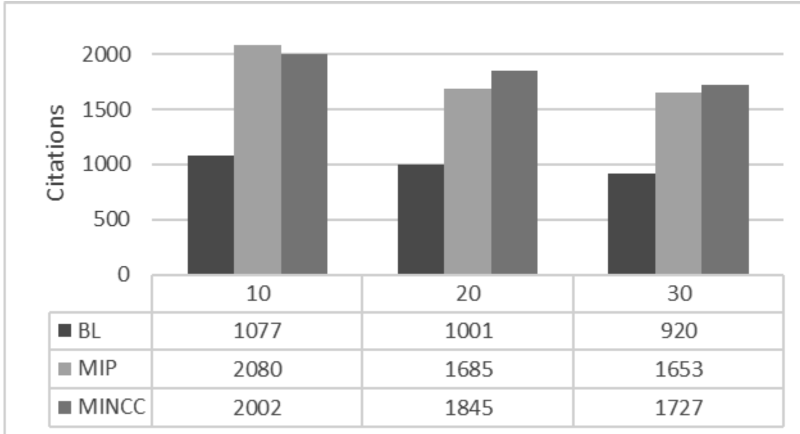


**Fig. 1.** Arithmetic mean of citations of top 10, 20 and 30 authors of BL, MIP and MINCC methods

**Table 2.** The top 20 authors ranked by MINCC

| | **MINCC** | | | |
|---|---|---|---|---|
| **Rank** | **Authors** | **Cits** | **Pubs** | **NoCA** |
| 1 | R. Agrawal | 3554 | 59 | 102 |
| 2 | P. S. Yu | 3154 | 205 | 160 |
| 3 | C. L. Giles | 878 | 85 | 101 |
| 4 | M. T. Kandemir | 1355 | 165 | 117 |
| 5 | J. Han | 3046 | 152 | 150 |
| 6 | L. Benini | 1609 | 145 | 160 |
| 7 | M. S. Chen | 1028 | 84 | 42 |
| 8 | K. G. Shin | 1390 | 143 | 109 |
| 9 | E. Bertino | 1469 | 137 | 126 |
| 10 | H. G. Molina | 3187 | 139 | 155 |
| 11 | J. Cong | 1428 | 127 | 104 |
| 12 | N. R. Jennings | 1364 | 107 | 106 |
| 13 | M. Pedram | 872 | 125 | 68 |
| 14 | D. Blaauw | 1581 | 117 | 110 |
| 15 | D. F. Towsley | 1576 | 109 | 133 |
| 16 | C. Faloutsos | 2655 | 116 | 145 |
| 17 | A. L. S. Vincentelli | 1114 | 116 | 146 |
| 18 | M. Wooldridge | 1196 | 80 | 65 |
| 19 | H. G. Molina | 3187 | 139 | 155 |
| 20 | B. A. Myers | 1259 | 96 | 103 |
| | **Average** | **1845** | **122** | **118** |

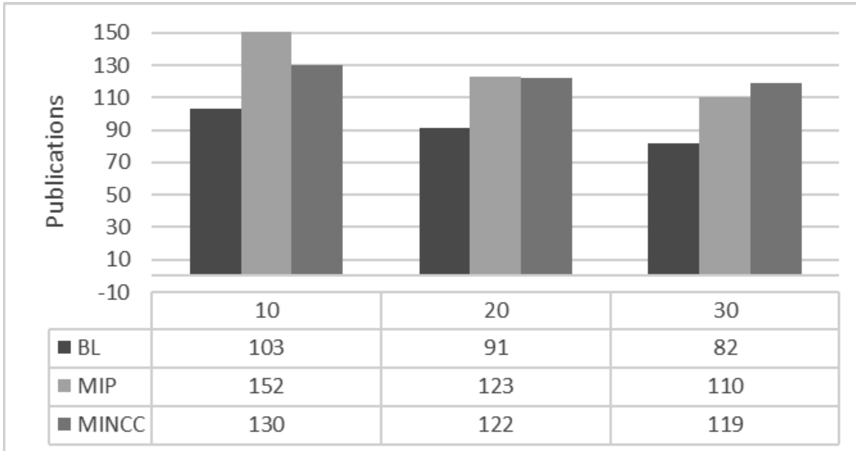


**Fig. 2.** Arithmetic mean of publications of Top 10, 20 and 30 authors of BL, MIP and MINCC methods

## 6. Conclusion and future work

The effect of MI of authors when they participate as collaborators has been studied in this research. This study presents method for ranking of researchers and scholars based on their own productivity along with the impact of MI of their co-authors as well as the normalized weight of their received citations. The weight of received citations has been normalized according the rank of an author in the list of co-authors of a paper. For purpose of evaluation and comparison, as the ground truth is not available, we have implemented BL as well as the proposed methods on same database using same parameter settings. The results show that it is not only the publications and citations of the authors that can be used as a weighing criteria, the impact of co-authorship also has a great influence and significance; and hence, it should also be considered for the ranking of researchers. The impact of influence increases when the circle of collaborators of an author include some highly reputed authors.

In future, we intend to find the MI based ranking of other academic entities like the publications and the venue of publications that may include the conferences as well as the journals. The correlation between the time of publication and the citations also needs attention. There are some publications that take more time to get noticed, while some get noticed early, and some have a steady rate of receiving citations while some do not receive citations after a certain period.

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# أثر التأثير المتبادل على تصنيف المؤلفين في شبكة تأليف مشترك

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## خلاصة

توفر قواعد البيانات الببليوغرافية على الانترنت موارد كبيرة لإجراء تحليل الشبكات الاجتماعية الأكاديمية. ونحن نعتقد أن عمل المؤلف يتأثر دائما بعمل المؤلفين المشاركين له.. في هذه الدراسة، نحن نقوم بدراسة تأثير الإنتاجية ونوعية العمل من المؤلف المشارك على تصنيف المؤلف جنبا إلى جنب مع مساهمته الشخصية. نقترح طريقة للتصنيف تعتمد على التأثير المتبادل (MI)، والتي تصنف المؤلفين على أساس (1) منشورات المؤلف، جنبا إلى جنب مع تأثير منشورات المؤلفين المشاركين له ، (2) موقف المؤلف المعدل، والذي يحسب من الاستشهادات التي وردت لهذا المؤلف على حسب موقع اسمه أو اسمها في قائمة المؤلفين المشاركين، (3) MINCC الذي يجمع بين تأثير كل من الطريقتين. وقد أجريت سلسلة من التجارب وتظهر النتائج أن النهج المقترح لديه القدرة على تصنيف المؤلفين بطريقة فعالة.

**الكلمات المفتاحية:**

الشبكات الأكاديمية. تأثير المؤلف. التأثير المتبادل (MI)؛ رتبة صفحة؛ تصنيف المؤلفين.