Using the algorithm of betweenness centrality in social network analysis to identify the influential author who published papers in JMIR mHealth and uHealth: A Bibliometric Analysis

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Running title: Using betweenness centrality to identify authors online on Google Maps

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ABSTRACT

Background: Many papers investigating author collaboration might have biases because some different authors with the same name exist. However, no study has dealt with the matter of duplicate names in bibliometric data. Although betweenness centrality (BC) is one of the most popular degrees of density in social network analysis (SNA), few have applied the BC algorithm to interpret a network’s characteristics.

Objective: This study aimed to apply the BC algorithm to examine possible identical names in a network and report the author collaboration characteristics for a journal related to international mobile health research.

Methods: We obtained 676 abstracts from Medline based on the keywords of “JMIR mHealth and uHealth” (Journal) on June 30, 2018. The author names, countries/areas, and author-defined keywords were recorded. The BCs were calculated for the following: (1) the countries/areas distributed for the first author in geography, (2) the author clusters dispersed on Google Maps, and (3) the keywords dispersed for the cluster with the most productive author on a dashboard. Pajek software was performed to yield the BC for each entity (or say node). The submission and acceptance days of articles submitted to a journal were compared using two-way ANOVA to examine the differences among authors’ areas over the years.
Results: We found that the top two countries with the highest BC were the USA and the UK. The most productive authors with seven papers were Urs-Vito Albrecht (Germany) and Sherif M. Badawy (the USA). The most influential author Ralph Maddison (Australia) earned the highest BC in the authoring network. The keyword of mHealth, as expected, gained the highest BC in the keyword network. All visual representations were successfully displayed on Google Maps. No difference in submission and acceptance days of articles submitted to JMIR mHealth and uHealth was found among continents ($F=0.08$, $df=5$, $p=0.99$) or over the years ($F=0.56$, $df=3$, $p=0.64$).

Conclusion: SNA provides deep insight into the patterns of international author collaborations for JMIR mHealth and uHealth. The results on Google Maps are novel and unique as knowledge concept maps for understanding the feature of a specific journal. The research approach using the BC to identify the same author names can be applied to other bibliometric analyses in the future.

Keywords: betweenness centrality, authorship collaboration, Google Maps, social network analysis, knowledge concept map

Introduction

Background

As of April 12, 2018, more than 146 papers were found by the keyword “author collaboration” [Title], 1,168 by “author collaboration,” and 53 by “author
63collaboration” and “bibliometric” in the Medline Library. A phenomenal increase has
64been found in the number of research papers with multiple authors [1]. The
65knowledge of discovery is no longer elaborated merely in departments of a local
66university but in an international article author byline [2]. Increasing academic
67pressure and prestige concerning individuals with prolific publications are also forced
68to claim authorship for many aspirants on paper publications [3]. Given the academic
69development in recent years, the features of author collaboration on one topic or for a
70specific journal should be investigated.

711.1 Issue of duplicate authors in a network

72The author’s publication features can be determined by social network analysis
73(SNA) [4–8]. However, no study in the literature describes the issue of duplicate
74names in bibliometric data, which might result in biases because some different
75authors with the same name exist [7]. For instance, authors [7] stressed that there
76might be some biases of understanding for author collaboration because some
77different authors with the same name or abbreviation exist, who are affiliated to
78different institutions. The result of author relationship analysis for mHealth research
79would be influenced by the accuracy of the indexing author.

80Three main centrality measures (i.e., degree, closeness, and betweenness) are
81frequently used to evaluate the influence (or power) momentum of an entity (or the
Few studies have applied the betweenness centrality (BC) to interpret a network’s characteristics. In this study, we aimed to explore whether the BC can solve the problem of detecting duplicate authors in a network.

### 1.2 Issue of submission and acceptance elapsed time

Authors generally prioritize journal quality and short publication times when selecting journals [11]. Thus, publication time and impact factors affect authors’ choice of journal for submission [12]. Chen H. et al. [13] examined 51 ophthalmology journals in 2010 and reported that the impact factor does not affect article submission and acceptance dates and publication times. However, Kalcioglu et al. [11] found a statistically significant relationship between those times and impact factor in about 37 otorhinolaryngology journals from 1999 to 2013. We also evaluated the submission and acceptance days for a journal related to international mobile health research.

### 1.3 Issue of a dashboard possibly shown on Google Maps

The author’s publication patterns are always presented with static jpg format pictures [4–7] instead of a dynamic dashboard that allows readers to see further details on their own. We have observed many bibliometric studies [7, 14–19] using co-word (or co-author) analysis to visualize study data. However, no work has displayed their findings with a zoom-in and zoom-out functionality on Google Maps.
A breakthrough on showing data on Google Maps is a worthwhile task to develop.

**Objectives**

The journal of JMIR mHealth and uHealth was targeted for applying the BC algorithm to examine possible duplicate authors with the same names in a network. Four goals were set to report the author collaboration characteristics. (1) What is the pattern of countries/areas distributed for the first author? (2) Who are the most influential authors in their cluster networks? (3) Which keywords are present in the collaboration network? (4) Are article submission and acceptance days affected by the authors’ areas over the past years? All visual displays will be developed and shown on Google Maps.

**Methods**

**Data Collection**

By searching the PubMed database (Pubmed.org) maintained by the US National Library of Medicine, we used the keywords of “JMIR mHealth and uHealth” (Journal) on June 30, 2018. We downloaded 676 articles published since 2013. An author-made Microsoft Excel VBA (visual basic for application) module was used to analyze the research data. All downloaded abstracts were based on the type of journal article involved. Ethical approval was not necessary for this study because all the data were obtained from the Medline library on the Internet.
2.2 SNA and Pajek software

SNA [22] was applied to explore the pattern of entities in a system using the software of Pajek [23]. In keeping with the Pajek guidelines, we defined an author (or paper keyword) as a node (or an actor) that is connected to other nodes through the edge (or say the relation). The weight between two nodes is usually defined by the number of connections.

Centrality is a vital index to analyze a network. Any individual or keyword in the center of a social network will determine its influence on the network and its speed to gain information [9,10,24]. The BC was used in this study.

2.3 BC used in this study

The BC may be defined loosely as the number of times a node needs a given node to reach another node [9,10,25], which is the number of shortest paths passing through a given node. The BC is expressed as follows:

\[ g(v) = \sum_{s,t} \frac{\sigma_{st}(v)}{\sigma_{st}} \]  
(Eq. 1)

By contrast, the BC of node \( v \), denoted as \( g(v) \), is obtained as \( \sigma_{sv} \) in Eq. 1. The BC of node \( v \) is the number of shortest paths from node \( s \) to node \( t \) (\( s,t \neq v \)). Finally, the BC should be divided by the possible number of connected notes (\( = (N-1)(N-2)/2 \), where \( N \) = number of notes in the network). If all notes go through \( v \) in a shortest path, \( g(v) \) equals 1.
Figure 1 Calculation of betweenness centrality

The BC for node b is calculated in Figure 1: \( g(b) = \left( \frac{\sigma_{ac}(b)}{\sigma_{ac}} + \frac{\sigma_{ad}(b)}{\sigma_{ad}} + \frac{\sigma_{ae}(b)}{\sigma_{ae}} + \frac{\sigma_{cd}(b)}{\sigma_{cd}} + \frac{\sigma_{ce}(b)}{\sigma_{ce}} + \frac{\sigma_{de}(b)}{\sigma_{de}} \right) / \left( (5-1)(5-2)/2 \right) = \left( \frac{1}{1} + \frac{1}{1} + \frac{2}{2} + \frac{1}{2} + 0 + 0 \right) / 6 = 3.5 / 6 \approx 0.583. \) The two nodes (i.e., a and e) have two equal shortest paths (i.e., abce and abde). The number of shortest paths from node a to node e is 2.

The method used to ensure there are no authors with duplicate names in the network is to identify the large bubble (i.e., with high BC) by clicking the linked coauthors and checking if the author is identical between any two neighbor subnetworks. Interested readers are recommended to read Multimedia file 1 and 2.

2.4 Pattern of author collaboration in JMIR mHealth and uHealth

We selected JMIR mHealth and uHealth as the target journal. The countries/areas of the first author for each published paper were extracted to show the distribution of countries/areas on Google Maps.

The large bubble indicates the most pivotal (or influential) role or bridge in the network if the BC algorithm is performed. The wide line indicates strong relations between the two (i.e., the nation or the author). Clusters separated by the algorithm of the partition communities (or components) are filled with bubbles in different colors.
Similarly, the authors (n1=3522, see Multimedia file 3) were collected to select the most pivotal influence in the recent six years. The top nine clusters were particularly extracted by SNA, and the representatives with the highest BC in their respective cluster were highlighted on Google Maps. The author-defined keywords (n2=1678) were filtered by SNA, and 123 terms were extracted in the biggest aforementioned author cluster to present the most pivotal influential topic for the network. Details about the graphical process using SNA and the Google map are illustrated in Multimedia file 4.

2.5 Gini coefficient (GC) applied to calculate the inequality of clusters

The GC [26] is a measure of statistical dispersion intended to represent the income or wealth distribution of a nation’s residents. The GC is commonly used to understand the inequality of resource distribution. The international institutions, such as the World Bank, UN, and news media, accept that the alarming level of the GC is 0.4 [27]. The GC calculation for national income distribution is (1) to rank personal income first and then (2) separate five strata with equal size. We applied Equation (2) to obtain the GC=0.8 under the following data elements: {1000, 0, 0, 0, 0}. Thus, the upper GC was limited at 0.8 if any extremely unequal element was assigned. The GC will approach 1.0 only when a large number of dissimilar elements (e.g., 1000 zeros) is included. Accordingly, we replaced the formula of GC calculation with Equation
where \( q \) is the number of elements of interest. Readers interested in GC calculation are recommended to see the link as the reference [28]. Thus, we computed the GC for the cluster network using the top five greater elements of the BC value by using Equation 3:

\[
Gini = \frac{\sum_i \sum_j |X_i - X_j|}{2 \sum_i \sum_j X_{ij}}, \quad \text{(Eq. 2)}
\]

\[
Gini = \frac{q}{q-1} \times \frac{\sum_i \sum_j |X_i - X_j|}{2 \sum_i \sum_j X_{ij}}, \quad \text{(Eq. 3)}
\]

### Results

#### 3.1 Pattern of countries/areas distributed by the first author

Figure 2 [29] shows that the GC was 0.51 (>0.40) for the county/area distribution, indicating an extreme inequality among nation’s paper publications in JMIR mHealth and uHealth due to influential authors most from the two countries (USA and the UK).
## Table 1 Dispersions of author collaboration across continents over the years

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<th>2016</th>
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<th>2018</th>
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<th>%</th>
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<td>95</td>
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</tr>
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</table>

The top six countries with the most increasing number of production outputs (i.e., \( \text{GC} > 0.90 \)) were the USA, the UK, South Korea, Canada, Australia, and New Zealand (Table 1). The top two countries with the most proportion of paper productions were the USA (36.83%) and Australia (9.47%). The number of author per article monotonously increased from 5.2 in 2013 to 6.0 in 2018 (bottom in Table 1).

**3.2 Most influential authors in their clusters of relation networks**

The most productive authors with seven papers were Urs-Vito Albrecht (Germany) and Sherif M. Badawy (the USA; Table 2). The most influential author Ralph Maddison (Australia) earned the highest BC in the authornetwork (Figure 3) [30]. The
218GC was 0.63 (>0.40) for the top five author clusters.

219Table 2 Most productive authors

<table>
<thead>
<tr>
<th>No</th>
<th>Author</th>
<th>Country/area</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>Total</th>
</tr>
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</table>

220Figure 3 Dispersion of author clusters for JMIIR mHealth and uHealth (Gini=0.63) and selection of most influential authors using the BC algorithm

221Note. Albrecht, Urs-Vito at the right-bottom cluster; Badawy, Sherif M at the middle left-bottom cluster

2223.3 Representative keywords for the most influential authors’ clusters

223The keyword of mHealth, as expected, gained the highest BC in the keyword
network for the most influential authors’ clusters (Figure 4) [31]. That is, keywords were collected from the most influential authors’ cluster. From which, the influential keyword was extracted by the BC in SNA.

Figure 4 Dispersion of keyword clusters for the first author clusters of JMIR mHealth and uHealth (Gini=0.50). The GC was 0.50 (>0.40) for the top five keyword clusters; all dashboard-type visual representations were successfully displayed on Google Maps [29–31].
Table 3 Two-way ANOVA of acceptance days from the day of paper submission across continents over the years

<table>
<thead>
<tr>
<th>Continent</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
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<th>2018</th>
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</table>

Note. No difference was found among continents over the years (2014, 2015, 2017,
3.4 Article submission and acceptance days for JMIR mHealth and uHealth

No difference in submission and acceptance days of articles submitted to JMIR mHealth and uHealth was found among continents (F=0.08, df=5, p=0.99) or over the years (F=0.56, df=3, p=0.64), whereas years (including 2014, 2015, 2017, and 2018) were included for analysis using two-way ANOVA.

Discussion

4.1 Principal findings

We found that the top two countries with the highest BC were the USA and the UK, thereby proving that the USA and Europe still dominated the publication output in science [32,33]. The most productive authors with seven papers were Urs-Vito Albrecht (Germany) and Sherif M. Badawy (the USA). If the BCs were applied, the author Ralph Maddison (Australia) played the most pivotal (bridge) role in the author network. The keyword of mHealth gained the highest BC in the keyword network. No difference in submission and acceptance days of articles submitted to JMIR mHealth and uHealth was found among continents (F=0.08, df=5, p=0.99) or over the years (F=0.56, df=3, p=0.64).

The number of authors per article increased from 5.2 in 2013 to 6.0 in 2018. This
number was higher than that in PubMed from 1.9 in 1975 to 5.67 in 2016 [34].

However, it was less than that of the three leading general medical journals (JAMA, The Lancet, and New England Journal of Medicine; from a range of 8–11 in 2005 to 11–18 in 2015) in 2005, 2010, and 2015 [35].

4.2 Strength of the study

Traditionally, in dealing with a test with multiple questions and answers, we often count the item with the highest frequency to present the most important one. For instance, many customers purchase their goods in a shopping cart, which is similar to the test of multiple answers. Accordingly, we merely present goods with the sale counts instead of the association of goods purchased by customers, such as the most productive authors Urs-Vito Albrecht (Germany) and Sherif M. Badawy (the USA) in Table 2, instead of the most influential author Ralph Maddison (Australia) with the highest BC associated with many coauthors in the network.

A commonly known apocryphal story is the concept of co-occurrence of beer and diaper sales, in which both beer and diaper sales are strongly correlated with Friday [36,37]. Many data scientists have developed ways to discover new knowledge from the vast quantities of increasingly available information [38], especially applying SNA [4–6] to large data analysis.

In addition, we ensured no author had duplicate names in the network via
Identification of the large bubble (i.e., with a high BC) first by clicking the linked coauthors (e.g., John Torous at the left-bottom bubble in Figure 3) and then checking the author (John Torous) without duplicate names in the network by clicking the associated coauthors in the opposite neighbor subnetworks to examine whether the author (John Torous) has the same names in each paper. The dashboard in [30] could be easily linked to the published papers in MEDLINE if the author was clicked. For further details about the steps made to ensure there were no authors without duplicate names, refer to Multimedia file 1 and 2.

Furthermore, we found 335 papers in Medline because of the keyword social network analysis [Title] as of May 20, 2018. In practice, we found studies on duplicative prescriptions using SNA in Japan [39] and one explaining HIV risk multiplexity [40]. However, no such study like ours has incorporated the GC with Google Maps to interpret the results.

The GC is the most commonly used tool to understand the inequality of resource distribution. It has a range of 0 to 1, in which a GC of 0 represents perfect equality, indicating that all elements have an equal number of counts or frequencies [41].

Authors [42] studied the association between journal citation distribution and impact factor in cardiovascular journals using the GC and found an inverse relationship between the GC and the log of the IF (coefficient: −0.13, p < 0.001). Thus, journals
with high IFs have low GCs. IFs are generally representative of the quality and
contribution of the entire spectrum of journal papers and not just a select few.

In terms of the incorporation of Google Maps with SNA, Google Maps are
deliberately linked in references [29–31] for readers interested in manipulating the
link as a dashboard. The country/area distribution in Figure 2 easily illustrates the
feature of international author collaborations in JMIR mHealth and uHealth. One
picture is worth 10,000 words. We hope subsequent studies can report other types of
information using Google API to readers in the future.

4.3 Limitations and Future study

Although findings were based on the above analysis, the results should be
interpreted with caution because of several potential limitations. First, this study only
focused on a single journal. Any generalization should be made in similar fields of
journal contents.

Second, although SNA is quite useful in exploring the topic evolution and
identifying hotspots on keywords, the results might be affected by the accuracy of the
author-defined terms. The medical subject headings terms included in Pubmed library
are recommended for use in the future.

Third, many algorithms are used for SNA. We merely applied community cluster
and density with BC in the figures. Any changes made along with algorithm will
present different patterns and inferences.

Fourth, SNA is not subject to the Pajek software we used in this study. Others
such as Ucinet [43] and Gephi [44] are suggested to readers for use in the future.
4.4 Conclusions

SNA provides wide and deep insight into the patterns of international author collaborations for JMIR mHealth and uHealth. The results displayed on Google Maps are novel and unique as knowledge concept maps to understand the features of a specific journal. The research approach using the BC to identify the same author names can be applied to other bibliometric analyses in the future.

List of abbreviations

BC: Betweenness centrality
GC: Gini coefficient
MESH: medical subject headings
SNA: Social network analysis
VBA: visual basic for application

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

TWC conceived and designed the study, SH and CC performed the statistical analyses and were in charge of dealing with data. SH and TWC helped design the study, collected information and interpreted data. HJ monitored the research. All authors read and approved the final article.
Multimedia files

Additional file 1:

MP4: Identifying the unique author name.
http://www.healthup.org.tw/marketing/course/marketing/uniqueauthordetect.mp4

Multimedia file 2: PDF: using between centrality to detect authors with duplicate names in a network.

Multimedia file 3: Txt: Pajek control file and dataset

Pajek_aa.net

Multimedia file 4: MP4 "How to deal with data and build the Google maps

http://www.healthup.org.tw/marketing/course/marketing/mapingGooglemapformedicine.mp4

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