Social Network Analysis of Research Collaboration in Information Reuse and Integration

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Abstract

The study of information reuse and integration (IRI) is a young research field and the increasing degrees of collaboration in this field can be attributed to a predominant trend of networked publication co-authorship which itself contributes a feedback effect to the growth of the IRI community as a whole. Our analysis is based on the positive trends in the IRI community over the process of research and knowledge diffusion. Prolific researchers often initiate new ideas and achieve impacts on the whole research community. The objective of our analysis is to provide accurate viewpoints into the social-networking nature among research collaborations, including identifications of prolific researchers and research groups, trends of their collaborations, and impacts to the research community. By applying analytical processes that discover various collaboration and networking degrees exhibited in the publication co-authorship statistics obtained from our IRI community, we are able to synthesize results which identify research groups, collaboration patterns, and trends.

Keywords: Scientific Collaboration, Social Network Analysis, Co-authorship Analysis, Information Reuse and Integration, Meta Analysis

1. Introduction

Studying scientific collaborations has become increasingly important to better facilitate and enhance the activities of scholarly research and communications [6]. In order to understand the creation process of academic knowledge, we need to first study the structures of the social networks to unfold the activities in the academia [21]. Collaboration network analysis provides an important literature-based perspective that considers the co-authorship patterns. A collaboration network is an indicative representation of the social network among authors since authors who collaborate papers are generally acquainted with each other: authors are connected in a collaboration network if they have written papers together [5].

Social network analysis (SNA) incorporates what emerges from the interaction among human actors [22]. It is an interdisciplinary research paradigm that combines information systems, sociology, physics, biology, computer science, and management science. When analyzing scientific collaborations patterns in a particular journal or conference, many authors employ methods from social network analysis [8].

The study of Information Reuse and Integration (IRI) is a relatively new research area. The International Conference on Information Reuse and Integration (IRI) is currently sponsored by the IEEE Systems, Man and Cybernetics Society. IEEE-IRI has become a major and highly regarded international conference. The proceedings of the IEEE IRI conferences are indexed and included in the IEEE Xplore, DBLP, Conference Proceedings Citation Index (CPCI), Scopus, and EI compendex citation databases [5].

We select IRI conferences over other sources, such as computer science (CS) journals and other CS-related conferences for a number of reasons. First, we consider IRI to be the most prestigious international conference in the field. For example, IRI has been consistently receiving more than 200 submissions annually from researchers all over the world, and has become the primary forum for researchers to interact, communicate, and demonstrate their research. Second, as a conference, IRI has a faster turnaround time than journals, i.e., its review process is much faster than most CS journals. As a result, papers published in IRI can report and represent new ideas, latest research directions, and up-to-date results in a timely manner.

The objective of this paper is to provide a comprehensive view of the IRI research community to understand the phenomena in collaboration among researchers. To this end, we analyzed the collaboration network of researchers who publish in the field of IRI through social network analysis at the domain/disciplinary level. The social network analysis (SNA) provides insights into the structural characteristics of research collaboration networks in IRI. In addition, we used the visualization methodology of SNA to identify main actors, clusters and components.

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The remainder of this paper is organized as follows. In Section 2, we introduce the background of this research. Section 3 describes our research methods and data used in this study. In Section 4, we detail the results of our analysis and discuss the implications. Finally, we summarize our conclusions and consider future research avenues.

2. Related Works

Numerous works on scientific collaboration patterns using various forms of social network analysis are reported in literature [1, 5, 6, 8, 10-12, 14-16, 18-21, 24, 25]. Most of the previous studies agree and consider the co-authorship among authors to be a scientific collaboration [10].

Fischbach et al. [8] reviewed the scientometric literature that examined co-authorship patterns in information systems (IS) research, especially those articles that analyzed a particular IS journal or conference. Prior studies show that many researchers used social network analysis (SNA) methods to analyze the co-authorship patterns in a particular journal or conference [3-5, 8, 13, 23], for example, Fischbach et al. [8] examined the co-authorship network of researchers publishing in Electronic Markets (EM) – The International Journal of Networked Business. Liu et al. [13] applied a social network analysis on the publication co-authorship in the past studies from the ACM, IEEE, and the Joint ACM/IEEE digital library conferences. In addition, Liu et al. [13] used a weighted directional method to examine the state of the digital library (DL), and proposed the AuthorRank method as an indicator of the impact of individual authors. They also look into the nature and amount of international participations in the Joint Conference on Digital Libraries (JCDL).

The research on scientific collaboration with social network analysis within Information System (IS) discipline has been reported for International Conference on Information Systems (ICIS)[23], European Conference on Information Systems (ECIS)[21], Australasian Conference of Information Systems (ACIS) [3], and Pacific Asia Conference on Information Systems (PACIS) [4].

Xu and Chau [23] investigated the social identity of IS by applying social network analysis to collaboration networks for ICIS conference papers over a period of 26 years (from 1980 to 2005) and identified the critical mass within the community, as well as the most productive authors and institutions. Their study observed that directors of large laboratories or research centers may be listed as co-authors in papers on multiple projects, but may not have directly participated in the projects.

Vidgen et al. [21] presented a social network analysis (SNA) of the ECIS community based on patterns of co-authorship from 1993 to 2005. They separated the ECIS contributions into research papers and panels to create social network that were then analyzed using a range of global network level and individual ego (co-author, panelist) measures. The ECIS research community was found to have few properties of the small world and present an agglomeration of co-authorships. The network of ECIS panels had the properties of small world and displayed a stronger sense of social cohesion.

Subsequently, Cheong and Corbitt [3] used social network analysis (SNA) model to investigate the co-authorship network of the ACIS from 1990 to 2006. They used bibliographic data extracted from an Endnote database and SNA to analyze the network of co-authors. The ACIS community was found to be a healthy small-world community that kept evolving in order to provide an environment that supported collaboration and sharing of ideas among researchers. Moreover, Cheong and Corbitt [4] also used SNA to study the co-authorship network of the PACIS from 1993 to 2008. SNA metrics and visualization techniques were able to reveal structural characteristics of the PACIS co-authors community and identify influential members in its community. Cheong and Corbitt [4] found that unlike similar analysis of the ECIS, the PACIS scene was not dominated by a couple of key researchers or a significant number of major performers were identified. The PACIS community was similar to the ACIS community with a number of popular researchers.

In summary, numerous works have been done to examine the scientific collaboration patterns in IS research as well as various journals and conferences. However, to the best of our knowledge, the topics addressed in IRI research have received little attention. In order to fill this gap of the literature, we consider the following research questions:

RQ1: What are the scientific collaboration patterns in the IRI research community?

RQ2: Who are the prominent researchers in the IRI community?

3. Methodology

Our research of scientific collaboration patterns via social network analysis was based on the study of the IEEE International Conference on Information Reuse and Integration (IEEE IRI), and the main reason of this was that the IEEE IRI conference is well established and focused on the IRI area. To compile the IRI literature list for analysis, we use two well-known online data sources: the IEEE Xplore and DBLP. The data sources supply the following information for each article: title, authors, conference title, publication year, number of pages, keywords, and abstract.

Table 1. The distribution the number of co-authors in IRI (2003-2010)

Number of co-authors	IRI2003	IRI2004	IRI2005	IRI2006	IRI2007	IRI2008	IRI2009	IRI2010	Frequency	%
1	16	5	13	7	12	4	12	11	80	10.4%
2	19	35	29	30	43	21	20	21	218	28.4%
3	30	33	33	37	30	33	29	22	247	32.2%
4	15	17	12	22	29	15	14	17	141	18.4%
5	4	12	5	5	2	6	9	4	47	6.1%
6		1	4	4	2	4	2	3	20	2.6%
7	1	1	3	1	1	1	1	1	10	1.3%
8	1			1	1				3	0.4%
10			1						1	0.1%
Total	86	104	100	107	120	84	87	79	767	100.0%
Percentage of Single Author	18.6%	4.8%	13.0%	6.5%	10.0%	4.8%	13.8%	13.9%	10.4%	
Percentage of co-authors	81.4%	95.2%	87.0%	93.5%	90.0%	95.2%	86.2%	86.1%	89.6%	

We developed a simple web focused crawler program to download the literature information of all IRI papers published between 2003 and 2010 from IEEE Xplore and DBLP. Note that only research papers were collected; keynotes and panel discussions were precluded.

After downloading all the data, we integrated the literature information into a spreadsheet. We have found some data inconsistencies from the IEEE Xplore and DBLP citations, for example, authors' names were sometimes abbreviated. We therefore checked the data manually to rectify the problem. After preprocessing the data, a list of 767 paper titles with 1599 distinct author names were gathered. It should be noted that single-authored papers are not considered in the co-authorship networks.

In order to conduct the social network analysis, we have developed a computer program to convert the list of co-authors into the format of a network file readable by the social network analysis software. *UCINet* [2] and *Pajek* [17] were used in this study for social network analysis of research collaboration.

As noted in the prior research [23], the most productive authors or leaders in a scientific discipline are important assets to its academic discipline. Treating scientific growth as a process of knowledge diffusion, prolific researchers are often the ones who initiate new ideas and achieve with impacts on the whole research community.

From the 1599 distinct authors of IRI between 2003 and 2010, we have identified those who publish the most articles. The top10 prolific authors were Stuart Harvey Rubin, followed by Taghi M. Khoshgoftaar, Shu-Ching Chen, Mei-Ling Shyu, Mohamed E. Fayad, Reda Alhajj, Du Zhang, Wen-Lian Hsu, Jason Van Hulse, and Min-Yuh Day. Note the data reported here are based on IRI records only.

Table 1 shows the overall statistics of the co-authorship and the distribution of the number of co-authors of IRI (from 2003 to 2010). For multi-authored papers, each author was assigned a full credit. The ratio of co-authored paper increases from 81.4% in 2003 to 86.1% in 2010. The top 3 categories were three-author papers (32.2%), two-author papers (28.4%), and four-author papers (18.4%). In total, 89.6% of the papers were written by multiple authors as appose to single-author papers which accounted for only 10.6%. The results support the commonly held view that co-authorship is a predominant trend in many academic and research fields including IRI.

4. Data Analysis and Discussion

Though social network analysis, we can identify the most "central" researchers in the co-authorship network [9, 16, 22]. Authors who are more prominent in a research community are often located closer to the strategic locations of the co-authorship network which allow them: (1) to communicate directly with numerous other researchers, (2) to be close to many other working authors, or (3) to be as intermediary in interactions among other author groups. We choose the closeness and betweenness measures to thus quantify the prominence of IRI researchers.

4.1. Closeness Centrality

In an undirected network, the distance between two vertices (to represent authors) is the number of lines or steps on the shortest path that connects them, and *geodesic* is the shortest path between two vertices. The distance from vertex v to vertex w is the length of the geodesic from v to w. The closeness centrality of vertex v is based on the total distance between vertex v and all other vertices ($<> v$), and a larger distance yields a lower closeness centrality scores. The closer a vertex is to all other vertices, the faster and easier information can reach it, and thus the higher centrality. The closeness centrality of vertex v is the number of other vertices divided by the sum of all distances between vertex v and all others [15, 16].

Table 2. Top 30 authors with the highest closeness scores

Rank	ID	Closeness	Author
1	3	0.024675	Shu-Ching Chen
2	1	0.022830	Stuart Harvey Rubin
3	4	0.022207	Mei-Ling Shyu
4	6	0.020013	Reda Alhajj
5	61	0.019700	Na Zhao
6	260	0.018936	Min Chen
7	151	0.018230	Gordon K. Lee
8	19	0.017962	Chengcui Zhang
9	1043	0.017962	Isai Michel Lombera
10	1027	0.017962	Michael Armella
11	443	0.017448	James B. Law
12	157	0.017082	Keqi Zhang
13	253	0.016731	Shahid Hamid
14	1038	0.016618	Walter Z. Tang
15	959	0.016285	Chengjun Zhan
16	957	0.016285	Lin Luo
17	956	0.016285	Guo Chen
18	955	0.016285	Xin Huang
19	943	0.016285	Sneh Gulati
20	960	0.016071	Sheng-Tun Li
21	946	0.016071	Huang-Chih Hsieh
22	465	0.016071	LiWu Chang
23	463	0.016071	Indika Kuruppu-Appuhamilage
24	785	0.016071	Dianting Liu
25	82	0.016071	Kasturi Chatterjee
26	279	0.016071	Chao Chen
27	476	0.015966	Yimin Zhu
28	1535	0.015966	Choochart Haruechaiyasak
29	1237	0.015966	Lin Lin
30	396	0.015659	Khalid Saleem

Table 3. Top 30 authors with the highest betweeness scores

Rank	ID	Betweenness	Author
1	1	0.000752	Stuart Harvey Rubin
2	3	0.000741	Shu-Ching Chen
3	2	0.000406	Taghi M. Khoshgoftaar
4	66	0.000385	Xingquan Zhu
5	4	0.000376	Mei-Ling Shyu
6	6	0.000296	Reda Alhajj
7	65	0.000256	Xindong Wu
8	19	0.000194	Chengcui Zhang
9	39	0.000185	Wei Dai
10	15	0.000107	Narayan C. Debnath
11	31	0.000094	Qianhui Althea Liang
12	151	0.000094	Gordon K. Lee
13	7	0.000085	Du Zhang
14	30	0.000072	Baowen Xu
15	41	0.000067	Hongji Yang
16	270	0.000060	Zhiwei Xu
17	5	0.000043	Mohamed E. Fayad
18	110	0.000042	Abhijit S. Pandya
19	106	0.000042	Sam Hsu
20	8	0.000042	Wen-Lian Hsu
21	94	0.000041	Wenying Feng
22	18	0.000037	Waleed W. Smari
23	97	0.000036	Yang Xu
24	72	0.000035	Chang-Tien Lu
25	32	0.000032	Y. Alp Aslandogan
26	12	0.000032	Meiliu Lu
27	14	0.000030	Eduardo Santana de Almeida
28	17	0.000029	Richard Tzong-Han Tsai
29	108	0.000022	Behrouz H. Far
30	83	0.000022	Behrouz Homayoun Far

The closeness can be defined as how close an author is on average to all other authors. Authors with high closeness values could be viewed as those two can access new information quicker than others and similarly, information originating from those authors can be disseminated to others much quicker [15, 16]. Formally, the closeness of a node *v* in a connected graph *G* is defined as follows:

$$C(v) = \frac{n-1}{\sum_{v,w \in G} d(v,w)}$$

Where *d(v,w)* is the pair-wise geodesic and *n* is the number of all nodes reachable from *v* in *G*. That means that, it is 1 over the average of the shortest paths from *v* to all other nodes in *G* [7].

Table 2 shows the top 30 authors with the highest closeness scores. It shows all those 30 researchers are closely connected to each other through collaborations, which could be viewed as a core component of the IRI community. The authors with high closeness centrality indicated that they collaborate widely. In respect of closeness centrality, the top 10 researchers are: Shu-Ching Chen, Stuart Harvey Rubin, Mei-Ling Shyu, Reda Alhajj, Na Zhao, Min Chen, Gordon K. Lee, Chengcui Zhang, Isai Michel Lombera, and Michael Armella. Since closeness centrality measures the distance of an author to all others in the network, the closer the author is to others, the more favored the author becomes. Authors with high closeness scores are likely to receive information more quickly than others since there are fewer intermediaries from himself/herself to any other.

4.2. Betweenness Centrality

The interaction between any two non-directly connected authors (i.e., who never collaborated before) may depend on the authors who connect them through their shortest path(s). These authors potentially play an important role in the network by controlling the flow of interactions. Hence the authors who lie between most of the shortest paths could be viewed as the central people in the community. This notion, known as the *betweenness* of a node *v*, *B(v)*, measures the number of geodesics between pairs of nodes passing through *v*, and formally defined as follows [9]:

$$B(v) = \sum_{v,w,x \in G} \frac{d(w,x;v)}{d(w,x)}$$

where *d(w,x)* is geodesic between *w* and *x*, and *d(w,x;v)* is a geodesic between *w* and *x* passing *v*. The equation can also be interpreted as the sum of all probabilities a shortest path between pair of nodes *w* and *x* passing node *v*.

Table 3 shows the top 30 authors with the highest betweenness scores. The authors with high betweeness centrality indicated that they collaborated diversely. In respect of betweeness centrality, the top 10 researchers are: Stuart Harvey Rubin, Shu-Ching Chen, Taghi M. Khoshgoftaar, Xingquan Zhu, Mei-Ling Shyu, Reda Alhajj, Xindong Wu, Chengcui Zhang, Wei Dai, Narayan C. Debnath. Thus Stuart Harvey Rubin, Shu-Ching Chen can be viewed as the most prolific researchers in the IRI community network for being on the shortest paths between any other two researchers and thus they are able to have control of the flow of information in the IRI social network.

4.3. Degree Centrality

In a simple undirected network, the degree centrality is the number of neighbors of a vertex, the degree of a vertex is equal to the number of vertices adjacent to the vertex. Vertices with high degrees are often found in dense sections of a network. A high degree of vertices yields a dense network, because vertices attain more ties to neighbors. Degree centralization of a network is the variation in the degrees of vertices divided by the maximum degree variation possible in a network of the same size. We can use an average degree of all vertices to measure the structural cohesion of a network [17].

Table 4 shows the top 30 authors with the highest degree scores. In respect of the degree centrality, the top 10 researchers are: Shu-Ching Chen, Stuart Harvey Rubin, Taghi M. Khoshgoftaar, Reda Alhajj, Wen-Lian Hsu, Min-Yuh Day, Mei-Ling Shyu, Richard Tzong-Han Tsai, Eduardo Santana de Almeida, and Roumen Kountchev. Authors with higher degrees of centrality collaborate with more authors frequently.

Degree centrality and closeness centrality measure authors' impacts on the field and their importance for the scientific collaboration [24]. Betweeness creates an advantage by lowering the risk of collaboration and by increasing the value of collaboration. Authors with high betweenness centrality have more opportunities to broker the flow of information and they have a higher value of scientific collaboration. Degree centrality measures both strong ties and weak ties of authors. Closeness centrality measures author's position and their virtual distance from others in the field.

The common traits of scientific collaboration are: co-authoring with multiple authors would yield a higher degree centrality; co-authoring articles with multiple authors would yield a higher closeness centrality which may also result in high closeness centrality, and authors involved in interdisciplinary research would yield higher betweenness centrality.

4.4. Visualization of Social Network Analysis

Table 4. Top 30 authors with the highest degree scores

Rank	ID	Degree	Author
1	3	0.035044	Shu-Ching Chen
2	1	0.034418	Stuart Harvey Rubin
3	2	0.030663	Taghi M. Khoshgoftaar
4	6	0.028786	Reda Alhajj
5	8	0.028786	Wen-Lian Hsu
6	10	0.024406	Min-Yuh Day
7	4	0.022528	Mei-Ling Shyu
8	17	0.021277	Richard Tzong-Han Tsai
9	14	0.017522	Eduardo Santana de Almeida
10	16	0.017522	Roumen Kountchev
11	40	0.016896	Hong-Jie Dai
12	15	0.015645	Narayan C. Debnath
13	9	0.015019	Jason Van Hulse
14	25	0.013767	Roumiana Kountcheva
15	28	0.013141	Silvio Romero de Lemos Meira
16	24	0.013141	Vladimir Todorov
17	23	0.013141	Mariofanna G. Milanova
18	5	0.013141	Mohamed E. Fayad
19	19	0.012516	Chengcui Zhang
20	18	0.011890	Waleed W. Smari
21	7	0.011264	Du Zhang
22	48	0.011264	Daniel Lucredio
23	29	0.010638	Timothy W. Simpson
24	27	0.010638	Viktor K. Prasanna
25	101	0.010638	Ryan T. K. Lin
26	20	0.010638	Chorng-Shyong Ong
27	22	0.010013	Huajun Chen
28	13	0.009387	Seung-yun Kim
29	30	0.008761	Baowen Xu
30	57	0.008761	Keivan Kianmehr

Fig. 1 shows the visualization of IRI co-authorship network using the *pajek* software [17]. The global view of IRI co-authorship network shows that the social network of IRI is not fully connected. It contains a number of separated components (subsets) among which there exist no paths between any two authors in different component which is in line with prior studies showing the ECIS network is also not fully connected [21].

Fig. 2 shows the largest component in the IRI coauthorship network using *pajek*. In this component, Stuart Harvey Rubin, Shu-Ching Chen, and Mei-Ling Shyu are closely connected through collaborations which can be viewed as the core collaboration component of the IRI community.

5. Conclusions

In this paper, we analyzed the collaboration network of researchers who publish in the field of IRI with methods of social network analysis. The result of our analysis provided insight into the structural characteristics of research collaboration networks in IRI. The visualization method has proved to be highly informative to identify main actors, clusters and components and a useful perspective in understanding the dynamics of collaborating networks.

The contributions of our study are as follows: (1) we have provided a better understanding of scientific collaboration with social network analysis at the

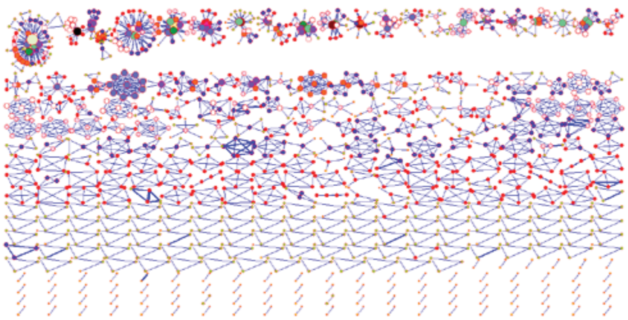

Fig. 1. Visualization of IRI co-authorship network (global view)

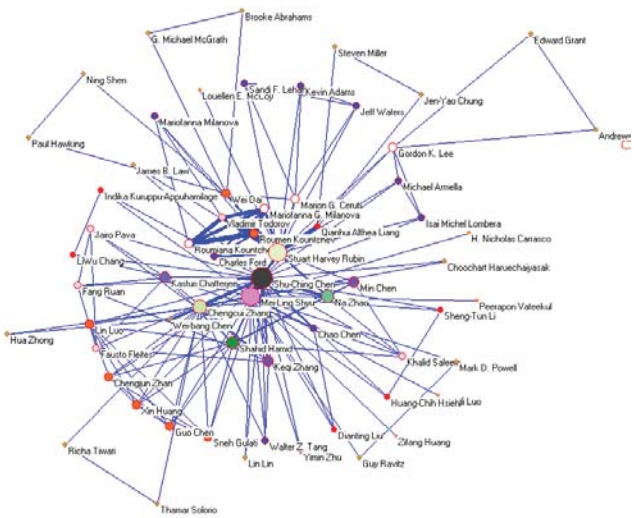

Fig. 2. The largest component (by size) in the IRI co-authorship network

domain/disciplinary level; (2) we have provided a more comprehensive view of the IRI research community by investigating the scientific network through social network analysis.

This research has certain limitations that should be addressed in future studies. Since most researchers publish in several conferences and journals, the analysis of bibliographical data from only IRI cannot give a more complete picture of their authorship patterns. Therefore, for a more complete coverage of the IRI field, the boundary of the network should be extended to include other related conferences and journals. Future works to provide a better understanding of the IRI community may thus includes: (1) incorporating institutional information in the analysis, and (2) identification of the various groups that exist in the network and their research areas.

6. References

[1] A. L. Barabasi, H. Jeong, Z. Neda, E. Ravasz, A. Schubert, and T. Vicsek, "Evolution of the social network of scientific collaborations," *Physica a-Statistical Mechanics and Its Applications,* vol. 311, no. 3-4, 2002, pp. 590-614.

[2] S. P. Borgatti, M. G. Everett, and L. C. Freeman, *UCINET for Windows: Software for social network analysis*, 2002.

[3] F. Cheong and B. Corbitt, "A social network analysis of the co-authorship network of the Australasian Conference of Information Systems from 1990 to 2006," in Proceedings of the 17th European Conference on Information Systems (ECIS) 2009.

[4] F. Cheong and B. J. Corbitt, "A social network analysis of the co-authorship network of the Pacific Asia Conference on Information Systems from 1993 to 2008," in Proceedings of Pacific Asia Conference on Information Systems (PACIS 2009), Hyderabad, India, 2009.

[5] M.-Y. Day, C.-S. Ong, and W.-L. Hsu, "An Analysis of Research on Information Reuse and Integration (2003-2008) " *International Transactions on Systems Science and Applications,* vol. 6, no. 2/3, 2010, pp. 146-157.

[6] Y. Ding, "Scientific collaboration and endorsement: Network analysis of coauthorship and citation networks," *Journal of Informetrics,* vol. 5, no. 1, 2011, pp. 187-203.

[7] E. Elmacioglu and D. Lee, "On six degrees of separation in DBLP-DB and more," *ACM SIGMOD Record,* vol. 34, no. 2, 2005, pp. 33-40.

[8] K. Fischbach, J. Putzke, and D. Schoder, "Co-authorship networks in electronic markets research," *Electronic Markets*, 2011, pp. 1-22.

[9] L. C. Freeman, "A Set of Measures of Centrality Based on Betweenness," *Sociometry,* vol. 40, no. 1, 1977, pp. 35-41.

[10] Y. Han, B. Zhou, J. Pei, and Y. Jia, "Understanding Importance of Collaborations in Co-authorship Networks: A Supportiveness Analysis Approach," in Proceedings of the Ninth SIAM International Conference on Data Mining, 2009.

[11] J. S. Katz and B. R. Martin, "What is research collaboration?," *Research Policy,* vol. 26, no. 1, 1997, pp. 1-18.

[12] B. Lee, O. Kwon, and H. J. Kim, "Identification of dependency patterns in research collaboration environments through cluster analysis," *Journal of Information Science,* vol. 37, no. 1, 2011, pp. 67-85.

[13] X. M. Liu, J. Bollen, M. L. Nelson, and H. Van de Sompel, "Co-authorship networks in the digital library research community," *Information Processing & Management,* vol. 41, no. 6, 2005, pp. 1462-1480.

[14] G. Melin and O. Persson, "Studying research collaboration using co-authorships," *Scientometrics,* vol. 36, no. 3, 1996, pp. 363-377.

[15] M. Newman, "Who is the best connected scientist? A study of scientific coauthorship networks," *Complex networks*, 2004, pp. 337-370.

[16] M. E. J. Newman, "Coauthorship networks and patterns of scientific collaboration," in Proceedings of the National Academy of Sciences of the United States of America, 2004, pp. 5200-5205.

[17] W. Nooy, A. Mrvar, and V. Batagelj, *Exploratory social network analysis with Pajek*: Cambridge University Press, 2005.

[18] P. Racherla and C. Hu, "A Social Network Perspective of Tourism Research Collaborations," *Annals of Tourism Research,* vol. 37, no. 4, 2010, pp. 1012-1034.

[19] L. Subelj, S. Furlan, and M. Bajec, "An expert system for detecting automobile insurance fraud using social network analysis," *Expert Systems with Applications,* vol. 38, no. 1, 2011, pp. 1039-1052.

[20] T. Velden, A. Haque, and C. Lagoze, "A new approach to analyzing patterns of collaboration in co-authorship networks: mesoscopic analysis and interpretation," *Scientometrics,* vol. 85, no. 1, 2010, pp. 219-242.

[21] R. Vidgen, S. Henneberg, and P. Naude, "What sort of community is the European Conference on Information Systems? A social network analysis 1993-2005," *European Journal of Information Systems,* vol. 16, no. 1, 2007, pp. 5-19.

[22] S. Wasserman and K. Faust, *Social network analysis: Methods and applications*: Cambridge university press, 1994.

[23] J. Xu and M. Chau, "The social identity of IS: analyzing the collaboration network of the ICIS conferences (1980-2005)." pp. 569-589.

[24] E. J. Yan and Y. Ding, "Applying Centrality Measures to Impact Analysis: A Coauthorship Network Analysis," *Journal of the American Society for Information Science and Technology,* vol. 60, no. 10, 2009, pp. 2107-2118.

[25] H. Z. Zhang, B. J. Qiu, K. Ivanova, C. L. Giles, H. C. Foley, and J. Yen, "Locality and Attachedness-Based Temporal Social Network Growth Dynamics Analysis: A Case Study of Evolving Nanotechnology Scientific Collaboration Networks," *Journal of the American Society for Information Science and Technology,* vol. 61, no. 5, 2010, pp. 964-977.