Int. J. Nonlinear Anal. Appl. 13 (2022) 2, 1663–1671
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2022.21079.2229

Visualizing the scientific collaboration of nonlinear analysis in co-authorship: A scientometrics study

Rahman Marefat, Rouhlah Khademi*

Knowledge and Information Science Department, Semnan University, Semnan, Iran

(Communicated by Madjid Eshaghi Gordji)

Abstract

Visualizing the scientific outputs in the field of nonlinear analysis (NA) and Mapping the co-author network of researchers in the Web of Science database (WOS) were the main purpose of this research based on scientometric methods. The rate of authors, source titles, Countries/Regions, research area and organizations in NA filed at WOS during 1985-2019 was determined. Co-author network, university co-authorship network and Country co-authorship network in NA filed at WOS during the time span investigated, also were identified by researchers. Totally, 12188 documents on NA subject were indexed on the web of science core collection from 1985 to 2019. The co-author network was mapped and analyzed. The results showed that there is an increasing rate of publishing documents in NA during the time of research.

Keywords: Nonlinear Analysis (NA), Visualization, bibliographic analysis, scientific collaboration
2010 MSC: 91A05, 91A22, 91A80

1 Introduction

Researchers and scientists on nonlinear analysis (NA), as one of the main fields in mathematics, have published over and over articles and publications all over the world in recent years. Although, it seems that published documents about scientific outputs in the field of NA is less than fingers. Some researchers have analyzed bibliometrics aspect of Mathematics [1] and others tried to analyze the publications on mathematics anxiety trough mapping the literature and via the bibliometrics analysis methods [6]. Also, other articles have a glance on mathematics and statistics related studies using co-authorship network analysis [9]. Some researchers believe that although mathematics has an important position in the structure and context of science, but the number of scientific publications in mathematics is very low, because transitions and changes of ideas in mathematics occur slowly in comparison with chemistry or other scientific fields of sciences [5].

Studying scientific collaboration on the area of Nonlinear Analysis is the main objective of this article. Other objectives of the article are as follows:

A. Studying the number of records and document types in NA filed which indexed at WOS during the 1985-2019 periods.

*Corresponding author
Email addresses: rmarefat@semnan.ac.ir (Rahman Marefat), r.khademi@semnan.ac.ir (Rouhlah Khademi)

Received: August 2020 *Accepted:* January 2022

B. Investigating the authors, source titles, Countries/Regions and organizations which have most published articles and scientific productions in NA filed at WOS during the 1985-2019.
C. Determining the co-author network in NA filed at WOS during the 1985-2019.
D. Identification of university co-authorship network in NA filed at WOS during the 1985-2019.
E. Country co-authorship network in NA filed at WOS during the 1985-2019.

2 Methodology

To retrieve all publications on NA, core collection of web of science (WoS) database, as one of the main bibliometrics databases, was searched on 8rd February 2020 and from 1985 to 2019. The year 2020 was abandoned because that NA articles not completely indexed yet until the end of 2020 on WOS. UCINet [3], Netdraw [2] and VOSviewer [13] as scientometic software's was used to analyze and mapping the scientific productions and co-authorships. Collaboration is considered as a common social interaction that consists of multiple actors and the relationships between them; a network graph can represent this by the nodes and edges [15] that we can consider it as a social network. So Social network analysis (SNA) was used for data analyzing. Centrality masseurs are common for SNA in order to identify the most importance of actors in a network. Degree, betweenness and closeness are the most prevalent of centrality. Otte and Rousseau (2002) defined these measures as below [11]: "Degree centrality of a node is defined as the number of ties this node has (in graph-theoretical terminology, the number of edges adjacent to this node). In mathematical terms degree centrality, d (i), of node i is defined as:

$$d(i) = \sum_j m_{ij}$$

Where $m_{ij} = 1$ if there is a link between nodes i and j, and $m_{ij} = 0$ if there is no such link. In a co-author graph the degree centrality of an actor is just the number of authors in the graph with whom she has co-authored at least one article".

"Closeness centrality of a node is equal to the total distance (in the graph) of this node from all other nodes. As a mathematical formula closeness centrality, c (i), of node i can be written as:

$$c(i) = \sum_j d_{ij}$$

Where d_{ij} is the number of links in a shortest path from node i to node j. Closeness is an inverse measure of centrality in that a larger value indicates a less central actor while a smaller value indicates a more central actor", "betweenness centrality is the number of shortest paths that pass through a given node. As a mathematical expression the betweenness centrality of node i, denoted as b (i) is obtained as:

$$b(i) = \sum_{j,k} \frac{g_{jik}}{g_{jk}}$$

Where g_{jk} is the number of shortest paths from node j to node $k(j, k \neq i)$ and g_{jik} is the number of shortest paths from node j to node k passing through node i".

3 Findings

A. Number of records in NA filed which indexed at WOS during the 1985-2019. Totally 12188 documents on NA subject were indexed on web of science core collection from 1985 to 2019. The gradually growth of NA records which indexed on WOS during 1985-2019 is drawn on below figure. From Totally 12188 documents, 9449 (77.52%) in article type published in NA fields during the 1985-2019 and 2856 (23.43%) in conference proceedings format and only, 143 records (1.17%) in review style has been published. Other formats of records, are shown in table 1. B. Rate of authors, source titles, Countries/Region and organizations which have most published articles and scientific productions in NA filed at WOS during the 1985-2019. During 1985-2019, some authors such as CHAN SL (with 65 records) and GE HX (with 62 records) have published more than 60 documents on NA at WOS. The rank of authors who published the most records on NA at WOS during 1985-2019 is visible in table 2.

Table 1: Document types of NA records on WOS during 1985-2019

Document Types	records	%of 12188
ARTICLE	9449	77.527
PROCEEDINGS PAPER	2856	23.433
REVIEW	143	1.173
MEETING ABSTRACT	44	0.361
EDITORIAL MATERIAL	42	0.345
DISCUSSION	24	0.197
EARLY ACCESS	21	0.172
NOTE	18	0.148
CORRECTION	16	0.131
LETTER	15	0.123
BOOK CHAPTER	6	0.049
BOOK REVIEW	4	0.033
BIOGRAPHICAL ITEM	3	0.025
CORRECTION ADDITION	3	0.025
DATA PAPER	1	0.008
REPRINT	1	0.008
RETRACTED PUBLICATION	1	0.008
SOFTWARE REVIEW	6	0.049
BOOK CHAPTER	1	0.008

Table 2: Authors who published the most records on NA at WOS during 1985-2019

Authors	records	%of 12188
CHAN SL	65	0.533
GE HX	62	0.509
BRADFORD MA	51	0.418
CHENG RJ	51	0.418
IZZUDDIN BA	46	0.377
YANG YB	45	0.369
REDDY JN	44	0.361
REZAIEE-PAJAND M	41	0.336
lIANG QQ	36	0.295
LEE J	32	0.263

Table 3: List of Journals published the most records on NA at WOS during 1985-2019

source Titles	records	%of 12188
ENGINEERING STRUCTURES	453	3.717
COMPUTERS and STRUCTURES	319	2.617
COMPOSITE STRUCTURES	202	1.657
JOURNAL OF STRUCTURAL ENGINEERING ASCE	186	1.526
JOURNAL OF CONSTRUCTIONAL STEEL RESEARCH	180	1.477
STRUCTURAL ENGINEERING AND MECHANICS	156	1.28
JOURNAL OF STRUCTURAL ENGINEERING	136	1.116
THIN WALLED STRUCTURES	132	1.083
APPLIED MECHANICS AND MATERIALS	128	1.05
ADVANCED MATERIALS RESEARCH	121	0.993

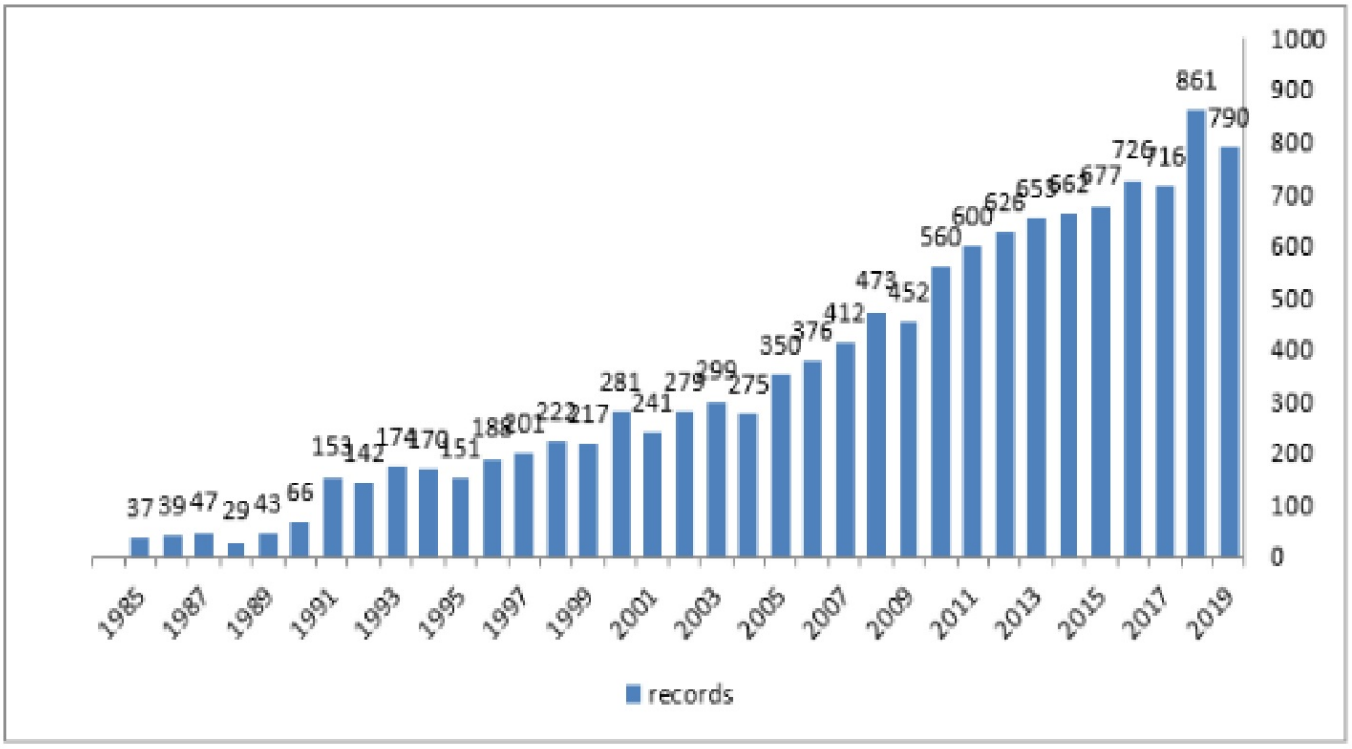


Figure 1. The growth of NA records on WOS during 1985-2019.

From Totally 12188 documents, 453 (3.71%) published in ENGINEERING STRUCTURES journal and 319 (2.61%) in COMPUTERS & STRUCTURES and only, 202 records (1.65%) in COMPOSITE STRUCTURES has been published. Other journals which have published the NA records, are observable in table3.

Table 4 shows that from Totally 12188 documents on NA at WOS during 1985-2019, exactly 2419 (19.84%) published from USA and 2394 (19.64%) form China. Italy, Iran, India and England' researchers have published more than 500 documents in NA at WOS during the research time. Other countries/regions are visible in below table.

Results showed that TONGJI University with 172 (1.41) records, Indian Intuition of technology with 137 (1.12%) and Islamic Azad University with 119 (0/97%) records are most prolific among other institutions and academic and scientific centers. Table 5, shows universities and scientific centers published the most records on NA at WOS during 1985-2019.

4 C. Determining the co-author network in NA filed

Co-authorship network tries to modeling relationships between authors by graph [8]. Figure 2, shows the co-author network of NA fields on WOS during 1985-2019. Density of any network is a fraction that ranges from a minimum of 0 to a maximum of 1, when all arcs are present [12]. Results showed that the density of co-author network in this study was very low (0.009).

A better measure of network cohesiveness is centrality metrics [12] and in this research, three common centrality measures (degree, closeness and betweenness) were considered. According to findings degree centrality of some authors were over 30, such as Hadi, Muhammad N. S. (33), Cheng, Rongjun (32), Ge, Hongxia (32), Liang, Qing Quan (32), and Patel, Vipulkumar Ishvarb (30). Table 6, reports the centrality measure of authors in this network on research time.

In any networks, a high closeness centrality for an author means that the author is characterized by many authors and has short connections to other authors [12].

Table 4: List of Countries/Region published the most records on NA at WOS.

Countries/Regions	records	% of 12188
USA	2419	19.847
CHINA	2394	19.642
ITALY	746	6.121
IRAN	743	6.096
INDIA	526	4.316
ENGLAND	514	4.217
SOUTH KOREA	484	3.971
JAPAN	481	3.947
AUSTRALIA	452	3.709
FRANCE	407	3.339

Table 5: Universities published the most records on NA at WOS during 1985-2019

Organizations	records	%of 12188
TONGJI UNIV	172	1.411
INDIAN INST TECHNOL	137	1.124
ISLAMIC AZAD UNIV	119	0.976
TECHNION ISRAEL INST TECHNOL	111	0.911
UNIV NEW S WALES	107	0.878
DALIAN UNIV TECHNOL	104	0.853
CHINESE ACAD SCI	96	0.788
HONG KONG POLYTECH UNIV	92	0.755
SHANGHAI JIAO TONG UNIV	92	0.755
NATL TECH UNIV ATHENS	89	0.73

Table 6: Authors' ranking based on Centrality measures.

Rank	Author	Degree centrality	Author	Closeness centrality	Author	Betweenness centrality
1	Hadi, Muhammad N. S.	33	Patel, Vipulkumar Ishvarb	305	Patel, Vipulkumar Ishvarb	4
2	Cheng, Rongjun	32	Reddy,J.N.	305	Reddy,J.N.,	4
3	Ge, Hongxia	32	Ghannadpour, S. A. M.	306	Ghannadpour, S. A. M.	3
4	Liang, Qing Quan	32	Thai, Huu-Tai	306	Thai, Huu-Tai	3
5	Patel, Vipulkumar Ishvarb	30	Hadi, Muhammad N. S	307	Others	0
6	Kitipornchai, S.	19	Liang, Qing Quan	307		
7	Albermani, Fga	18	Liew,K.M.	307		
8	Ghannadpour, S. A. M.	17	Zhang, L. W.	307		
9	Ovesy, H. R.	16	Ovesy,H. R.	309		

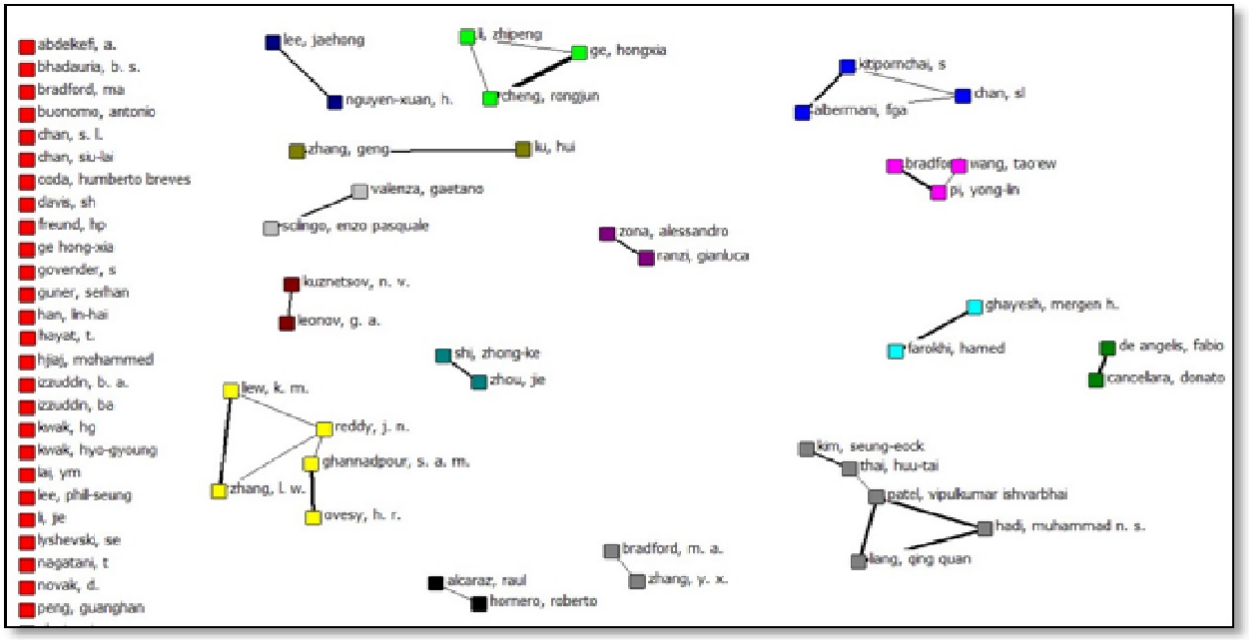


Figure 2. The Co-author network of NA fields on WOS during 1985-2019.

5 D. Identification of university co-authorship network in NA filed

Findings showed that the density of University co-authorship network in this study was very excellent (0.093), as shown at figure 3 and table 7. According to the findings, the five universities, Ningbo University (80), Jiangsu Prov Collaborat I (55), Zhejiang Univ (54), Tongji University (44) and Islamic Azad University (35), ranked on top of table 6 on the basis of Degree centrality measure. Zhejiang University and Tongji University's position between other universities, on top of table 6 is notable and shows their co-authorship network effect at NA fields on WOS during the research time. Centrality measure of universities in this network on research time has reported on table 7.

6 E. Country co-authorship network in NA filed at WOS during the 1985-2019

Results showed that the density of country co-authorship network in this study was very excellent (0.371).

Centrality measure of country co-authorship ranking in this network on research time has reported on table 8. USA (with 830), China (443), England (261), Italy (261) and Australia (195), were the five countries among others, which have increasingly co-authorship network on basis of Degree centrality metric.

7 Conclusions and remarks

As Newman (2004) mentioned that "networks are not new to bibiometrics" [10], there are some evidences about investigating on co-authorship networks in several aspect of sciences, such as [4, 7, 16]. Bibliometrics analysis of Mathematics, in generally, and investigating of Mathematic journals or citation impacts of authors of journal were considered by some researchers such as [1, 7, 14, 16]. But on the area of NA, there isn't any research which try to visualize the scientific collaboration of NA in co-authorship. This research tries to resolve this gap. According to the results, the number of documents which published about NA, show an increasingly rate during the 1985-2019, so that there was an obvious rise especially after 1991. This study showed significant information about the researcher's trends in the field of NA on publishing their outputs in articles and conference paper formats. Although review format also was few considered by authors, but other formats were not noticed remarkably. Only several central authors contain

Table 7: Universities' ranking based on Centrality measures.

Rank	University	Degree centrality	University	Closeness centrality	University	Betweenness centrality
1	Ningbo Univ	80	City Univ Hong Kong	124	Univ Illinois	242.871
2	Jiangsu Prov Collaborat I	55	Zhejiang Univ	127	Zhejiang Univ	209.928
3	Zhejiang Univ	54	Tongji Univ	127	City Univ Hong Kong	196.413
4	Tongji Univ	44	Hunan Univ	129	Tongji Univ	192.313
5	Islamic Azad Univ	35	Dalian Univ Technol	131	Hunan Univ	153.205
6	City Univ Hong Kong	29	Univ Illinois	133	Univ New S Wales	143.226
7	Hong Kong Polytech Univ	21	Univ New S Wales	135	Texas A&M Univ	141.983
8	Southeast Univ	19	Hong Kong Polytech Univ	139	Dalian Univ Technol	135.336
9	Hunan Univ	18	Texas A&M Univ	139	Nanyang Technol Univ	85.077
10	Shandong Univ	17	Harbin Inst Technol	140	Politecn Torino	82.236

Table 8: Country co-authorship ranking based on Centrality measures

Rank	Country	Degree centrality	Country	Closeness centrality	Country	Betweenness centrality
1	Usa	830	Usa	56	Usa	181.475
2	China	443	Italy	67	Italy	80.498
3	England	261	England	69	Germany	72.776
4	Italy	261	Germany	70	England	68.311
5	Australia	195	Iran	70	Iran	60.775
6	Germany	191	China	72	France	52.241
7	France	185	France	73	China	49.748
8	Iran	149	Japan	78	Belgium	34.824
9	Canada	143	Spain	78	Spain	33.306
10	Japan	141	Belgium	78	Japan	27.079

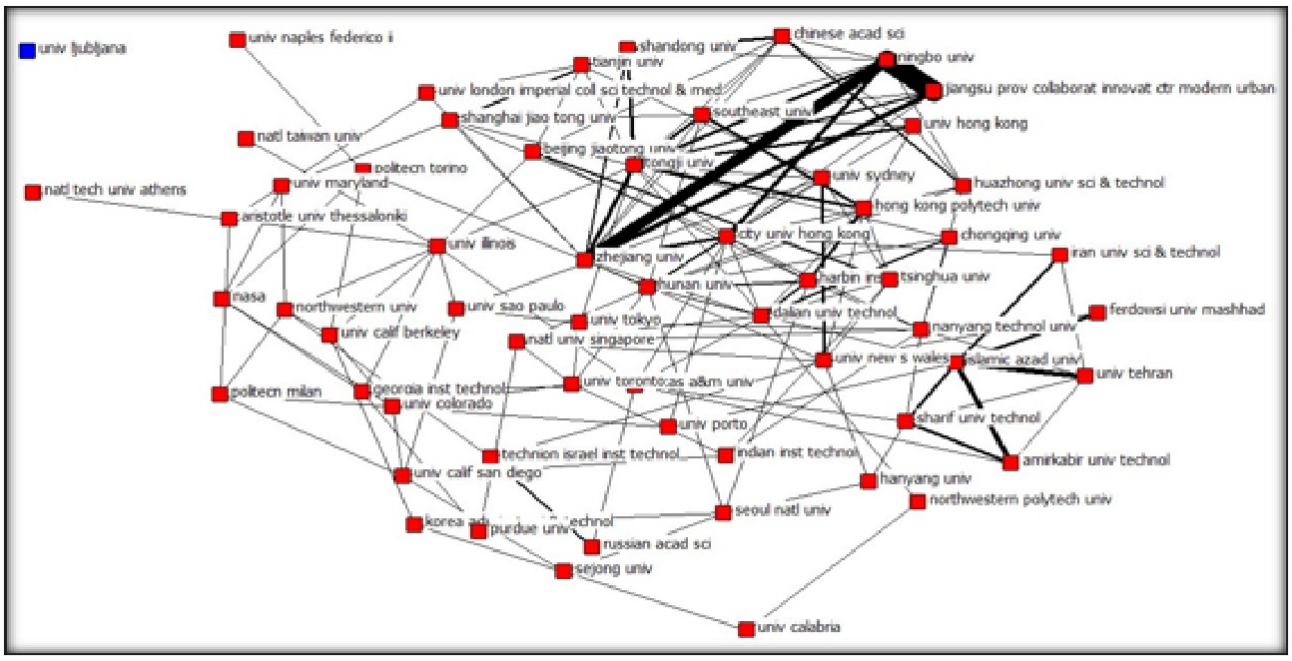


Figure 3. University co-authorship network of NA fields on WOS during 1985-2019.

entire connections within network. Although the density of co-author network in this study was very low (0.009), but the density of University co-authorship network (0.093) and the density of country co-authorship network (0.371) in this network were very excellent.

References

[1] H. Behrens and P. Luksch, *Mathematics 1868–2008: a bibliometric analysis*, Scientometrics **86** (2011), no. 1, 179–194.

[2] S.P. Borgatti, *NetDraw: Graph visualization software*, Harvard, MA: Anal. Technol., 2002.

[3] S.P. Borgatti, M.G. Everett and L.C. Freeman, *Ucinet for windows: Software for social network analysis*, Harvard, MA: Anal. Technol. **6** (2002), 12–15.

[4] H. Bozdogan and O. Akbilgic, *Social network analysis of scientific collaborations across different subject fields*, Inf. Serv. Use **33** (2013), no. 3-4, 219-233.

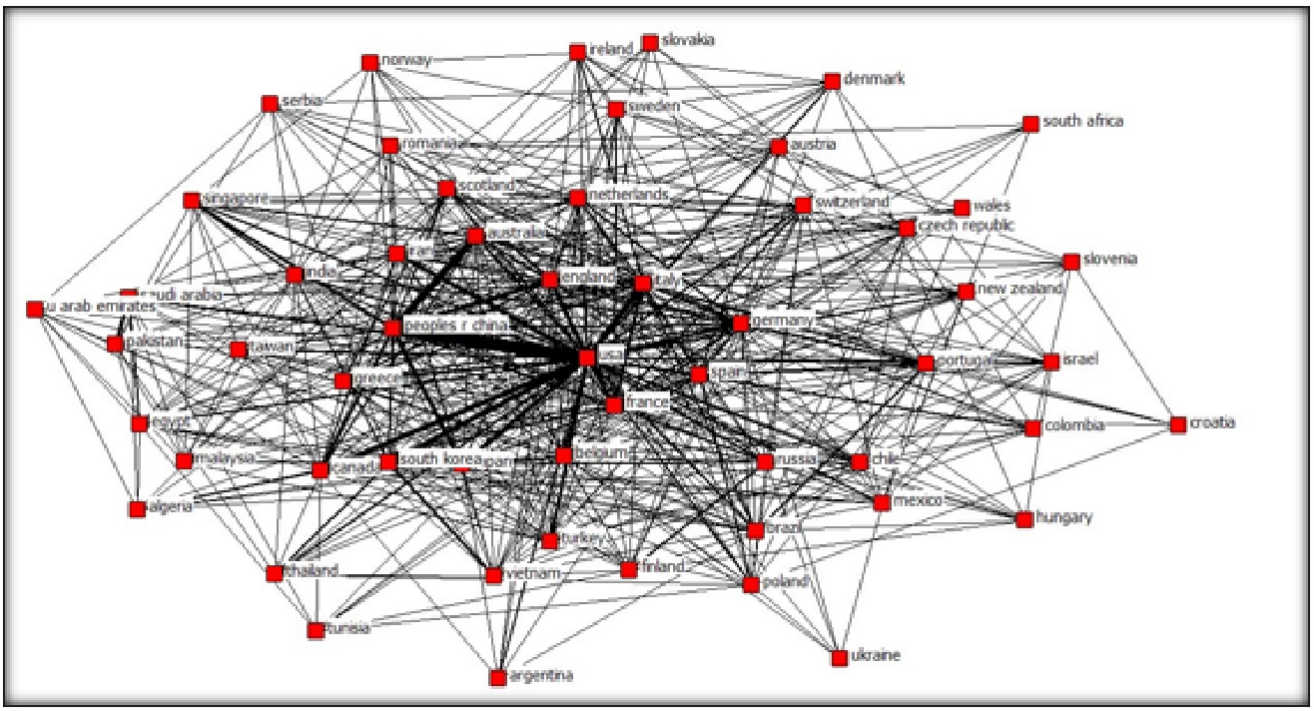
[5] S. Ebrahimy and F. Osareh, *What are the scientific notions formed in mathematics discipline in SCI and SSCI databases?*, Int. J. Inf. Sci. Manag. **10** (2012), no. 2, 1–13.

[6] Z. Ersozlu and M. Karakus, *Mathematics anxiety: mapping the literature by bibliometric analysis*, Eurasia J. Math. Sci. Technol. Educ. **15** (2019), no. 2, em1673.

[7] B.A. Herbel-Eisenmann and S. Otten, *Mapping mathematics in classroom discourse*, J. Res. Math. Educ. **42** (2011), no. 5, 451–485.

[8] J. Kim and C. Perez, *Co-authorship network analysis in industrial ecology research community*, J. Ind. Ecol. **19** (2015), no. 2, 222–235.

[9] I.M. Nadhiroh, R. Hardiyati, M. Amelia and T. Handayani, *Mathematics and statistics related studies in Indonesia using co-authorship network analysis*, Int. J. Adv. Intell. Inf. **4** (2018), no. 2, 142–153.



[10] M.E.J. Newman, *Coauthorship networks and patterns of scientific collaboration*, Proc. Nat. Acad. Sci. **101** (2004), 5200–5205.

[11] E. Otte and R. Rousseau, *Social network analysis: a powerful strategy, also for the information sciences*, J. Inf. Sci. **28** (2002), no. 6, 441–453.

[12] P. Racherla and C. Hu, *A social network perspective of tourism research collaborations*, Ann. Tourism Res. **37** (2010), no. 4, 1012–1034.

[13] N.J. Van Eck and L. Waltman, *VOSviewer manual*, Leiden, Univeristeit Leiden, **1** (2013) no. 1, 1–53. .

[14] P. Wang, F. Zhu, H. Song, and J. Hou, *A bibliometric retrospective of the journal Eurasia journal of mathematics, science and technology education between 2012 and 2017*, Eurasia J. Math. Sci. Technol. Educ. **14** (2017), no. 3, 765-775.

[15] Q. Ye, H. Song and T. Li, *Cross-institutional collaboration networks in tourism and hospitality research*, Tourism Manag. Perspect. **2** (2012), 55–64.

[16] P. Zhou and L. Leydesdorff. *The citation impacts and citation environments of Chinese journals in mathematics*, Scientometrics **72** (2007), no. 2, 185–200.