Exploring Research Collaboration through Network Analysis*

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Abstract

Research collaboration is crucial to driving innovation, sustainable economic development and promoting social and environmental sustainability. Academic research collaboration is an efficient means of enhancing research productivity. This study aims to explore the co-authorship network of the "Recent Trends and Advances in Computer Science and Information Technology" (RTA-CSIT) conference, conducted in four years: 2016, 2018, 2021, and 2023, in Albania. The objectives of this study are to understand the collaborative interactions among researchers and to identify key contributors and research groups contributing to this conference. A co-authorship network with 183 nodes (authors) and 286 unique edges (collaborations) is explored. Various network, edge, and node measures are assessed. The network measures include density, clustering coefficient, centralisation, and the number of components; the edge measures include the edge weight and the edge betweenness centrality, whereas the node measures include measures such as degree, strength, betweenness, and PageRank centralities, to identify the most influential researchers. The network analysis found that the network is fragmented into a considerable number of connected components, and it is sparse. The giant connected component of the co-authorship network discovers the existence of five tight-knit communities with some bridges in between them. The study delves into the Computer Science and Information Technology research collaboration network, identifying influential researchers who play critical roles in fostering future research collaboration and driving advancements in these fields.

Keywords

co-authorship network, strength, density, clustering coefficient, assortativity, computer science & information technology

1. Introduction

Research collaboration, between universities, businesses and governments, is crucial to driving innovation, sustainable economic development and promoting social and environmental sustainability. Academic research collaboration, as a form of collaborative research, has recently gained increasing prominence, and it is an efficient way to increase not only the quantity but also the quality of research publications. Researchers are not independent, but they are members of research collaboration networks looking for innovative solutions to different problems. Through collaboration networks, researchers can share ideas (resources and information), generate and deliver new knowledge, and create innovations. For a better understanding of the theoretical diversity, identifying the research gaps, and future research directions within every discipline, it is required to understand its collaboration structure and dynamics. Co-authorship networks are one of the academic social networks that are increasingly used, as co-authorship is one of the most important indicators of research collaborations ([1], [2], [3]). By co-authorship network analysis, co-authorship network collaboration patterns, influential researchers, influential groups of researchers, and the connectivity of the whole research community can be identified. Understanding the structure of collaborative networks amongst Computer Science and Information Technology (CS & IT) researchers and practitioners is fundamental for a better understanding of the development, exchange and diffusion of knowledge within it.

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Universities and research institutions engage in international collaboration for competitiveness and marketisation, to strengthen research and develop knowledge capacity. Conferences, as a research activity, are platforms where researchers exchange information and experiences, where scientific, economic, and social relationships are formed, and research groups are created. Experts' opinions, academic discussions, valuable feedback, and comments are some of the benefits of attending and participating in scientific conferences. The study by [4] shows that businesses can learn and use scientific knowledge from intense participation in computer science conferences. The "Recent Trends and Advances in Computer Science and Information Technology" (RTA-CSIT) conference is a significant event for sharing the recent breakthroughs in the fields of CS & IT in Albania, the Balkans, and internationally. This conference offers a dynamic environment for fostering collaboration, discussing emerging trends and challenges, and advancements in areas such as Artificial Intelligence, Computing technologies, Cybersecurity, Data Science, and E-commerce and E-business. It provides opportunities to exchange new ideas and experiences, encourage collaboration and innovation, and find future collaborators. Regardless of its ever-growing reputation, little research has been conducted to evaluate the conference's impact in terms of research collaboration.

This study attempts to fill this gap by conducting a co-authorship network analysis of the RTA-CSIT conference, offering an overview of the collaborative environment in these fields over the last decade. The findings of this study will help not only the organisers of this event but also other institutions to better understand collaborative relationships amongst researchers in the fields of CS & IT and related fields. Identification of the most influential researchers and research groups in the co-authorship network is important as they can help foster collaborations and advance these fields further.

Three research questions to give responses in this study are:

- How geographically distributed are the researchers contributing to the RTA-CSIT conference?
- What structural properties do the co-authorship network and its giant connected component have?
- Who are the most influential researchers?

Understanding the behaviour of the CS & IT research community helps to better understand how this community is going to develop and strengthen in the future.

In the next section, this paper continues with the related work on co-authorship network analysis. Then the data and methods are presented. Following that, the results and discussion section is presented, including network (node and edge) metrics, key authors, number of components, and the giant component analysis. A summary of the results, with implications, limitations, and some directions for future research work, is presented in the last section of conclusions.

2. Related work

Many researchers have examined co-authorship networks of different institutions, countries, and research fields. For example, researchers [5] studied research collaboration networks in the field of medicine (gastroenterology), and the co-authorship network analysis showed an evolution of the network over time, from a sparse, highly fragmented network to one with a growing number of connected components. Similarly, scholars [6] studied the co-authorship network of Iranian researchers in the field of osteoporosis for authors with at least five papers; a network with 183 authors and only two components; and showed low collaboration between researchers. Furthermore, [7] studied the co-authorship network in health research with nodes indicating the countries and institutions, and France, the United States, and Spain emerged as the most central countries, and the University of Texas was the most central institution in the network. In a study

on research collaboration in various fields, [8] explored the co-authorship relationships amongst Indonesian authors in a specific institution and identified the most influential authors using centrality measures and the prominent communities in the network. Another study, [9], examined the structure and dynamics of the co-authorship network amongst researchers at an Italian research centre. For the two analysed networks, it was found that they were decentralised, and the most central researchers were members with the longest experience at the centre. Moreover, they found positive correlations between the centrality measures and between the centrality measures and the research performance (number of publications and citations) of each author. Furthermore, in a study about research collaboration in the field of management, [10] analysed the co-authorship network of Chinese researchers and unveiled a low density, that is, not a tight collaboration between them.

Several studies have analysed the research collaboration in several research fields, along with the field of computer science. The study by [11] explores the behaviour of a large community of Italian researchers in four academic disciplines and finds that researchers in computer science-related fields are more disposed to collaborate with researchers from the same country, compared to researchers in other fields. Similarly, scholars [12] analysed the co-authorship network of different scientific areas and two main domains: computer science and biology-related fields and revealed that computer science authors have more co-authors and collaborate more than others. Another study, [13], investigated the co-authorship network of research articles published in the Bulletin of the Natural Sciences in Albania, revealing that the co-authorship network in the field of Informatics was more connected compared to networks in other fields, but with not well-structured groups. Relating to conferences, [14] examined the dynamics of three computer science education conferences and found a modest increase in collaborations and the number of authors, and collaboration between authors with the same country of affiliation.

Research collaboration in various research fields is examined in the contemporary literature using co-authorship network analysis, including the field of computer science, and little research is done on research collaboration focusing on Albanian authors.

3. Data & Methods

Network analysis was performed using the following steps: the collection of the research papers, standardisation of information about authors such as their country of affiliation and gender, visualisation of the global network, and the giant connected component, assessment of centrality measures and other measures, and then the final step, the interpretation of results.

In this study, the co-authorship network of the research papers presented at the RTA-CSIT conference is analysed. This event is organised by the Department of Informatics, Faculty of Natural Sciences, University of Tirana, in Albania. Data were gathered from the online proceedings' books published on the CEUS-WS.org website (for years 2016, 2018, 2021, and 2023), the conference website, and Google Scholar. In total, 100 research papers and 183 authors were analysed. The dataset includes information about the author's name, country of affiliation, gender, number of research papers, research paper title, and the total number of citations of the research papers. Data about the number of citations was retrieved from Google Scholar on 10 March 2025. In total, 383 citations were found for 100 research papers.

In this co-authorship network, the nodes are the authors of research papers, and the edges indicate the pair of authors who have collaborated in writing these research papers. Co-authorship demands mutual collaboration between the authors, so all connections in the network are considered undirected, and the network is undirected. The weight of an edge equals the number of research papers that two authors have collaborated with. The weight of a node equals the total number of research papers that an author has presented.

For the network, density, centralisation, diameter, and the clustering coefficient (transitivity) measures are calculated. For each edge (collaboration), the edge weight and edge betweenness centrality values are calculated. For each node (author), several centrality measures are evaluated,

such as degree, betweenness, and the PageRank centralities. For more detailed information about these measures, see, for example, [9], [13], and [15].

Visualisation of the global network and its largest connected components is used to better understand their structures. Each author contributing to the conference is displayed as a circle, its colour indicates its characteristics such as gender or country of affiliation, and its size indicates the total number of research papers presented at the conference. The width of an edge indicates the total number of collaborations between two authors, as well as the edge betweenness centrality value.

The R software and the 'igraph' package are used to visualise the network and its largest connected components and to calculate the selected measures of the global network, edges, and nodes of the network.

4. Results and Discussion

4.1. Global co-authorship network analysis

The co-authorship network consists of 183 authors and 286 unique edges. Most authors (107 or 58.5%) are from Albania, 21 authors are from Italy, 12 are from Croatia, 12 are from North Macedonia, 9 are from Turkey, 7 are from Kosovo, and other authors are from other countries (Romania, Bangladesh, the United Kingdom, Switzerland, Bulgaria, India, Nigeria, and Brazil). Ninety-two authors (50.27%) are female, and sixty-four authors (35%) are affiliated with the University of Tirana.

Figure 1 on the left displays our co-authorship network by authors' country of affiliation, indicating that authors collaborate more with authors from the same country, which is in line with the literature, for example, [9], [11], and [14]. Figure 1 on the right depicts the global co-authorship network by authors' gender.

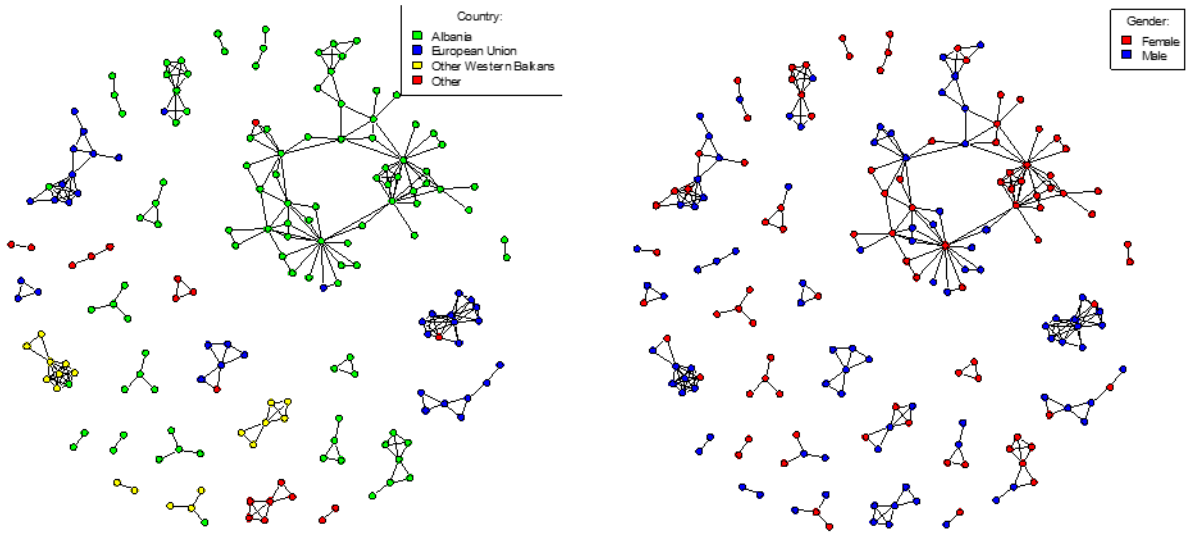

Figure 1: The global co-authorship network by authors' country of affiliation and gender.

Figure 2 illustrates the global weighted co-authorship network, considering the weights of the nodes and edges. The visualisation of the global network indicates an unconnected network with many components (29 in total) and a few connected components with a high number of authors. Thus, some research groups have participated in the conference.

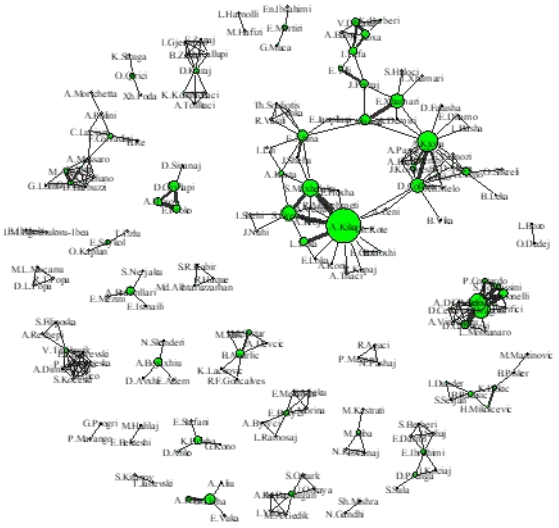

Figure 2: The global weighted co-authorship network.

The measures of the global network (183 nodes and 286 unique edges) are given in Table 1. The average degree centrality value is 3.12, while the average strength value is 3.66. Hence, the frequency of collaboration between two authors is higher for loyal participants of the conference. Regarding research papers, the average number of research papers per author is 2.73, while the average number of authors per research paper is 1.57. Regarding citations, the average number of citations per research paper is 3.83, while the average number of citations per author is 5.84.

Table 1
The measures of the global co-authorship network

Measure	Value
Number of nodes	183
Number of unique edges	286
Average degree centrality	3.1257
Average strength	3.6612
Density	0.0172
Degree centralisation	0.0707
Clustering coefficient	0.5339
Diameter	8
Average shortest path length	3.0412
Degree assortativity	0.0193
Average edge weight	1.1713
Average edge betweeness centrality	19.443

The density value of the global network, 1.7%, indicates that the number of existing collaborations is less than the maximum number of possible collaborations between the authors. The degree centralisation value of 7% indicates that the global network has many influential authors, and the research impact is determined by the contributions of many authors. The probability of two collaborators collaborating again (the global clustering coefficient) is 0.534. The longest path between any two nodes in the global co-authorship network, that is, the diameter, is 8. The average shortest path length is 3. The value of degree assortativity (or degree correlation) of 0.019, close to zero, indicates no preference for collaborating with authors based on their number of collaborations. Regarding edge measures, the average edge weight is 1.17, whereas the average value of edge betweenness centrality is 19.44. Only nine edges (approximately 3%) of the global network have an edge betweenness centrality value higher than 100. These nine edges, as depicted in Figure 3 in red colour, are bridges or critical collaborations in the network, as they control the flow of information and its diffusion in the network.

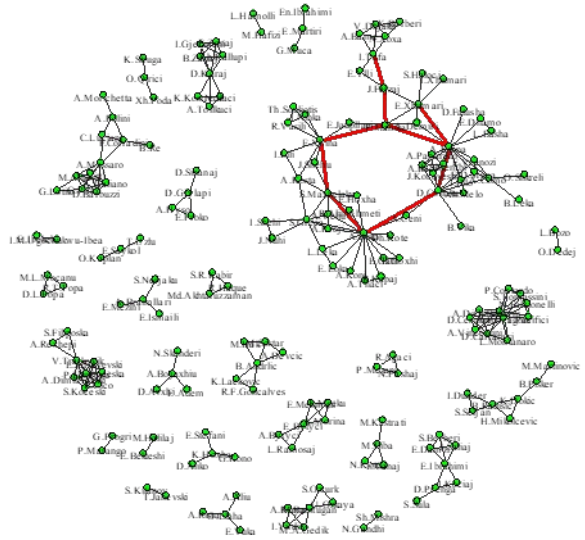

Figure 3: The global co-authorship network with edges betweenness centralities in red colour.

Table 2 lists the top 10 highly connected authors in the global co-authorship network. The top researcher on the list is A. Kika, an Albanian researcher, followed by two Italian researchers, A. F. Dragoni and P. Sernani. These authors have collaborated with many others for one or more research papers; they are highly connected or popular, and they have more opportunities to collaborate for academic publications with other authors in this network. Based on the highest values of PageRank centrality, two Albanian researchers, A. Kika and A. Ktona, are the most influential authors in the network, with respective values of 0.026 and 0.020.

The co-authorship network consists of many nodes with low degrees and a few nodes with high degrees, also called hubs. Thus, a few researchers collaborate extensively with others, while most researchers collaborate with only a few authors.

Moreover, the correlation coefficients between the centrality measures, the number of research papers, and the number of citations are calculated. A very strong and positive correlation exists between degree centrality and strength (0.93). The correlation coefficient values are high and positive between degree and PageRank centralities (0.80), strength and PageRank centrality (0.79), and as well as, between betweenness and PageRank centralities (0.72). There is a moderate and positive correlation between degree centrality and betweenness centrality (0.69), as well as between strength and betweenness centrality (0.64). The number of research papers is highly and positively correlated with the PageRank centrality, strength, betweenness and degree centralities (0.88, 0.85, 0.76, and 0.75, respectively) and moderately correlated (0.59) with the total number of citations. The number of citations is moderately and positively correlated with strength (0.52). Closeness centrality is weakly or not correlated with other considered measures, confirming that it is not a

good centrality measure for unconnected networks. These results regarding correlation coefficient values are consistent with the findings of [2] and [9].

Table 2
The top 10 popular authors of the network by degree centrality and strength values

Rank	Author	Degree	Author	Strength
1	A. Kika	16	A. Kika	23
2	A. Ktona	16	A. F. Dragoni	21
3	D. Çollaku	13	P. Sernani	21
4	A. F. Dragoni	10	A. Ktona	19
5	P. Sernani	10	D. Çollaku	15
6	E. Xhina	9	S. Maxhelaku	14
7	S. Maxhelaku	9	S. Greca	12
8	S. Greca	8	N. Falcionelli	11
9	V. Trajkovik	8	D. Calvaresi	10
10	A. Massaro	7	E. Xhina	10

4.2. Connected components

To better understand the structure of the co-authorship network, only its three largest connected components with at least 10 nodes are considered, as depicted in Figure 4. These connected components consist of 78 authors (42.62%) and 160 unique collaborations (55.94%) of the global network. Amongst these three largest components, the largest one (giant) contains 55 authors (30%) and 105 unique collaborations (36.7%) of the global network and consists mainly of Albanian researchers. Note that six out of the top ten popular authors of the network are in the giant component. Two other connected components have 12 authors and 24 unique collaborations; 11 authors and 31 unique collaborations, respectively, and the authors are Italian researchers.

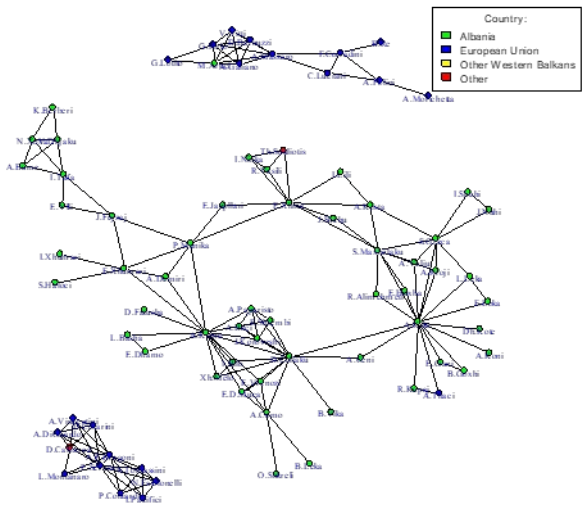

Figure 4: The three largest connected components of the co-authorship network.

4.3. Giant connected component analysis

The giant connected component, which is the connected component with the highest percentage of nodes in the global network, consists of the core group of researchers who collaborate actively. Tables 3 and 4 give the centrality measures for the five central authors of the giant connected component. The betweenness centrality values show that authors A. Kika and A. Ktona have significant intermediary roles (serve as bridges) between other authors in the network. The PageRank centrality values indicate that A. Kika and A. Ktona are two authors who have collaborated with other influential authors in the co-authorship network and are embedded in the highly influential research group.

Table 3
The top five researchers in the giant component by betweenness and closeness centralities

Rank	Author	Betweenness	Author	Closeness
1	A. Kika	608.33	A. Ktona	0.0094
2	A. Ktona	490.00	D. Çollaku	0.0094
3	D. Çollaku	430.00	A. Kika	0.0090
4	E. Xhina	389.67	S. Maxhenaku	0.0088
5	P. Manika	384.00	P. Manika	0.0083

Table 4
The top five researchers in the giant component by eigenvector and PageRank centralities

Rank	Author	Eigenvector	Author	PageRank
1	A. Ktona	1.000	A. Kika	0.086
2	S. Maxhelaku	0.884	A. Ktona	0.068
3	S. Greca	0.755	D. Çollaku	0.053
4	L. Leka	0.427	S. Maxhelaku	0.049
5	A. Rroji	0.284	S. Greca	0.043

Discovering communities – that is, authors who have common research interests and collaborate with themselves – is an important part of network analysis. Greedy optimisation and the Walktrap algorithms display five communities with some bridges in between them, as depicted in Figure 5. Each of these five communities has dense connections within and sparse connections with other communities.

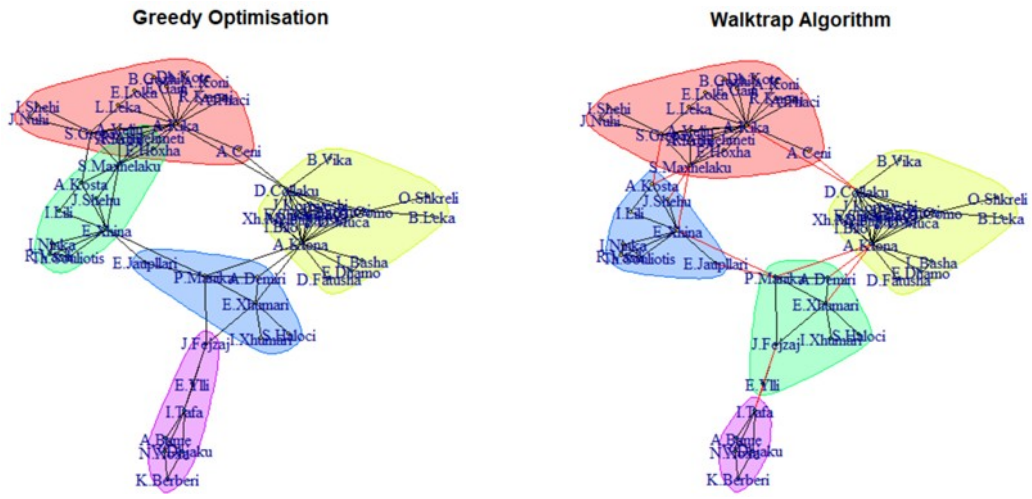

Figure 5: Detection of five communities.

5. Conclusions & Directions for future researcch

This study is an initial endeavour to explore the structure of the research collaboration of the RTA-CSIT conference using network analysis. It aims to construct and analyse the co-authorship network of this conference, focusing on the identification of key contributors, detection of collaboration communities, and displaying research collaboration at national and international levels. The low values of density (1.7%) and centralisation (7%) suggest a sparse co-authorship network and/or diverse research interests of the authors. The highly connected (popular) authors in the network are identified, and amongst them, one is an Albanian researcher, and two others are Italian researchers. The two most influential Albanian authors in the network are A. Kika and A. Ktona. The five most influential researchers are identified, as well as the five communities in the giant connected component of the network. These influential authors drive innovation, foster collaboration, and influence future research directions in the CS & IT fields.

Based on the findings, this study calls for more diverse collaboration amongst CS & IT researchers and practitioners, such as collaboration across different countries and institutions. A more decentralised collaboration network is demanding, to improve the quality of research ideas and topics, and drive forward transformational change in these fields. These results can be used to design strategies to strengthen and develop new collaborations, identify research gaps, evaluate collaboration at national, regional, and international levels, map priority areas, and intensify collaboration with other institutions. Furthermore, collaboration with experts in these and related fields and interaction with other universities, government institutions, and businesses is required to foster collaboration and advance these fields further and strengthen the prominent role of the institution managing the RTA-CSIT conference.

As the authors affiliated with the Faculty of Natural Sciences, University of Tirana, have a prominent role in the co-authorship network, the most influential authors amongst them must use their potential to retain contact with all the participants of the conference, and more importantly, to attract and collaborate with young researchers aiming to maintain and develop further the research network.

Limitations of this study: it does not consider the dynamics of the co-authorship network in different years and the main topics of the conference, and co-authorship is only one of the indicators of the research collaboration.

Future research: the dynamics of the co-authorship network over time, the topic modelling of the abstracts of these research papers and other co-authorship networks with countries or institutions as nodes can be studied.

Declaration on Generative AI

The author has not employed any Generative AI tools.

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