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Engineering Gender: Mapping Disparities and Scholarly Networks in Computer Science Faculties of IITs

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Abstract

This study aims to explore gender differences, co-authorship patterns, and keyword co-occurrences among faculty members in the field of Computer Science and Engineering (CSE) across Indian Institutes of Technology (IITs), assessing gender disparity and research collaboration through bibliometric analysis. A total of 14,900 publications from 2014 to 2023 were analyzed using the Gender-API for gender identification, Bibliometrix (R package) for bibliometric indicators, and VOSviewer for mapping co-authorship and keyword networks. Results reveal that among 521 CSE faculty across 23 IITs, 456 (87.52%) are male and 65 (12.48%) are female. Male faculty contributed 88.28% of total publications, while female faculty accounted for 11.72%. Although a significant disparity in faculty representation exists, the publication performance gap is relatively narrow, with male faculty contributing only 0.76% more. Male authors were more frequently listed as first authors. Citation impact per paper showed minimal difference, with 10.78 for male first authors and 10.48 for female first authors. The findings indicate persistent gender imbalance in representation and authorship, though the comparable citation rates suggest that female faculty perform nearly on par, emphasizing the need for greater gender inclusion in academic research ecosystems.

Keywords: Co-authorship studies, Co-occurrences, Computer Science and Engineering (CSE), Bibliometrix R, Gender differences, IITs

1. Introduction

The higher participation of women in higher education and research is encouraged across the world. Even, UNESCO in its 2030 mandate mentioned that SDG-5 “calls for achieving gender equality and empowering all women and girls”. It emphasizes equal participation of women in higher education and related research activities and thereby reduces gender disparity and creates a healthy work-culture of a nation. The main motivation of the study is to understand the status of woman participation in computer science teaching and research in higher education in India. Now-a-days, computer science including artificial intelligence and machine learning are most demanding subjects by students because of the high job prospects. With respect to gender disparity in various disciplines, the researcher conducted many studies and found 15-30% are female researchers for computer science [24], mathematics [12], chemical science [4], biomedical sciences [16] etc. Many researchers study international collaboration and found it is gradually increasing from only 20.73% of internationally collaborated papers in 2001 to 32.35% internationally collaborated papers in 2020 [5]. Indian Institute of Technology (IITs), a group of 23 institutions functioning under

Ministry of Education, Government of India in the field of engineering and technology governed by Institute of Technology Act 1961. IIT Kharagpur is the first IIT established in 1951 and thereafter till 2016, total 23 IITs are established and they are fully functioning. Although IIT Madras – Zanzibar and IIT Delhi - Abu Dhabi were established in 2023, the present study did not consider them due to very recent ones and having less students and faculty. IITs are considered as top most engineering colleges in India and students have the dream to study in these institutions. Faculty members eagerly prefer to join to the IIT family because of good ambience and research facility. Bibliometric study on IITs established before 2015 was conducted to rank these institute based on various citation-based metrics [19].

Bibliometric studies are one of the pillars in the field of library and information science since long. It encompasses the studies of bibliometric laws, authorship studies, metric studies, bibliographic coupling, citation analysis, collaboration studies, etc. Co-authorship is all about joint authorship including multi-authorship of a publication under study. Co-occurrences are two or more things occurring together. Co-occurrences can happen for documents, journals, author, country, and organization level. Co-citation, co-word and bibliographic coupling yield networks that indicate the representation of research landscape and new ideas in the field of study. Visualization of authorship, co-occurrences studies determine the major the relative strength of bibliometric parameters like retrieving top ten authors, articles, preferred journals and topical relatedness and its trends [14]. The participation of women and girls in higher education and research is encouraged across the world. Encouragement, special measures and initiatives from government and non-government organizations towards the reduction of gender differences help in creating a healthy work-culture of a nation. This led to motivate us to take up a study to understand the current situation of gender differences among the faculty members in the field of computer science and engineering in India with a case study of 23 IITs. The lens of literature studies motivated us to take up the issues to know the gravity of gender disparity in creamy layer of the institutes like Indian Institute of Technology (IITs) in the department of computer science. The present study not only undertakes the gender disparity at institute level and in scholarly publications but also studies the collaboration pattern in authorship and co-occurrence in the concerned subject areas.

2. Review of Literature

The experiences of Indian female enrolled in CSE programs at IIT Madras and IIT Kanpur are investigated in this seven-month ethnographic study by Saxena [18]. It examines their starting points, goals for the future, and obstacles they encounter. The study conducted by Kordaki & Ilias analyzes 1,957 diplomas that were given during a 21-year period at the University of Patras, Greece, to investigate gender disparities in computer science and engineering education at the university level [11]. Building on a prior quantitative analysis, Hosseini & Sharifzad discovered that, from 2013 to 2018, female researchers at Dublin City University's Faculty of Computing and Engineering had less publications, citations, and worldwide partnerships than their male counterparts [10]. Torukwein David-West & Akameze investigated the ways in which University of Port Harcourt undergraduates studying library and information science, both male and female, use ICT for both work and play [3]. There is a notable gender gap in computer science research; studies by Yamamoto & Frachtenberg estimate that female account for 15–30% of published researchers in the field [26]. Fietta, et al. look on gender inequality in STEM, particularly in the University of Padua's Bachelor of Computer Science program [8]. According to Master, Meltzoff & Cheryan, societal stereotypes portray girls as having lower interest in computer science and engineering compared to boys [15]. In their work, Erdemli & Castelló address the growing acceptance of online learning tools,

particularly in the wake of the Covid-19 pandemic. It centers on a study that looks at gender disparities in online learning using data from a Spanish online math learning platform [6]. Using Google as a case study, Feng examines the gender pay gap in this research. By examining wage disparity and gender discrimination within the organization, it looks at associated materials, corporate culture, and compensation data [7].

Co-authorship is all about joint authorship including multi-authorship of a publication under study. Co-occurrences are two or more things occurring together. Co-occurrences can happen for documents, journals, author, country, or organization level. Co-authorship and co-occurrences in research collaboration between India and Bangladesh based on 1156 paper from Scopus was analyzed and found the major collaboration were made in the field of medical science followed by agriculture and biological sciences. Kurata examines international co-authorship networks in publications from 1999 to 2021 to compare social entrepreneurship and entrepreneurship research [13]. Mainly two data analysis and visualization tools i.e. bibliometrix R and VOSviewer are being extensively used in the paper towards generating the network graph for co-authorship and keyword co-occurances. Wani & Ganaie explored visualization of science mapping on grey literature and focused on collaboration, research network and visualization using bibliometrix R [23].

3. Research Objectives

The study amenable to delineate the pertinent research questions, as mentioned below:

- To understand the status of gender disparity among faculty in computer science and engineering of IITs;
- To explore the designation as well as gender-wise faculty distribution in computer science and engineering during the last 10 years;
- To know the situation of gender differences in female and male faculty in CSE during the last 10 years in IITs;
- To find out top ten preferred sources of publications by the faculty in CSE of IITs;
- To examine the citation distribution per paper based on first author-gender;
- Mapping and identifying the prolific authors in the field of computer science thought centrality measures;
- Identifying the subject mapping and trends through keyword co-occurrences analysis.

4. Materials and Methods

The faculty names, gender and their respective institute affiliation were collected visiting individual websites of all IITs and tabulated in excel. We found total 521 faculty members available in the department of computer science and engineering among 23 IITs as on July 2024. After that, we have traced their Scopus IDs from Scopus database with thorough checking their names and affiliation. After getting the ScopusIDs of all faculty, we carried out the search query for male and female faculty separately to retrieve their publications. The query structure is comprised of: a) Institute Affiliation ID denoted by AF-ID, b) Connecting Operator i.e. AND, c) Multiple Author IDs/ScopusIDs (denoted by AU-ID) are connected using OR operator. Example of query used in the study: (AF-ID (60025757) AND AU-ID (55599163600) OR AU-ID (56290153700) OR AU-ID () ……etc…)) AND PUBYEAR > 2013 AND PUBYEAR < 2024. On executing the query in Scopus database, we found total 14,900 publications altogether (male and female) during period of 2014-2023. After retrieving the data in various file formats compatible for the

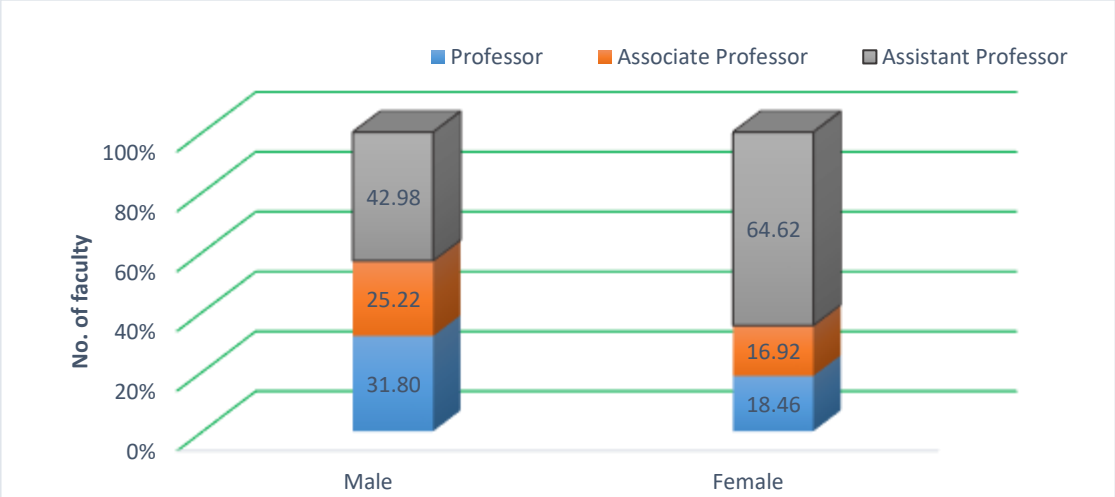
software for analysis, we deployed BibliometrixR [2], a worldwide reputed statistical open-source software and specially designed for bibliometric and scientometric analysis purpose. The study also used VOSviewer [21]– a promising data visualization tool to build network graphs specifically for co-authorship and co-occurrence analysis.

5. Data Analysis and Discussions

5.1. Different Faculty Positions in CSE of IITs

Figure 1 deals with different faculty members of Computer Science and Engineering (CSE) working at 23 IITs as on July 2024 from the respective websites of the institutes.

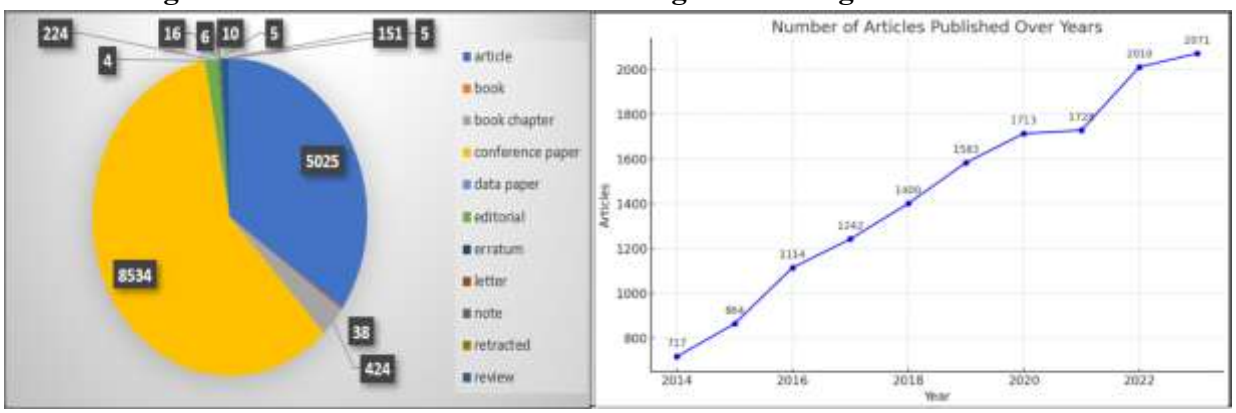
Figure 1: Gender and Designation-wise Distribution of Faculty at CSE, IITs



For the case of female faculty are concerned, Assistant Professors are more (i.e. 64.62%) in comparison with combined figure of Associate Professors and Professors (35.38%). On the other hand, male faculty are concerned, Assistant Professors are less (i.e. 42.98%) in comparison with combined figure of Associate Professors and Professors (57.02%). IIT Bombay has the highest number of both male (n=38) and female (n=8) faculty members. Total male faculty of CSE is 456 whereas only 65 are female faculty. It is worth to point out that there are no female faculty of CSE in IIT Bhilai and IIT Tirupati. Therefore, data underscores a significant gender disparity, with fewer female in senior academic positions.

5.2. Document Types and Publications Growth

Figure 2: Growth of Publications among IITs during the Last 10 Years



From 2014-2023, the number of articles published in CSE annually shows (see Figure 2) a steady increase. Starting with 717 in 2014, the count rises each year reaching to 2,071 in 2023. The growth is particularly notable from 2018 onwards with a significant jump from 1,400 articles in 2018 to 2,071 in 2023. Out of total publications, the largest contribution is being conference papers at 8,534 (57.28%) followed by articles5,025 (33.73%) and the rest (8.99%) are other types of documents like letters, short communications, books, and book chapters etc.

5.3. Gender-wise Publications Distribution

The summary of faculty publications (see Table 1) in CSE across IITs reveals a total of 14,900 publications with male faculty contributing 88.28% (13,154 publications) and female faculty contributing 11.72% (1,746 publications). IIT Kharagpur is the top contributor with 2,602 publications followed by IIT Bombay and IIT Patna, where both male and female faculty have made notable contributions. Significant gender disparities are evident, with some IITs like IIT Bhilai and IIT Tirupati having 100% male faculty publications, while IIT Jodhpur has the highest female faculty publication rate at 35.48%. The lowest contributors are IIT Dharwad and IIT Palakkad, each with 62 publications.

Table 1: Gender Ratio on Faculty Publications Based on Maximum Faculty Number

Sl	Name of IITs	Male Faculty			Female Faculty		
		Total Faculty	Total Publications	Average Publications	Total Faculty	Total Publications	Average Publications
1	IIT Bombay	38	937	24.66	8	245	30.63
2	IIT Kharagpur	38	2455	64.61	4	147	36.75
3	IIT Delhi	34	840	24.71	5	46	9.20
4	IIT Kanpur	30	594	19.80	4	48	12.00
5	IIT Madras	29	905	31.21	4	82	20.50
6	IIT Guwahati	25	758	30.32	3	146	48.67
7	IIT Mandi	25	557	22.28	2	4	2.00
8	IIT Hyderabad	24	680	28.33	2	6	3.00
9	IIT Jodhpur	19	260	13.68	5	143	28.60
10	IIT Ropar	19	308	16.21	4	77	19.25
11	IIT Varanasi	18	618	34.33	3	117	39.00
12	IIT Dhanbad	18	1023	56.83	2	10	5.00
13	IIT Roorkee	17	918	54.00	2	112	56.00
14	IIT Indore	16	474	29.63	3	88	29.33
15	IIT Patna	17	787	46.29	1	364	364.00
16	IIT Dharwad	14	57	4.07	2	5	2.50
17	IIT Jammu	12	111	9.25	3	16	5.33
18	IIT Bhilai	15	152	10.13	0	0	0.00
19	IIT Gandhinagar	12	290	24.17	1	56	56.00
20	IIT Palakkad	10	44	4.40	2	18	9.00

21	IIT Goa	7	58	8.29	4	13	3.25
22	IIT Bhubaneswar	10	229	22.90	1	3	3.00
23	IIT Tirupati	9	99	11.00	0	0	0.00
Total		**456**	**13154**	**28.85**	**65**	**1746**	**26.86**

Table 1 highlights the disparity in the number of male and female CSE faculty members across various IITs, with male faculty members (456) significantly outnumbering female faculty members (65). Male faculty members have published 13,154 papers, averaging 28.85 publications per person, while female faculty members have published 1,746 papers, averaging 26.86 publications per person. IIT Kharagpur and IIT Roorkee stand out for their high publication averages, with IIT Patna notably having a female faculty member with an exceptionally high publication rate. Overall, publication rates vary widely across the IITs.

5.3. Top Ten Preferred Scholarly Publication Sources

Table 2 depicts top 10 sources comprising of journals, proceedings and lecture notes in computer science and engineering as indexed in Scopus. The sources of publications along with number of articles published; total citations, impact factor (IF) and Scimago Journal Ranking (SJR) values are mentioned to understand their reputation.

Table 2: Top 10 Publications Sources based on Maximum Number of Articles Published

Rank	Sources	Publisher	Articles Published	TC	IF	SJR
1	Lecture Notes in Computer Science	Springer Verlag	1199	5617	1.27	0.32
2	ACM International Conference Proceeding Series	Association for Computing Machinery (ACM)	477	1676	0.50	0.209
3	Communications In Computer and Information Science	Springer Science and Business Media Deutschland GmbH	235	1020	0.53	0.194
4	Advances in Intelligent Systems and Computing	Springer Nature	226	1047	0.63	0.215
5	Leibniz International Proceedings in Informatics, LIPIcs	SchlossDagstuhl-Leibniz-Zentrum fur Informatik GmbH, Dagstuhl Publishing	183	656	0.96	0.832
6	Multimedia Tools and Applications	Springer Netherlands	151	2215	4.27	0.72
7	IEEE Access	Institute of Electrical and Electronics Engineers Inc.	103	1528	4.82	0.926

8	CEUR Workshop Proceedings	CEUR-WS.org	102	306	0.39	0.202
9	Proceedings of the International Joint Conference on Neural Networks	Institute of Electrical and Electronics Engineers Inc.	96	913	1.39	0.422
10	Expert Systems with Applications	Elsevier Ltd.	84	2234	10.35	1.873

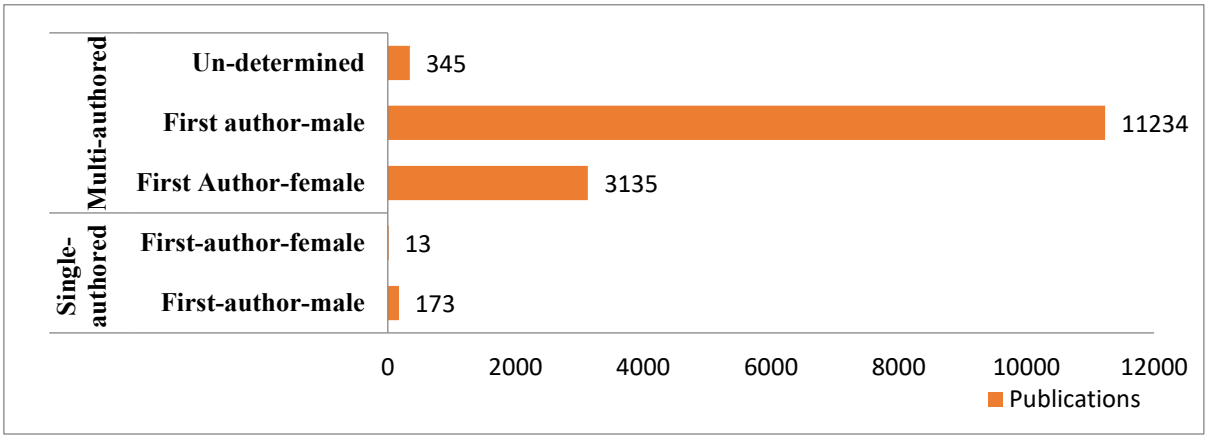
Impact factor (IF) and SJR are popular journal metrics in evaluating journals. IF is calculated based on 2-years citation windows whereas SJR is calculated based on 3-years citation windows. The ranking of sources in computer science publications shows that 'Lecture Notes in Computer Science' from Springer Verlag leads with 1,199 articles with impact score of 1.27. 'ACM International Conference Proceeding Series' follows with 477 articles with impact score of 0.50. Other notable sources include 'Communications in Computer and Information Science' and 'Advances in Intelligent Systems and Computing,' both from Springer, with impact scores of 0.53 and 0.63 respectively. 'Leibniz International Proceedings in Informatics' stands out for its high SJR of 0.832, while 'Multimedia Tools and Applications' and 'IEEE Access' have high impact scores of 4.27 and 4.82, respectively. 'Expert Systems with Applications' leads in impact score with 10.35 and an SJR of 1.873.

5.4. Collaboration Studies

5.4.1. Publications and Citation (Single Vs Multi-Authored)

Papers with female authors have received citation even in key position of the authorship order than male authors. The analysis of 14,442 unique records comprising of articles, conference papers and review articles, book chapters etc. revealed that only 1.29% of research documents are singled-authored and the rest of 98.86% of papers are multi-authored (see Figure 3). Gender assignment and its calculation may be some errors due to not having a strong gender specific database, although a few are used in the study e.g. genderAPI, genderize.io. Besides there may be some journals, which make the authors according to alphabetic order; some cases may be the influence or biasness factor works in the order of author.

Figure 3: Authorship distribution in CSE of IITs



The gender-api [9], an AI-database tool employed for gender determination using first name of the author. The tool is accessible free for few credits (one request equals to one name) and subscribed for based on various pricing model. We have subscribed this gender-api database to carry out male-female authorship determination purpose. After uploading the .csv or excel file to the site, the gender-api allots gender as male or female against given name with score and then rechecking was done manually wherever low-probability score mentioned by the software. For the case of multi-authored publications in the field of computer science and engineering, the result shows that more than 75% of the publications belong to first-author male whereas 21% are female first author.

Table 3. Distribution of Citations per Paper Based on First Author-Gender

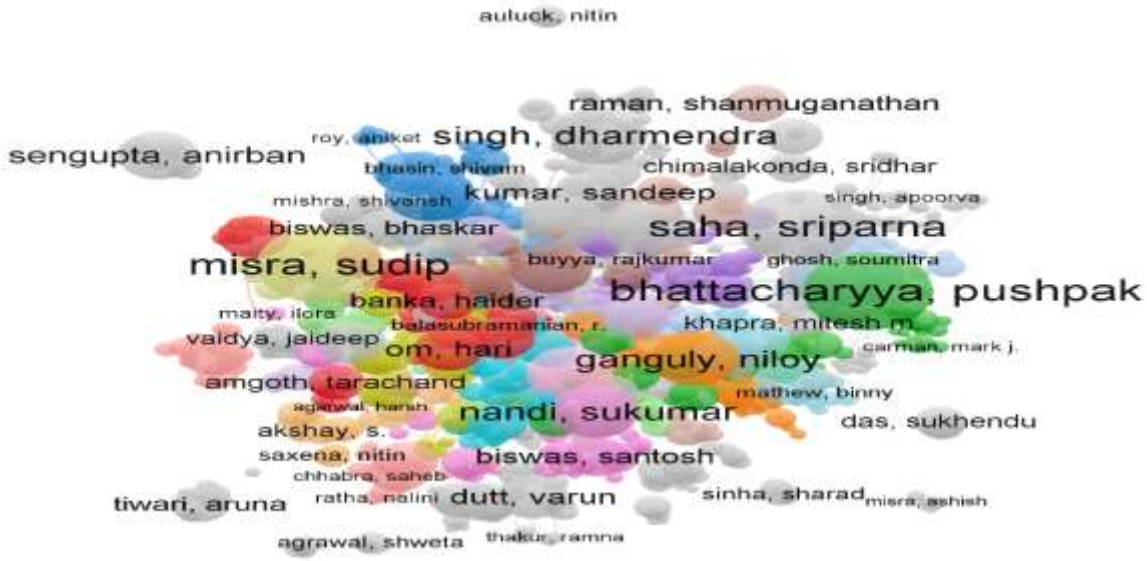
Citation Distribution/ First Author	Papers	Citation	Citation per Paper
Male-first author	11,232	121,101	10.78
female-first author	3,031	31,767	10.48

As far as citation related with respect to gender is concerned, the analysis of 14,263 (where we could able to determine gender of the first author) out of 14,900 articles in CSE revealed that there is no much disparity in citations pattern. The average citation per paper for the case of female-first author is 10.48 as against citation per paper for first-authored male faculty is 10.78.

5.4.2. Co-Authorship Analysis and Centrality Measures

Co-authorship is a scientific phenomenon, which indicates the strong association and collaboration in authorship while sharing ideas and nascent thoughts that fosters the growth and development of the subject. Collaboration may happen at institutional, national, and international level. The study prompts to identify the significant authors and their level of collaboration. Many researchers pointed out that the more the collaboration, the more the citation received for the case of international collaboration [22] and more distant the more be the collaboration [17].

Figure 4: Co-authorship Analysis using VOSviewer



In this co-authorship analysis, full counting, and a minimum threshold of 5 documents per author is presumed. The authorship network shows that out of 15,363 authors, 2,072 meet the criteria. From these, 1,000 authors selected for the study. The analysis involves 981 items, 46 clusters, 3,774 links, and total link strength of 18,861 (see Figure 4).

Collaboration network may be formed for authors, journals, country at the national and international level. In a network graph, nodes are generally represented as authors for the case of co-authorship graph and links are represented by citation. The graph may be directed as well as undirected, measures may be betweenness centrality, closeness centrality, degree centrality [25]. The VOSviewer software helped to generate the co-authorship network, which also provides some parameters like clusters, links, and link strengths to understand the nature of the network. Each link is having its strength and measured by citations. Total link strength is calculated by the sum of all links traverse from one node over other nodes. Network centrality is a vital measure to understand how important of a node in a network, may it be authorship network, may it be country network or it may be a document network. For the case of authorship network, centrality measures tell us who are the most prolific and influencing author in the group of authors.

5.4.3. Co-occurrences Studies

The analysis uses co-occurrence with author keywords as the unit of analysis and applies full counting. Out of 26,449 keywords, 1,619 meet the minimum occurrence threshold of 5 keywords as threshold. From these, 1,000 keywords were selected, resulting in 993 items clustered into 18 groups with 9,268 links and a total link strength of 14,928.

Figure 5: Keyword Co-occurrences Analysis using VOSviewer

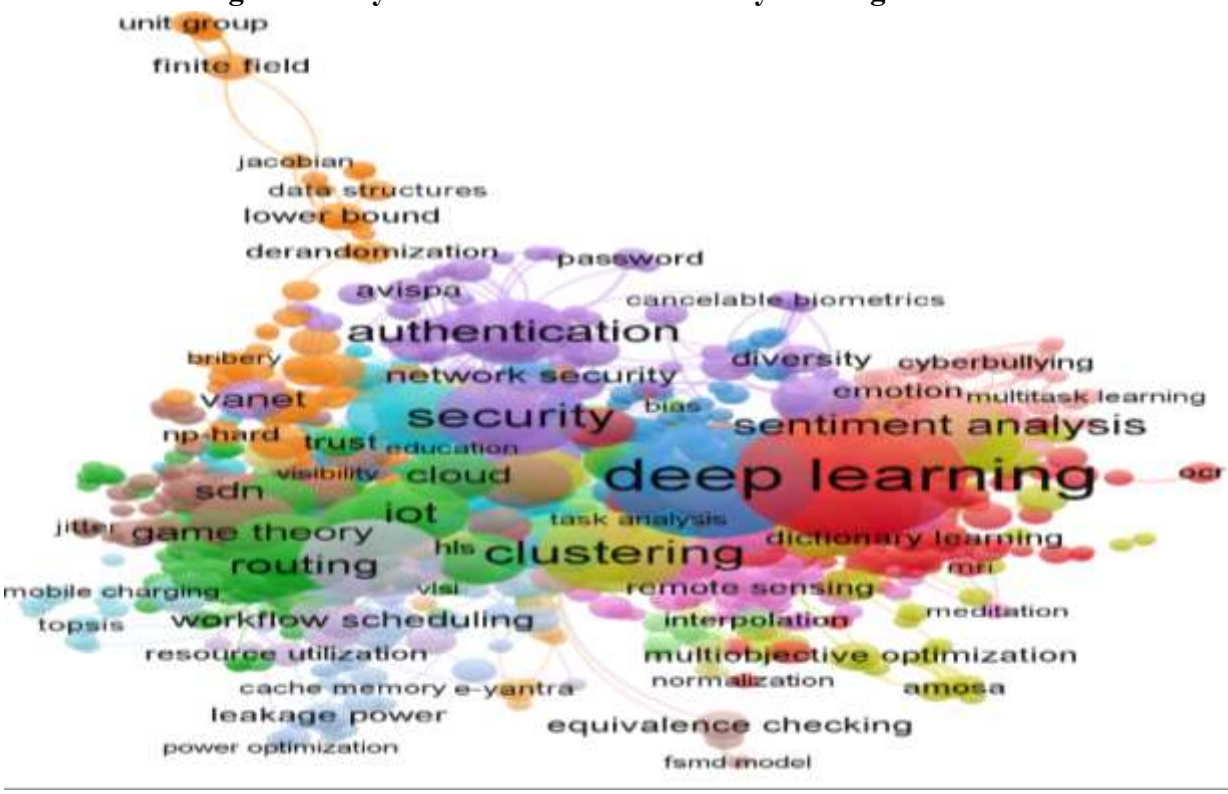


Figure 5 clearly depicts that deep learning, IoT, clustering, cloud computing, game theory security and authentication and of course, remote sensing, emotion, sentiment analysis are some of the important areas where research are being undertaken by the faculty members and their research scholars.

6. Discussion

The ratio of female and male faculty in computer science among 23 IITs is 1:7, which is not a healthy ratio leading to a great disparity in the field. However, it is interesting to note that more and more young female assistant professors are joining to the institute (Fig.1). While addressing another crucial research question i.e. whether the productivity of female faculty in scholarly publication differs significantly or not. The study revealed that marginal difference (0.74% less) for female to male faculty exists in scholarly publication. This is an encouraging phenomenon. Sugimoto [20] studied to know the global gender disparity in science through bibliometric analysis and found that woman contribution is less in terms of publications, citation, collaboration, and expensive research areas e.g. high energy physics less than men. But our study shows that citation per paper for female and male faculty are almost at per. Another finding of the study found that more than 55 percent research papers in computer science and engineering published by IIT faculty members in Scopus indexed conferences proceedings, which were not normally notices in other subjects including humanities and social sciences. Another researcher mentioned that age, designation, and years of experience have a direct relationship with research productivity of law in Nigeria [1].

7. Conclusion

It is evident through various literature studies that gender disparities in scholarly publications exist in most of the discipline like science, social sciences and humanities and medical sciences. But such disparities are comparatively less in medical sciences. Our study revealed that the gender disparity exists computer science and engineering. It is more evident from the study that vey a smaller number of female faculty are on roll in CSE. But, percentage of female faculty as Assistant Professor are comparatively more and they are keen to publish papers. A general tendency is found recently that faculty are more publishing more papers in conference volume. The probable reason may be less time lag in publication and indexed these papers in Scopus, dblp and other reputed databases. The significance of the study is that male-female faculty is equally contributing in the scholarly communication in the field of computer science although there is huge disparity in number of female faculty in higher educational technical institutes like IITs. The limitation of the study is that it covers only IITs. Future research may be carried out in the field by including NITs, IIITs and reputed GFTIs in India. However, the study is meticulously undertaken based on theories, evidences and many bibliometric indicators, techniques and software used to get the result. Various thrust research areas in computer science being identified through co-occurrences analysis of keywords may help the young researcher to undertake and extend it further.

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