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Understanding the Bibliometric Patterns of Publications in IEEE Access

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ABSTRACT The *IEEE Access* journal started in 2013, and in a short period, it has attained recognition for being a preferred multidisciplinary journal, with characteristics of rapid and continuous publishing. It is now ranked among the top journals in Engineering and Computer Science (General) by Scopus. Recognizing the distinctive nature of the journal and its contributions in the broader area of Engineering and Computer Science, this article attempts to present a detailed bibliometric analysis of the journal to identify publishing patterns, authorship and collaboration structure, citation impact, funding patterns of the published research, and the thematic structure of the publication. The gender distribution is also computed to identify papers published by male and female authors. The social media visibility of the articles and the Sustainable Development Goals (SDG) connections of articles were also identified. The results indicate that the IA journal can attract novel, high-quality multidisciplinary research, which aligns with the relevant and the most pressing SDGs. Furthermore, the journal has experienced increased multi-authored multidisciplinary research, and it is publishing a more significant percentage of articles with female first authors.

INDEX TERMS Bibliometric analysis, citation impact, collaboration structure, gender distribution, IEEE Access, thematic structure, sustainable development goals.

I. INTRODUCTION

The Institute of Electrical and Electronics Engineers (IEEE) started publishing—*IEEE Access* (IA)—a new peer-reviewed, open-access multidisciplinary scientific journal with unique characteristics in 2013. Unlike other traditional journals of IEEE that focus on a specific subject/theme, *IEEE Access* presents the results of original research and development across all IEEE's fields of interest. Therefore, it has a multidisciplinary origin. Its hallmarks include a rapid peer review, binary decision of accept or reject, and a continuous publication process with 4 to 6 weeks turnaround time. It uses an APC (Article Processing Charges) based open-access publication model and is now indexed by major journal indexing services, such as Web of Science, Scopus, Dimensions, DOAJ etc.

The IA journal has gained a significant reputation and has emerged as a preferred avenue for submitting quality papers due to its unique characteristics. According to Scopus, IA is ranked in the 81st and 87th percentile on General Computer Science and General Engineering topics, respectively, based on CiteScore. *IEEE Access* has a Scimago Journal Rank (SJR) of 0.775 (Q1), Source Normalized Impact per Paper (SNIP) of 1.734, and Journal Impact factor (JCR-2020) of 3.367 (Q2). Google Scholar ranks IA 3rd in the top 10 among Engineering and Computer Science (general) journals. It has an h-index of 150 as per the Dimensions database.

Motivated by the emergence of IA as a reputed publication avenue, this article attempts to carry out a bibliometric and analytical study of research publications in IA during 2013–2020. The analysis includes understanding the bibliometric patterns, the gender distribution of contributing authors, social-media visibility of papers, and the thematic structure evident in the documents. A combination of scientometrics, network theoretic, and text analysis-based methodology is used for this purpose. More precisely, the analysis in the paper addresses the following aspects:

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- Identify the year-wise research publication volume and patterns in IA,
- Understand the authorship and collaboration structure of articles published in IA,
- Measure the citation impact of publications,
- Identify what amount of research articles in IA have associated funding and from which agencies,
- Understand the thematic structure of publications in IA,
- Analyze the gender distribution of authors who published in IA,
- Measure the social-media visibility of articles published in IA,
- Understand connections of research published in IA with the Sustainable Development Goals SDGs) proposed by the United Nations (UN), and
- Identify publications related to COVID-19 research.

The analytical study provides an informative and valuable account of IA's publication patterns and trends, which helps better understand IA's focus, reach, and thematic/topical structure. The analysis, thus, presents a comprehensive picture of the bibliometric and other related patterns identified in the IA journal. This is the first such exercise undertaken on IA journal to the best of our knowledge.

The rest of the paper is organized as follows: Section II presents the data and methods used for the analysis. Section III presents the various analytical results on publication patterns (Section III.A), authorship and collaboration structure (Section III.B), citation impact (Section III.C), funding patterns in published articles (Section III.D), thematic structure of publications (Section III.E), the gender distribution of authors (Section III.F), social media visibility of articles (Section III.G), connections of publications with UN SDGs (Section III.H), and research on COVID-19 published in IA (Section III.I). The article concludes with the study's limitations in Section IV and a summary of significant findings in Section V.

II. DATA & METHODOLOGY

The bibliographic data for this study was obtained from the Dimensions database, a scholarly research-information system provided by Digital Science. It is similar to abstract indexing and metadata providing databases like Scopus (from Elsevier) and Web of Science (from Clarivate Analytics). The Dimensions database has more extensive coverage of journals than Web of Science and Scopus [1]. It has been found helpful for bibliometric analysis [2]–[7]. Dimensions database provides many useful APIs for performing bibliometric analysis. For obtaining the data for IA journal, the Dimensions database was searched for publication records of IA for the period 2013 to 2020. A total of 44,227 publication records are found indexed in the database. The complete metadata and cited references and concepts were downloaded from the database for different analyses. A bibliometric study of a journal is a popular approach for identifying the trends of the journal in terms of topics, contributing institutions, authorship structure, highly cited papers etc. Bibliometric analysis approaches are used to perform bibliometric analyses of disciplines [8]–[15], institutions [16]–[21], and journals [22]–[26] etc. The present study uses a combination of standard bibliometric approach, network theoretical approach, and text analysis-based approach for analysis and mapping of IA journal. In addition to computing standard metrics of publication, citations, collaboration, h-index [27] etc., we have also computed the gender distribution of authors in IA, using the Gender API, as applied in Paswan and Singh's work [28]. The social media visibility of articles published in IA has also been computed using the standard altmetrics analysis approach, as reported in several previous studies [29]–[31]. Our study also used Visualization of Similarities (VOS) viewer software [32] to map and visualize the bibliometric data. VOS viewer is a software tool specifically designed for constructing and visualizing bibliometric maps; such science mapping illustrates scientific research's structural and dynamic aspects. With this software, we demonstrated influence patterns in co-citations [33] and bibliographic coupling [34]. The funding patterns in IA publications were identified by analyzing the acknowledgment section in publication records. The thematic structure of publications, comprising major themes occurring in IA publications and their co-occurrences, were analyzed by processing the keyword and concept field obtained from the database. Finally, the connections of IA publications with UN SDGs and COVID-19 research were identified and reported. Various analytical results are reported in different tables, and figures and results obtained were interpreted in multiple contexts.

A. LIST OF BIBLIOMETRIC INDICATORS USED

- TP: Total number of publications of IA in dimensions database
- TC: Number of times a publication has been cited by other publications in the dimensions database. The values per year are the citations received in each year.
- TC/TP: Total Citations/Total Publications
- h-index: maximum value of h such that the given journal has published at least h papers that have each been cited at least h times.
- TC/Year: Total Citations received in a year
- SJR: SCImago Journal Rank. According to this Rank, prestige is transferred between journals based on their citation links.
- Impact Factor: is calculated as the average of the sum of the citations received in a given year to a journal's previous two years of publications, divided by the sum of ''citable'' publications in the last two years
- TPA: Total publications with Altmetrics Attention Score. It is a weighted count of all the online attention. The values per year represent the years in which the publications were published.
- TPA (%): Percentage of publications with Altmetrics Attention Score

TABLE 1. Publication trends.

Year	TP	AGR (%)	CAGR (%)
2013	67	-------	122.12
2014	128	91.04	
2015	259	102.34	
2016	858	231.27	
2017	2638	207.46	
2018	6990	164.97	
2019	15414	120.52	
2020	17873	15.95	

TABLE 2. Top contributing countries/regions.

Country/Region	TP	TC	Cited %	TC/TP
China	27343	214251	85.33	7.84
United States	4388	66180	89.38	15.08
South Korea	3200	27611	85.72	8.63
United Kingdom	2543	33542	91.15	13.19
Saudi Arabia	1706	22417	92.67	13.14
Pakistan	1562	18842	92.64	12.06
Australia	1505	21019	90.10	13.97
Canada	1449	22250	90.27	15.36
Spain	1349	12463	88.88	9.24
Taiwan	1202	11306	86.69	9.41
India	1137	19605	93.32	17.24

III. ANALYTICAL RESULTS

The analytical results obtained through a combination of Scientometric, network theoretic, and text analysis-based approaches are presented in the following subsections.

A. PUBLICATION PATTERNS AND GROWTH RATE

The IA journal has published 44,227 papers during 2013–20. In Table 1, TP represents Total Publications in a year; AGR represents Annual Growth Rate, and CAGR represents Compounded Annual Growth Rate for all years. Table 1 shows the number of papers and the growth rate of IA publications since the advent of the journal in 2013 to the year 2020. The yearly number of publications has grown by a factor of 282, rising from 67 publications in 2013 to 17,873 publications in 2020. Since the journal's beginning, the growth rate of publications in *IEEE Access* has been high, starting with an AGR of 91.04% from 2013 to 2014. The highest AGR value of 231.27% was recorded from 2016 to 2017, followed by 207.46% growth from 2017 to 2018.

Overall, the publications in *IEEE Access* have grown with a CAGR of 122.12% from 2013 till 2020. One possible explanation for the dramatic growth in publications starting in 2017 might have to do with massive funding support from multiple Chinese govt. agencies for open access. The Chinese govt funds over 95% of the studies. agencies. This period also coincides with the starting of the New Chinese Double First-Class University plan funded by the Chinese govt. This is a significant increase in the number of publications for any journal. It can be seen that the rapid and continuous publication model of the journal may be the primary reason for such a high number of publications in the journal.

We next analyzed which countries/regions were the major contributors to the publications in the IA journal. In Table 2, TP represents total publications in a year; TC represents total citations received; Cited % represents % of publications that have received >=1 citation, and TC/TP represents average citation per paper. Table 2 presents the list of top contributing countries in the IA journal from 2013 to 2020. It can be observed that China, the United States, South Korea, the UK, and Saudi Arabia lead the list. Interestingly, China alone accounts for over 60% of the total share of publications, followed by the United States and South Korea with around 9% and 7% of total publications. This is an interesting observation and agrees with overall growth in publications from China, both in general and in IEEE journals in particular. However, this does not mean that the most influential research comes only from China. In fact, the influence as measured by the citations per publication (TC/TP) shows that Chinese publications are among the least cited. The leader in this respect is India, followed by Canada and the United States.

We observe that publications from China-based authors and institutions have increased significantly since 2016, rising over 6.5 times between 2015 and 2016. Between 2013 and 2020, the number of publications from China has increased from 4 to 10,191, rising over 2,500 times. While publications from all countries have increased, the rise in the US is around 40 times, for comparison. The Asian countries of China and South Korea exhibit the highest factor of publication growth. It is also interesting to note that there is a particular focus in China to publish in journals indexed in Web of Science, which is evident in the publication pattern observed in IA, which shows a very rapid rise from the year when IA's impact factor was published.

The next analysis involved identifying the top contributing institutions to IA journal. The institution affiliation field in data is processed to get an institution-wise count of publications. Table 3 presents the major contributing institutions. It is observed that, out of the top 15 universities with the highest number of publications, 14 are from China. Thus, the Chinese institutions are identified as the most significant contributors to publications in the IA journal, which is in line with the findings reported in Xie and Freeman that highlighted the considerable focus on publishing in China and its impact on the global research ecosystem [35]. In terms of influence, the single university from Saudi Arabia figuring in the list, King Saud University, has a large number of citations per publication (value of 17.27 for TC/TP) when compared to

TABLE 3. Top contributing institutions.

Institution Name	Country	TP	TC	Cited %	TC/TP
University of Electronic Science and Technology of China (UESTC)	China	963	9638	87.54	10.01
Beijing University of Posts and Telecommunications (BUPT)	China	909	9006	89.77	9.91
Southeast University (SEU)	China	847	7036	86.30	8.31
Xidian University	China	837	7257	87.22	8.67
Harbin Institute of Technology (HIT)	China	719	6422	87.34	8.93
National University of Defense Technology (NUDT)	China	700	3987	83.86	5.72
Beihang University (BUAA)	China	695	5418	84.17	7.83
South China University of Technology (SCUT)	China	593	6049	89.21	10.2
Northwestern Polytechnical University (NPU)	China	545	3815	86.97	7.11
Tsinghua University (THU)	China	536	5366	86.75	10.01
Zhejiang University (ZJU)	China	534	4745	86.52	8.89
Beijing Jiaotong University (BJTU)	China	533	4093	88.56	7.68
Wuhan University (WHU)	China	500	3638	87.43	7.28
King Saud University (KSU)	Saudi Arabia	493	8516	94.52	17.27
Beijing Institute of Technology (BIT)	China	487	4100	86.65	8.42

the value of 10.01 from the University of Electronic Science and Technology of China (UESTC), which has the highest total number of publications. Interestingly, the publications from all these universities have more than 85% of their publications have received at least one citation. This high number of cited articles, especially from Chinese Universities, can be attributed to a focus on quality and influence that the Chinese academic sector has focused on in recent times [36].

B. AUTHORSHIP & COLLABORATION STRUCTURE

The publication records of IA have been analyzed to calculate the percentage of single-authored and multi-authored papers and to evaluate whether there is a general trend towards multi-authored papers. Figure 1 shows the year-wise trend of authorship. It can be observed that the proportion of single-authored papers has decreased from 2013 to 2020. The majority share of publications comes from papers authored by 2 to 5 researchers. A good proportion of papers are authored by 6–10 authors, a trend that increases with time. This trend is consistent with studies showing a general increase in multi-authored papers [37], [38]. The proportion of papers having more than ten authors has decreased and is very low in recent years.

The most contributors and proficient authors in IA from 2013 to 2020 are also identified in Table 4. The table also provides some citation metrics and indicators for these authors. Based on the total publication number, Lajos Hanzo is the top-contributing author in IA with 129 publications, followed by Mohsen Mokhtar Guizani and Hou-Bing Song with 59 and 52 publications. While these authors are heavily cited, the citation metric total citation (TC) shows that Mohsen Mokhtar Guizani arguably has the most influence

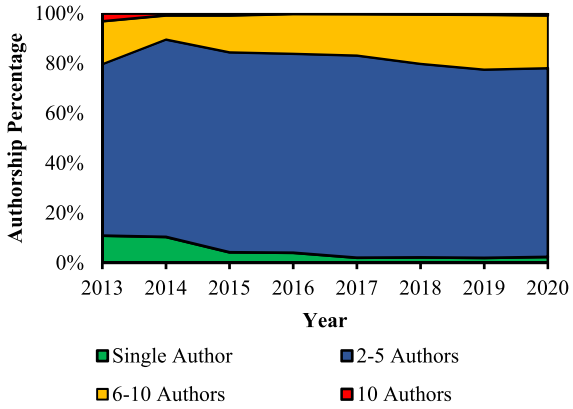

FIGURE 1. Proportion of papers with single, 2 to 5, 6 to 10, and 10+ authors.

on peer researchers, with 2,498 total citations (TC) for the 69 publications. This is closely matched by Hou-Bing Song, who has a total citation score of 2,102 for a significantly lower count of 59 publications. Hou-Bing Song also holds the highest average citations per article (TC/TP) of 35.63 for the said 59 publications, showing that more peer researchers have relied on Song's work. Our analysis includes self-citations.

Overall, data relating to the authorship analysis of IA articles show that this journal has successfully attracted a significant number of articles from top-performing and influential international scholars. For example, Hanzo, Guizani, and Blaabjerg are identified as prolific and collaborative authors by a number of studies [39], [40]. Additionally, IA has managed to attract authors having high h-index, such as Frede Blaabjerg, who is among the 250 most-cited engineers, vice president of Danish academic of technical sciences, winner

TABLE 4. Top contributing authors.

Name	Country	TP	TC	Cited %	TC/TP	h-index
Lajos Hanzo	United Kingdom	129	1821	96.90	14.12	79
Mohsen Mokhtar Guizani	Qatar	69	2498	98.55	36.21	68
Hou-Bing Song	United States	59	2102	96.61	35.63	52
Guan Gui	China	52	751	94.23	14.44	34
Muhammad Ali Imran	United Kingdom	50	1345	92.00	26.90	54
Joel José Puga Coelho Rodrigues	Brazil	50	933	92.00	18.66	63
Naixue N Xiong	United States	50	602	88.00	12.04	44
Xiaojiang James Du	United States	46	951	95.65	20.67	48
Sanjeevi Kumar Padmanaban	Denmark	46	945	95.65	20.54	32
Zhi Wu Li	China	45	345	97.83	7.67	55
Neal NaixueXiong	United States	45	638	91.11	14.18	29
Lei Shu	China	44	2097	95.45	47.66	50
Mohammed-Slim Alouini	Saudi Arabia	43	744	95.45	17.30	77
Frede Blabjerg	Denmark	43	884	97.67	20.56	128
Zhu Han	United States	42	534	85.71	12.71	87

of global energy prize, and IEEE energy prize, among other recognitions [41] and Lajos Hanzo, who is the former editor in chief of IEEE press and an author of over 18 books related to wireless communication [42]. Clearly, IA has successfully attracted top researchers who have made significant contributions to the field.

To understand the international-collaboration patterns in the publications from the journal, the author affiliation field has been analyzed to identify the extent of international collaboration in articles published in IA. Figure 2 shows the proportion of papers that involve international collaboration as well as those produced domestically. The domestic papers are further categorized under papers from authors of a single institution and papers from authors belonging to multiple institutions of the same country. It can be observed that the proportion of international collaborative papers (ICP) in IA has increased over time, except for a slight decrease in recent years. Overall, about 30% of the papers in IA involve international collaboration. There are studies that have indicated that articles with authors from different countries receive higher mean citation rates [43], [44]. The domestic papers involving a single institution constitute the highest proportion, which has more or less remained constant during the whole period. The proportion of papers involving collaboration between authors from different institutions of the same country has increased during the period.

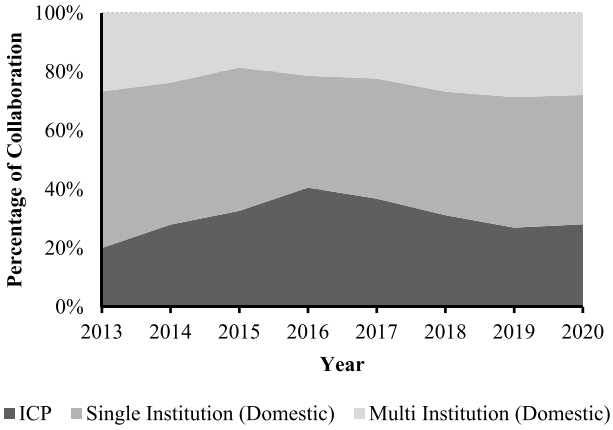

FIGURE 2. Proportion of international collaborative and domestic papers.

C. CITATION IMPACT

Citations are an essential metric while measuring the impact of an article and a journal in the scientific community [10], [45]. Therefore, citation metrics—including citation numbers, journal sources—are used in this study to investigate the influence of IA publications and the usage and recognition of the journal in the scientific field. We have computed various citation-related measures to understand the citation impact of papers published in IA.

Table 5 shows that between 2013 and 2018, over 90% of the articles published have received at least one citation (Cited % rising to 98.07% in 2015). A slight decline is observed during 2019. However, in 2020, 76.24% of the published articles were cited. A moderate value for TC/TP was observed during the subsequent years. This trend can partly be due to the recent publication time frame, and the percentage of cited articles in 2019 and 2020 will likely increase over the coming years as annual citation count on articles typically peaks in the third year [46]. It is noteworthy that in the beginning year of 2013, the highest value of average citation per paper (TC/TP) was observed at 88.70 [47].

TABLE 5. Citation structure of publications.

Year	TP	TC	Cited %	TC/TP
2013	67	5943	91.04	88.70
2014	128	6247	93.75	48.80
2015	259	12049	96.91	46.52
2016	858	28297	97.79	32.98
2017	2638	60499	98.07	22.93
2018	6990	99814	96.05	14.28
2019	15414	128418	91.66	8.33
2020	17873	64498	76.24	3.61

Over the 2013–2020 period, IE has 683 (2%), 3563 (8%), 6652 (15%) publications in Top 1%, 5% and 10% Citation Percentiles respectively. Effectively, the journal has not only managed to increase the number of publications, but it has also improved the reach of influential publications, attracting more influential research publications overall. In line with the observations of Winter and Halevi, and Moed, these citation-based indicators indicate that the relevance of IEEE publications has increased over the years [48], [49].

Author Co-citation Analysis (ACA) is a proven analytical method to trace the intellectual structure in scholarly communication and is one specific type of co-citation analysis. When two documents are cited by the same third document, co-citation occurs [50]. Analysis of co-citation relies on the assumption that two papers cited together are highly related [51] and thus should be concentrated in a cluster solution of a visualization map. Figure 3 shows a network visualization resulting from the analysis of the co-citation of authors in IA. The citation threshold was set to a minimum of 50. Nodes or circles represent authors, and links between nodes indicate connections between authors (i.e., by co-citations). The distance between the two authors on the map indicates the relatedness of the two authors in terms of co-citations [52]. Each node is assigned a weight based on how strong its links are. The larger the author's name and the larger the circle, the higher the weight.

Our results show that the largest nodes belong primarily to authors from China. For example, the largest nodes belong to Wang X, Wang J, and Wang Y. All three researchers belong to the Beijing University of Post and Telecommunication. Naturally, collaborations among these authors are also numerous. As indicated by the colors, four major clusters can be identified here. The higher degree of collaboration between authors of the same institutional affiliation is already well documented [53] and attributed to higher interpersonal connections and pure physical proximity. It is also evident here with collaborations between all prominent researchers from the Beijing University of Post and Telecommunication.

Similarly, X Li is from North-western Polytechnical University, Xi'an, China. Multiple significant players with collaboration links are from institutes of similar standing from the same geographic region. This observation aligns with the findings reported in Stephens and Cummings, where a much higher chance of collaboration among researchers in the same geographical area was documented [54].

We have also identified the most cited articles of IA during 2013–20. Table 6 provides a list of the 15 most cited IA articles where TC stands for Total Citations and TC/Year stands for citations per year. All 15 influential publications fall within the top 10% of most-cited publications worldwide. The most cited articles may be expected to be the oldest, as it is likely that more researchers would cite the article over time. However, no such trend is observed. Only one

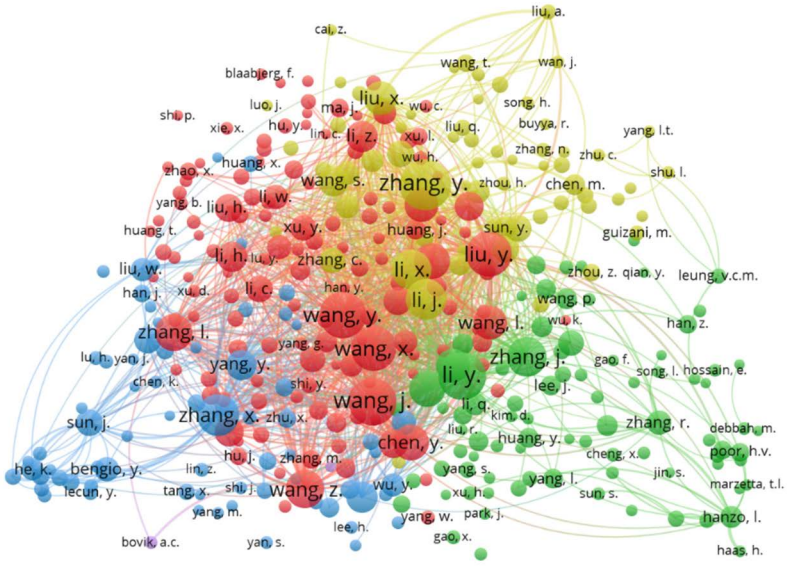

FIGURE 3. Co-citation of IA authors.

article from 2013 made it to the list of the most cited articles. This most cited article with 4,178 citations in total is titled "Millimeter wave mobile communications for 5G cellular: It will work!" It is also exceptional in its influence as it has the highest number of annualized citations among the top-cited articles, 596.86 citations per year. The highest number is 458.5 citations per year for an article published in 2016. An article from 2018 also made it to the list, with 499 citations and 249.5 citations per year. This increase in the presence of recent highly cited articles attests that IA has attracted more and more influential contributions over the years. It is assumed that upcoming areas such as IoT and 5G technology are frequently the topics involved, as they are of critical importance and popularity in the field. This is in line with the findings of Pan *et al.*, which identified wireless 5G communication and millimeter waves as highly popular in 2019 [55]. Similarly, Li and Ho have reported the increased relevance of publications related to IoT [56]. This further attests to the ability of IA to attract relevant publications.

For a more detailed representation of the citation structure of IA, we have created a journal-level citation network for the papers appearing in IA. Figure 4 presents the journal-level citation network, where each node represents a journal, and each represents a citation from one journal to another—in this case, to papers in IA. Of the clusters presented in Figure 4, it can be seen that wireless communication, power grid, power electronics, artificial intelligence, etc., form major groups from which IA publications attract citations. IA looks to have a diverse citation profile, indicating its wider readership and usage. Table 7 shows a tabular list of the top journals citing IA publications ranked by Impact Factor along with their Scimago Journal rank. While preparing this table, we selected only those journals which have impact factors in JCR 2020 and have corresponding SJR 2020. It is observed that *IEEE Communications Surveys & Tutorial* with SJR

TABLE 6. Most influential publications.

Authors	Title	Year	TC	TC/Year
Rappaport, Theodore S.; Sun, Shu; Mayzus, Rimma; Zhao, Hang; Azar, Yaniv; Wang, Kevin; Wong, George N.; Schulz, Jocelyn K.; Samimi, Mathew; Gutierrez, Felix	Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!	2013	4178	596.86
Christidis, Konstantinos; Devetsikiotis, Michael	Blockchains and Smart Contracts for the Internet of Things	2016	1834	458.50
Islam, S. M. Riazul; Kwak, Daehan; Kabir, Humaun; Hossain, Mahmud; Kwak, Kyung-Sup	The Internet of Things for Health Care: A Comprehensive Survey	2015	1381	276.20
Gupta, A.; Jha, R. K.	A Survey of 5G Network: Architecture and Emerging Technologies	2015	1191	238.20
Adadi, Amina; Berrada, Mohammed	Peeking Inside the Black-Box: A Survey on Explainable Artificial Intelligence (XAI)	2018	685	342.50
Hu, Han; Wen, Yonggang; Chua, Tat-Seng; Li, Xuelong	Toward Scalable Systems for Big Data Analytics: A Technology Tutorial	2014	657	109.50
Zhang, Zheng; Xu, Yong; Yang, Jian; Li, Xuelong; Zhang, David	A Survey of Sparse Representation: Algorithms and Applications	2015	610	122.00
Chen, Xue-Wen; Lin, Xiaotong	Big Data Deep Learning: Challenges and Perspectives	2014	607	101.17
Yin, Chuanlong; Zhu, Yuefei; Fei, Jinlong; He, Xinzheng	A Deep Learning Approach for Intrusion Detection Using Recurrent Neural Networks	2017	571	190.33
Akpakwu, Godfrey Anuga; Silva, Bruno J.; Hancke, Gerhard P.; Abu-Mahfouz, Adnan M.	A Survey on 5G Networks for the Internet of Things: Communication Technologies and Challenges	2017	569	189.67
Parhizi, Sina; Lotfi, Hossein; Khodaei, Amin; Bahramirad, Shay	State of the Art in Research on Microgrids: A Review	2015	559	111.8
Wang, Shuo; Zhang, Xing; Zhang, Yan; Wang, Lin; Yang, Juwo; Wang, Wenbo	A Survey on Mobile Edge Networks: Convergence of Computing, Caching and Communications	2017	506	168.67
Akhtar, Naveed; Mian, Ajmal	Threat of Adversarial Attacks on Deep Learning in Computer Vision: A Survey	2018	499	249.50
Sun, Yunchuan; Song, Houbing; Jara, Antonio J.; Bie, Rongfang	Internet of Things and Big Data Analytics for Smart and Connected Communities	2016	488	122.00
Basar, Ertugrul; Di Renzo, Marco; De Rosny, Julien; Debbah, Merouane; Alouini, Mohamed-Slim; Zhang, Rui	Wireless Communications Through Reconfigurable Intelligent Surfaces	2019	482	482.00

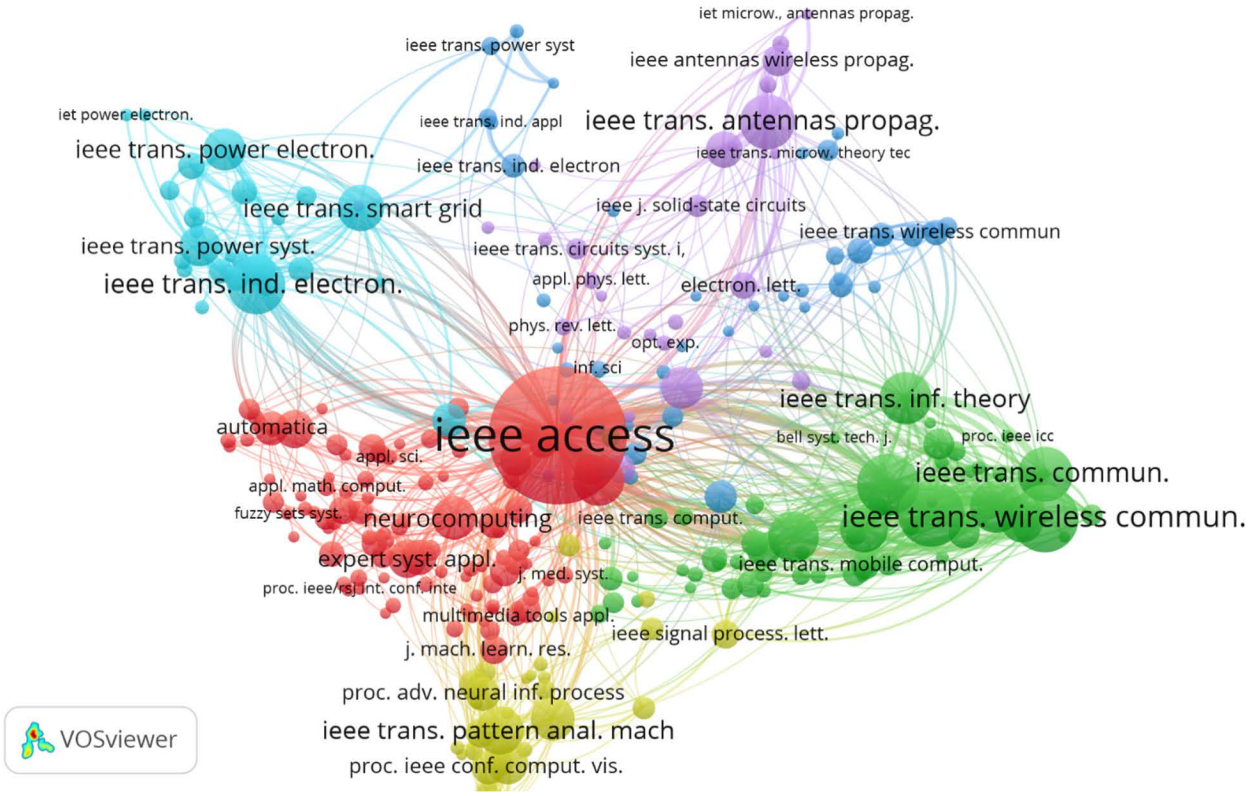

FIGURE 4. Sources citing IA publications.

TABLE 7. Journals that frequently cite IA publications.

Citing sources	Impact Factor	SJR
IEEE Communications Surveys & Tutorials	23.7	6.6
IEEE Transactions on Pattern Analysis and Machine Intelligence	17.9	3.8
IEEE Journal on Selected Areas in Communications	11.4	3.0
IEEE Communications Magazine	11.1	2.8
Proceedings of the IEEE	10.3	2.4
IEEE Transactions on Image Processing	9.3	1.8
IEEE Transactions on Smart Grid	8.3	3.6
IEEE Conference on Computer Vision and Pattern Recognition	8.0	1.1
IEEE Transactions on Industrial Electronics	7.5	2.4
IEEE Transactions on Wireless Communication	6.8	2.0
IEEE Transactions on Power Electronics	6.4	2.2
IEEE Transactions on Communications	5.6	1.5
IEEE Transactions on Vehicular Technology	5.4	1.4
IEEE Transactions on Signal Processing	5.0	1.6
Neurocomputing	4.4	1.1
IEEE Transactions on Antennas and Propagation	4.4	1.7
IEEE Communications Letters	3.4	0.9
IEEE Sensors	3.3	0.6
IEEE Transactions on Information Theory	3.0	1.2

TABLE 8. Top funding sources.

Funding Sponsor	Supported Publications
National Natural Science Foundation of China (NSFC)	19555
Ministry of Science and Technology of the People's Republic of China (MOST)	4730
National Research Foundation of Korea (NRF)	1697
China Postdoctoral Science Foundation	1509
European Commission (EC)	1446
Ministry of Science ICT and Future Planning (MSIP)	1413
Ministry of Education of the People's Republic of China	1282
Ministry of Science and Technology (MOST)	746
China Scholarship Council (CSC)	651
Ministry of Economy, Industry and Competitiveness (MINECO)	632
Chinese Academy of Sciences (CAS)	630
Engineering and Physical Sciences Research Council (EPSRC)	613
Japan Society for the Promotion of Science (JSPS)	465
Natural Sciences and Engineering Research Council (NSERC)	445

6.6 and impact factor 23.7 has most publications citing IA publications. The overall high SJRs and impact factors of the journals citing IA publications highlight IA publications' relevance to general research.

D. FUNDING PATTERNS IN IA PUBLICATIONS

The publication metadata of the IA papers have been further analyzed to identify how many papers in IA have associated research funding and which are the primary funders. It has been observed that nearly 31% of papers did not acknowledge any specific funding agency. An average of 1.22 funders was reported per paper. Primarily, governments are the primary funding agencies globally. Among the various funding agencies, China takes a significant lead, as we observed that most of the funding agencies are Chinese, as listed in Table 8.

These patterns are evident because China has accounted for nearly 60% of publications in IA, and 13 of the top 14 most contributing institutes are based in China. Similarly, there is a significant representation of Chinese scientists among the top contributing authors to the journal. Among the non-Chinese entities on the list, the National Research Foundation of Korea and the European Commission have sponsored the maximum number of publications. However, the dominance of Chinese government agencies in articles published in IA is significant.

E. THEMATIC STRUCTURE OF PUBLICATIONS

Since IA is a multidisciplinary journal, it has attracted papers from various related disciplines of Engineering, Computer Science etc. To understand the subject area distribution of papers in IA, the Fields of Research (FoR) for each publication, as assigned by the Dimensions database, is identified and analyzed. The FoR classification is a component of the Australian and New Zealand Standard Research Classification (ANZSRC) system and has been adopted by the Dimensions database. The FoR has three hierarchical levels: Divisions, Groups, and Fields. The division represents a broad subject area or research discipline, while Groups and Fields represent increasingly detailed subsets of these categories. There are 22 Divisions, 157 Groups, and 1238 Fields [57].

For the subject area distribution analysis, we have emulated the second level of the system only, Groups. Table 9 below presents the various research fields covered in IA publications and the count of publications and citations for papers in each FoR. As can be observed from the table, Information and Computing Sciences followed by artificial intelligence and then technology are the major fields present. Nearly 75% of total publications and total citations are from Information and Computing Sciences. AI and Image Processing account for 42% of publications and citations. It clearly indicates the journal's popularity among various engineering and computer science research fields.

To further analyze the contribution from the major FoRs, the number of papers in different publication years from the

TABLE 9. Fields of research for IA publications.

Fields of Research (FoR)	TP	TC
Information and Computing Sciences	33295	299827
Artificial Intelligence and Image Processing	18664	171975
Technology	16177	157794
Engineering	15093	113815
Communications Technologies	7525	99494
Information Systems	5025	66428
Electrical and Electronic Engineering	3237	33086
Data Format	2077	27502
Computer Software	1429	17922
Computation Theory and Mathematics	1104	10620

TABLE 10. Evolution of fields of research for IA publications.

FoR/Year	2013	2014	2015	2016	2017	2018	2019	2020
Information and Computing Sciences	73%	72%	73%	69%	62%	83%	76%	77%
Artificial Intelligence and Image Processing	25%	29%	33%	33%	30%	45%	43%	45%
Engineering	55%	40%	36%	29%	26%	35%	35%	35%
Technology	41%	52%	54%	52%	42%	45%	36%	34%
Communications Technologies	9%	27%	35%	36%	28%	25%	16%	13%

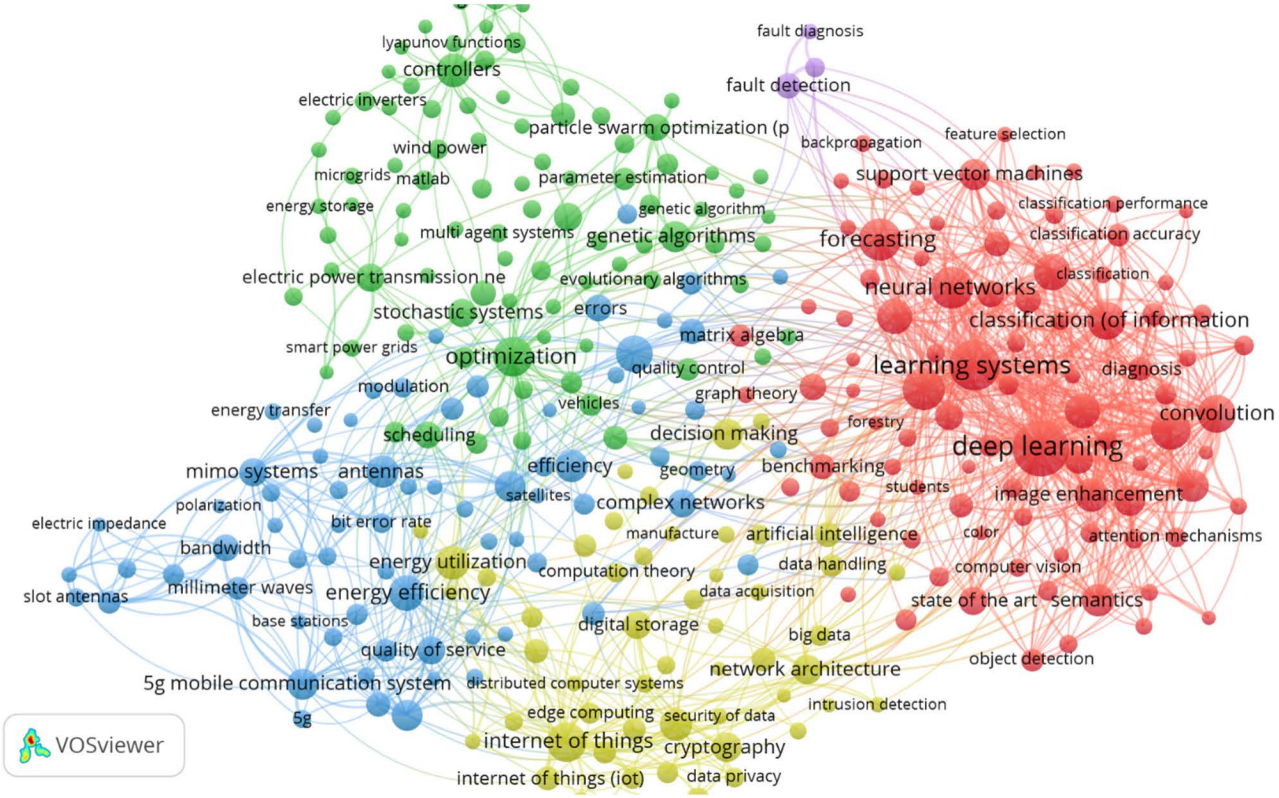

FIGURE 5. Keyword co-occurrence network for publications in IA.

top contributing FoRs are identified and analyzed. Table 10 shows the number of publications year-wise for the top 5 FoRs. It can be observed that the total publications in the Information and Computing Sciences area rose from 47 in 2013 to 13,841 in 2020, an increase of 284 times. Though the absolute number of AI and Image Processing publications is relatively less, its growth is over 503 times. Similarly, publications in Communication Technology have increased over 395 times in the same period. This trend highlights the increasing importance of fields such as artificial intelligence and image processing in the IA journal. It may be noted that other reports on AI [58] have also reported that there is a 34.5% growth of AI publications between 2019 and 2020.

For a more detailed understanding and visualization of the thematic structure of publications in IA, we have also created a keyword co-occurrence network and concept density plot for publications in IA. Co-occurrence of keywords can help identify the relevance of an article with regards to specific topics and is linked to precision and recall during searches [59]. VOSviewer software is used to produce the keyword co-occurrence network, which consists of a cluster of nodes of various colors. Nodes having the same colors indicate that they are in the same cluster. Occurrences and weights of the keywords determine the size of the node. The keyword with the biggest circle has the largest weight. The distance between the keywords determines the relatedness of the keywords. The shorter the distance, the stronger their

relatedness is. Figure 5 presents the keyword co-occurrence network for publications in IA. We can see that five significant clusters of keywords are identified. Cluster 1 (red color), the largest, contains 92 keywords, cluster 2 (blue color) includes 90 keywords, cluster 3 (yellow color) has 72 keywords, cluster 4 (green color) has 52 keywords, and cluster 5 (pink color) has 3 keywords. These clusters of keywords are clearly linked by topical similarity. For example, deep learning, learning systems, machine learning, among others, fall within the umbrella of methods to mimic learning as a way to create artificial intelligence.

Similarly, the keywords linked to 5G systems such as antennas, bandwidth, etc., cluster together. The linkages between these clusters are also interesting. For genetic algorithms, part of the green cluster dealing with optimization and related methods is also heavily linked to the cluster on learning systems. Similarly, the keyword artificial intelligence and decision-making are linked to deep learning and learning systems. Many such linkages can be identified from Figure 5.

To better understand the themes discussed in IA publications, the database assigned keywords, known as concepts, have been further analyzed and visualized. These concepts are key phrases occurring in the paper and usually represent the themes discussed in the paper. Such concepts are extracted by several machine learning-based approaches used by the database. For each such extracted concept, a relevance score is also assigned. We have identified the 1000 most frequent concepts and plotted a concept density plot in Figure 6. It can be observed that some of the major themes are 'algorithm,' 'network,' 'simulation results,' 'neural network,' 'convolutional neural network,' 'images,' and 'deep learning.' Total Link Strength (TLS), which indicates the number of publications in which two keywords occur together, are indicated by yellow, green, and blue colors. The font size of the themes indicates greater TLS and TLS of yellow is > green > blue.

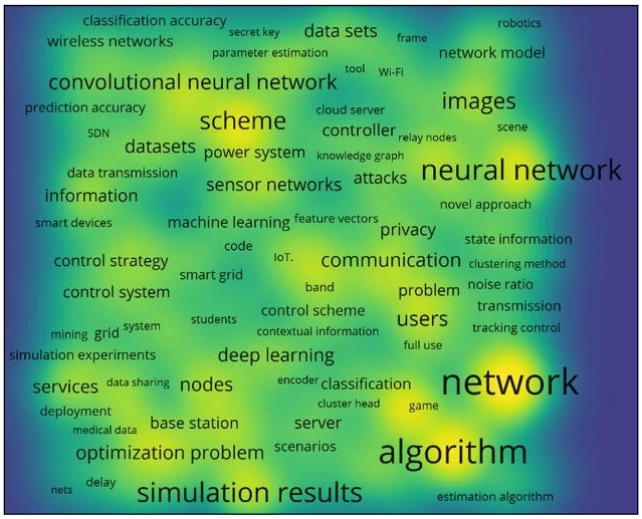

FIGURE 6. Concept-density plot of the most-frequent concepts.

We observe less dispersion of themes with reasonably high degree of connectivity among them, which confirms the journal's interdisciplinary nature and its focus on contemporary research trends.

F. GENDER DISTRIBUTION OF AUTHORS

The gender distribution of authors contributing to IA is the next topic of analysis. For this purpose, the gender of the first author has been determined by using the Gender-API service. The first name, last name, researcher id, affiliation, and year of publication for all the records was extracted from the publication metadata and analyzed for this task. The author records were then passed to the Gender-API. The Gender-API provides the gender for each record using the first name and country field. Along with the gender, male or female, the accuracy of the assignment is also provided. The Gender-API returned the gender with more than 70% accuracy value. The gender value of these records was then processed to calculate the year-wise gender distribution of authors. Figure 7 shows the year-wise proportion of female and male 1st authored papers. It can be observed that the proportion of female first-authored papers in IA has increased from about 7% in 2013 to approximately 22% in 2020. Thus, there is an overall increase in female 1st authored papers in IA over the 2013–20 period. A similar analysis of top-cited publications in the medical profession showed that 40% of authors were women [60], suggesting a better gender distribution than general engineering. Thus, the gender value for an author with an accuracy value of more than 70% indicates that we used the gender values on which the gender-API returned a value of gender that was more than 70% accurate. Thus, we processed the gender values of first authors of publications that were determined with greater than 70% accuracy and discarded those gender values whose reliability or accuracy was less than 70%.

G. SOCIAL MEDIA VISIBILITY

Typically, citation-based indicators such as impact factor and the number of cited publications make up the bulk

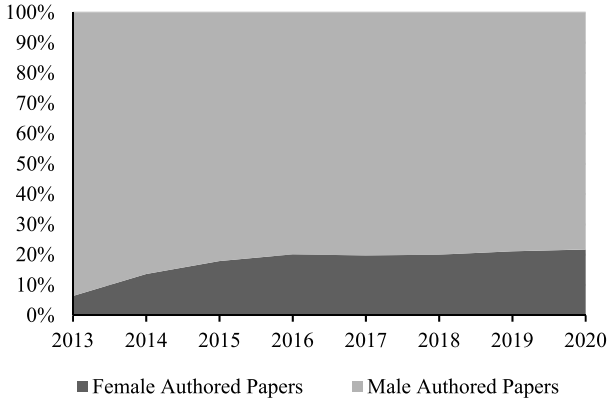

FIGURE 7. Proportion of female and male 1st authored papers.

TABLE 11. Altmetrics attention of IA publications.

Name	TP	TPA	TPA%
Information and Computing Sciences	33295	2819	8.47
Artificial Intelligence and Image Processing	18664	1523	8.16
Technology	16177	1320	8.16
Engineering	15093	1097	7.27
Communications Technologies	7525	680	9.04
Information Systems	5025	618	12.3
Electrical and Electronic Engineering	3237	232	7.17
Data Format	2077	223	10.74
Computer Software	1429	202	14.14
Computation Theory and Mathematics	1104	107	9.69
Materials Engineering	974	62	6.37

of bibliographic studies. However, the alternative field of Altmetrics carries the weight of its own and is a key component of a complete bibliographic analysis [61]. These metrics explore factors such as how often a publication is cited in social media, reference managers, public policy documents, whether mainstream media has covered a publication. Essentially, these metrics provide an alternative way of assessing the significance of an article aside from citations.

To identify the social media visibility of papers published in IA, we have used the altmetrics data integrated into Dimensions and obtained social media coverage data, in different platforms, for those papers from Altmetric.com. It was found that only 14.60% of papers got some social media attention. Table 11 shows % publications with attention for different FoR.

It is seen that Information and Computing Sciences have a relatively higher number of publications with attention. This FoR also has the highest number of citations, indicating a correlation between the two. Essentially, peers cited fields with greater relevance, and the Web visibility follows a similar trend. It can also be seen that more generic FoR such as computer software and Information systems receive greater attention when Altmetrics are considered. Table 12 shows the platform-wise visibility of 6456 publications in IA, which have Altmetrics attention for the period 2013–2020. The platforms covered are Twitter, Facebook, News, Blog, Wikipedia, and Mendeley. Mendeley has the highest proportion of papers with attention, followed by Twitter and Facebook among different platforms. Mendeley is considered as an Academic Social Network (ASN) platform, which explains the high number of articles (98.43%) covered under it. It is exciting to observe Twitter having good coverage of 40.3%, possibly indicating that academics value sharing their research work via tweets. Other platforms have a very low altmetrics coverage.

TABLE 12. Altmetrics attention of IA publications in different platforms.

Platform		
Twitter	Total no. of articles	6,456
	Articles covered in Twitter	2,602
	Coverage (%)	40.30%
	Avg. Mentions/ paper	4.87
Facebook (FB)	Total no. of articles	6,456
	Articles covered in FB	284
	Coverage (%)	4.40%
	Avg. Mentions/ paper	1.65
News Mediums	Total no. of articles	6,456
	Articles covered in News	184
	Coverage (%)	2.85%
	Avg. Mentions/ paper	3.19
Blog Platforms	Total no. of articles	6,456
	Articles covered in Blog	108
	Coverage (%)	1.67%
	Avg. Mentions/ paper	1.17
Wikipedia	Total no. of articles	6,456
	Articles covered in Wikipedia	148
	Coverage (%)	2.29%
	Avg. Mentions/ paper	1.39
Mendeley	Total no. of articles	6,456
	Articles covered in Mendeley	6,355
	Coverage (%)	98.43%
	Avg. Mentions/ paper	40.70

TABLE 13. SDG related research in IA.

Name	TP	TC
7 Affordable and Clean Energy	6434	76042
13 Climate Action	699	9032
3 Good Health and Well Being	589	7110
11 Sustainable Cities and Communities	322	5812
4 Quality Education	209	2062
10 Reduced Inequalities	92	435
12 Responsible Consumption and Production	64	1005
16 Peace, Justice and Strong Institutions	64	480
8 Decent Work and Economic Growth	52	477
9 Industry, Innovation, and Infrastructure	41	332
2 Zero Hunger	14	422
6 Clean Water and Sanitation	12	54
14 Life Below Water	12	124
1 No Poverty	9	24
15 Life on Land	6	54

We also studied the correlation between citation counts and altmetrics attention scores for the publications between 2017 and 2018. Altmetrics scores showed a weak positive correlation with citation counts ($r = 0.158$). For those two years, there were a total of 8962 publications with

TABLE 14. Evolution of SDG related research in IA over years.

UN SDG	2013	2014	2015	2016	2017	2018	2019	2020
7 Affordable and Clean Energy	5%	14%	20%	21%	16%	17%	13%	15%
13 Climate Action	0%	0%	2%	1%	1%	1%	1%	2%
3 Good Health and Well Being	2%	2%	0%	1%	1%	1%	1%	2%
4 Quality Education	0%	0%	1%	0%	1%	0%	0%	1%
11 Sustainable Cities and Communities	0%	0%	1%	1%	1%	1%	1%	1%

citations ranging from 0 to 905 and altmetrics scores ranging from 1 to 190. About 3% of the publications had zero citations, while 89% of the publications did not have altmetrics scores. These results are consistent with the previous studies that publications with altmetrics counts are still very low. Still, these results are insufficient to conclude the publications' quality with no altmetrics score [62], [63].

H. CONNECTIONS WITH SDGs

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015. There are 17 goals and 169 indicators, with targets to be achieved by 2030. Given the global reach of the goals and their importance to human well-being—including addressing issues ranging from poverty to promoting innovation and fighting climate change—it is understandable that research related to the SDGs is gaining attention [64]. The publication of SDG-related articles has increased in every field ranging from life sciences to arts [65]. There is a proportionate increase in technology publications like the review on AI and the SDGs by Vinuesa *et al.* [66], and by Gupta *et al.* [67]; therefore, we tried to find out whether there are publications in IA-related SDGs. The Dimensions database provides an automated classification of publication records into different SDGs based on the article's content. The Dimensions database provides an automated classification of publication records into different SDGs based on the article's content. Table 13 shows several publications in IA that relate to different SDGs. It can be observed that SDGs 7 (on clean energy), 13 (on climate action), 3 (on health), and 11 (on sustainable cities) have gained maximum attention in IA publications. The focus on SDG 7 in IA publications can be understood in the context of developing more efficient energy solutions and the associated electric consumption of currently-developed algorithms, which is a highly specialized area. Therefore, it can be inferred that novel technology applications [68] towards achieving the SDGs are most relevant regarding SDGs 7 and 13, and there is a relatively higher emphasis in IA publications on these areas. In particular, there is a very high potential of data-driven methods in the context of sustainable solutions to fight climate change, for instance, optimizing the usage of the available energetic resources [69].

The top-5 areas from Table 13 are further analyzed in terms of their publication year, as shown in Table 14. The numbers show an increase in interest in the five SDGs, but sustained and substantial growth is most evident in SDG 7, the relevance of which was discussed above. Perhaps an additional aspect of novel technology related to SDG 7 is the steep increase of electricity consumption associated with formation-and-communications technologies (ICTs): an increase from 1% of the global electricity consumption today up to 20% is projected by 2030 [70]. On the other hand, the critical nature of climate change is natural, and research on this topic has increased since 2012. Again, the focus on climate action and affordable energy may be related to the more technical nature of the publications in IEEE.

I. COVID-19 RELATED RESEARCH IN IA

As with any other sector, the recent coronavirus disease 19 (COVID-19) crisis has affected the world of academic publishing in unique ways [71]–[73]. There are publications in IA too that deal with one or the other aspect of COVID-19 research. Table 15 presents the country-wise IA publications related to Covid-19 research. It can be seen that China has the maximum number of articles followed by the US, Saudi Arabia, and the UK. However, most citations are for Australia, India, and the US papers. Interestingly, while just 17 publications from India are identified, as opposed to 50 from China and 49 from the US, these 17 publications have amassed 665 citations, as opposed to 361 for Chinese publications and 622 for those from the US. It implies that the Indian publications received 39.12 citations per publication, followed by 12.69 from publications in the US and 7.22 from the Chinese studies. Similarly, though Australia and the UK have almost similar publications, the citations are significantly higher for Australian publications, nearly 67% more. These numbers show the importance of bibliographic studies in identifying the significance of publications, critical research groups, etc., instead of just assessing the number of publications [74], [75].

IV. LIMITATIONS OF THE STUDY

Our study has certain limitations. The citation analysis tool used in this study focuses only on the magnitude of the impact of the cited papers, and highly cited papers are not necessarily high-quality papers [76]. H-index is somewhat meaningless without a context within the author's discipline, and it should

TABLE 15. COVID-19 related research in IA.

Name	TP	TC	TC/TP
China	50	361	7.22
United States	49	622	12.69
Saudi Arabia	29	425	14.66
United Kingdom	26	433	16.65
Canada	24	343	14.29
Spain	23	197	8.57
Australia	22	723	32.86
Egypt	17	167	9.82
India	17	665	39.12
Italy	17	87	5.12

be used with care to make comparisons because of its bias against early career researchers and those who started late or had career breaks. It also does not fully consider differences in disciplines. Dimensions is a new database, which has been improving significantly recently. Regarding coverage of data for journals, they source data from CrossRef and PubMed and then refine that through their direct agreement with publishers. For analyzing patterns in a journal, we do not see a problem in using the data from the Dimensions database. This is confirmed by the fact that we used some data from Scopus earlier, but now, even after getting data from Dimensions, those patterns observed remain largely the same. There have been several studies comparing the coverage of Dimensions database with Scopus and Web of Sciences [77], [78] while highlighting its limitations also. It is possible to indirectly spam the dimensions database through preprint servers by uploading batches of non-peer-reviewed articles. There are also inconsistencies in the indexing of journal articles, such as article types like ''list of reviewers'' or ''editorial board'', which may inflate the number of articles in the dimensions database. In the case of Altmetrics, the Attention score does not necessarily indicate that the article is of high quality but indicates its popularity with the public, as seen in the social media platforms.

V. CONCLUSION

The article presents analytical results of publication and citation patterns, authorship structure, collaboration patterns, major funding sources, thematic structure, gender distribution, social-media visibility, and UN SDG connections of papers published in the IA journal. It is observed that in a very short period, IA has emerged as a preferred venue for the publication of research work in different areas of Engineering and Computer Science. The rapid and continuous publication model is a distinctive characteristic of the IA journal, which can be attributed as a significant reason for its fast growth in publication numbers. As a result, the journal has attracted research papers from very well-established researchers. At the same time, the impact of the publications has also increased over time, as measured through citations.

There has been an increasing trend of multi-authored papers and the proportion of papers involving international collaboration. A significant number of research publications are from China, and Chinese funding agencies are also the most prominent funders of research published in IA. The number of papers in IA having a female 1st author has also increased between 2013 and 2020. The social-media attention to IA publications, however, is not very significant. The thematic structure of the publications in IA indicates a powerful multidisciplinary nature and focus on critical research areas having contemporary relevance. The number of publications in IA connected to the SDGs has steadily increased over the years, reflecting the importance of these issues and the potential of novel technologies to tackle the challenges associated with them [66], [68]. There is significant focus on SDGs 7 (on clean energy) and 13 (on climate action), which arguably constitute humanity's most important challenges in the near future. The third-most-popular SDG in IA publications is SDG 3 (on health), due to the enormous potential of technology in this area and the numerous health-related challenges arising in today's societies, for instance, in the context of the COVID-19 pandemic. Regarding IA publications on the pandemic, China, the US, and Australia lead in terms of the number of publications, while India exhibits a large number of citations per publication.

An area of future work would be comparing IA performance with similar open access journals, as open access is becoming a significant driver for publications.

Overall, it is seen that the IA journal has excellent potential when it comes to attracting novel, high-quality, multidisciplinary research. Given the focus areas connected to the SDGs, this journal is perfectly positioned to provide plausible solutions to these complex challenges. Two additional encouraging indicators of this journal are the increase of multi-authored interdisciplinary research and the percentage of articles with female first authors.

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