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How Scopus is Shaping the Research Publications of Feature Fusion-Based Image Retrieval

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Abstract

Research trends have shown an increase in the preferences for feature fusion-based image retrieval. The primary objective of this study is to show the current state of research regarding image retrieval and feature fusion. The research papers indexed in the Scopus database are considered here for quantitative analysis. A bibliometric analysis of the research publications indexed in Scopus is presented in this study. During this study, 461 documents from 276 different sources are obtained. The important keywords, sources, authors, countries, and funding agencies are presented, which will help future researchers in research directions.

Keywords: Image retrieval, feature fusion, bibliometric analysis.

1. Introduction

With the enormous growth in digital imaging technology, the complexity of multimedia data has increased drastically. The advancements in storage and networking technologies have resulted in complex multimedia data, especially images being shared through various social media applications and websites. Searching and retrieving the images of interest from the huge data repositories is becoming a key bottleneck. Retrieving the images efficiently is an open-ended research problem. Trademark image retrieval (IR), beauty product IR, flower IR, fish species IR, crime scene investigation IR, face IR, fabric IR, remote sensing IR, document IR, digital library retrieving historical manuscripts' images, sketch-based IR, photo retrieval system based on face sketch are some of the applications of the image retrieval system. Image retrieval is used widely in the medical domain for the retrieval of Alzheimer's disease images, skin cancer images, and medical equipment images (Wang et al., 2021) (Ji et al., 2020) (Yang et al., 2021) (Dewan & Thepade, 2020).

Simple text-based image retrieval systems are not suitable for complex images, as it is difficult to describe the image content in text form. Image retrieval based on the image content is one of the most suitable options available. The important image contents are extracted and described using various image features to overcome the issues related to geometric distortion like scaling, rotation, translation, occlusion, and change in viewpoint. The low-level image content features are generally used to describe the images. These features are categorized as color, shape, and texture-based features.

The color-based features are simple and robust to changes in scale, translation, and rotation but their performance is not robust to illumination changes. The color features are generally extracted from RGB, HSV, Lab, and LUV color spaces. Color moment, histogram, and coherence vector-based techniques are widely used in literature. Color moment-based

techniques require less storage memory and are fast but the retrieval accuracy is low. Coherence-based and histogram-based techniques have high accuracy but the size of the feature vector is high and hence requires more time and memory space (Dewan & Thepade, 2020) (Dewan, J.H., Thepade, 2021).

Shape-based techniques are categorized as region-based and contour-based. Shape-based techniques require the segmentation of images for segregating objects, which is very difficult for generic images (Latif et al., 2019).

Texture-based techniques are categorized as structure-based and statistical-based. Structure-based techniques are suitable for images containing consistent patterns. Statistical-based techniques consider the quantitative information about the pixel intensities of an image. Local binary patterns and their variants (Ojala et al., 1996), gray level co-occurrence matrix (Dewan & Thepade, 2021), transforms like a cosine transform, curvelets, ridgelets, and wavelets are some of the most commonly used techniques to extract and describe the features. Texture-based techniques are robust to illumination but the feature vector generated is larger as compared to other methods (Latif et al., 2019) (Hee-Jung Bae & Sung-Hwan Jung, n.d.) (Sadafale & Bonde, 2017) (Kishore & Rao, 2021).

The image contents can be specified by considering the whole image (global features) or parts of the image (local features). Global feature-based image retrieval techniques give better results to find near-duplicate images but are not suitable for images with occlusion. Local feature-based techniques divide the image into sub-parts, extract the features and then describe them. These techniques generate feature vectors of larger size and thus require high execution time. FREAK(Alahi et al., 2012), ORB (Rublee et al., 2011), FAST (Rosten & Drummond, 2006)**,** SUSAN(Smith & Brady, 1997), MSER(Matas et al., 2004), SURF (Bay et al., 2006), SIFT (Lowe, 2004), and their variants and, BRIEF (Calonder et al., 2010) are mainly used in literature to describe local features.

In recent years, deep learning and convolutional neural network-based techniques are widely used to retrieve similar images with transfer learning. Since the images are complex and diverse in nature, a single type of feature cannot describe the contents of the image. Therefore, from the year 2002, researchers started using feature fusion of diverse features to describe the image. Fusion of text-based and content-based image retrieval, global and local features, color, texture, and shape-based features, cross-modal images such as infrared and visible images, Optical and Synthetic Aperture Radar images, local features, and deep learning features have been experimented in recent years (Yang et al., 2021)(Li et al., 2021)(Rao & Prasad, 2021)(Kanwal et al., 2021).

2. Why bibliometric analysis?

Science is cumulative. For the new research, it is necessary to identify and review the existing research work globally as well as explore new directions in a specific domain. Good innovative research practices are being followed for the last two decades and have resulted in a high number of research publications across the globe. These publications are stored in bibliographic databases that use bibliometrics tools to analyze and measure scientific literature. Bibliometrics is a statistical analysis tool that was introduced by Pritchard in 1969 as "the application of mathematics and statistical methods to books and other media of communication" (Pritchard,

1969). The term was derived from the Greek language, where “Biblio” means book and “metric” means measure.

3. Analysis

3.1. Documents and Source

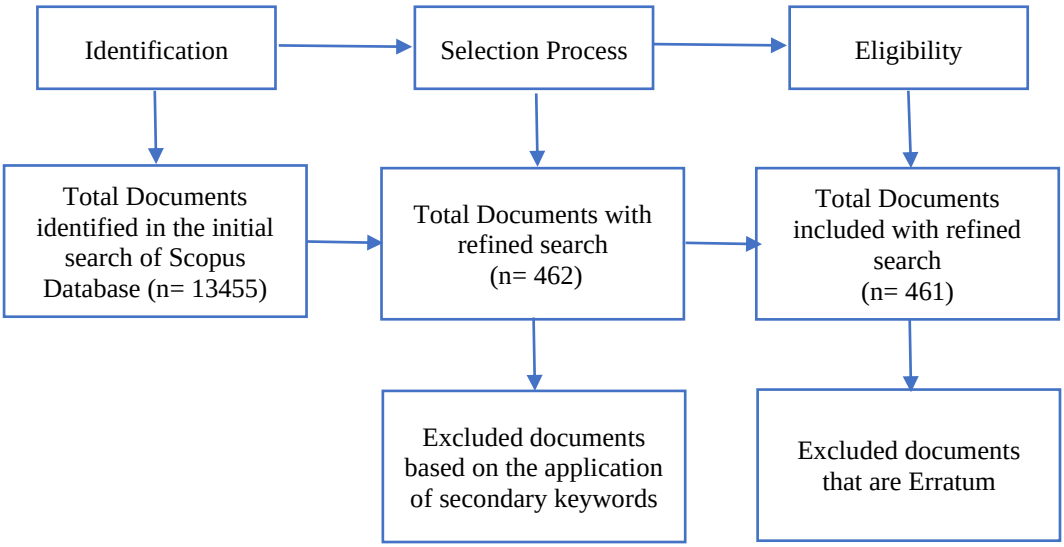

Fig 1: PRISMA method Based Procedure for Identifying the Documents for Analysis

The documents are searched using the Scopus database due to its multidisciplinary nature and availability of references (accessed on 08/05/2021). The primary keyword “image retrieval” generated a total of 13455 relevant documents. The search was then refined using the secondary keyword “feature fusion”. The refined search generated 462 relevant documents with one erratum document. So finally, 461 documents are used for performing the bibliometric analysis.

Figure 1 shows the method used for identifying the documents for analysis. The final refined query used to generate the relevant documents from the Scopus database is:

(TITLE (image AND retrieval) AND TITLE-ABS-KEY (feature AND fusion)) AND (EXCLUDE (DOCTYPE, “er”))

In 1966, the work in the field of “image retrieval” started getting published. However, the publication of “feature fusion” based image retrieval work started in the year 2002. In the initial years up to 2012, 11 articles were published in a year. However, from 2013 till 2020, an average of 38 papers are being published every year. It is evident that in the last five years, the numbers have grown as researchers and academicians are publishing a significant number of papers. Biblioshiny is used to perform statistical analysis (Aria & Cuccurullo, 2017). Figure 2, highlights the year-wise published articles from 2002 to 2020.

Table 1 indicates the publication language of these documents. The documents are published in English, Chinese, French and Spanish languages. Major work is published in the English language i.e., 430 (93.275 %) followed far by Chinese (6.3%).

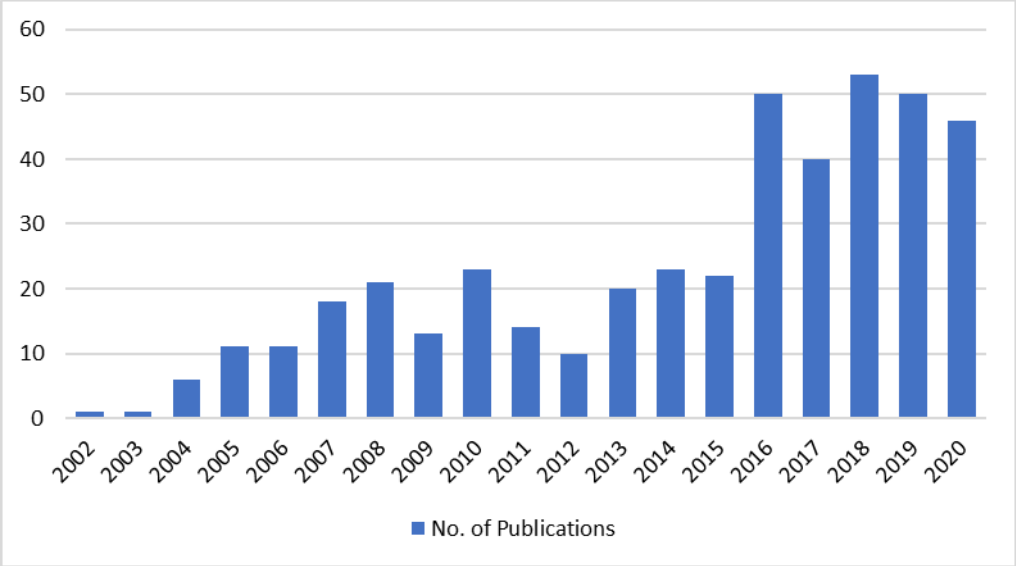

Fig 2: Documents Published Annually

Table 1: Publication Languages

Language	Documents	Percentage (%)
English	430	93.275
Chinese	29	6.291
French	1	0.217
Spanish	1	0.217
Total	461	100

Figure 3 represents the various sources of the documents. Out of the total 461 documents, 47.51% documents are from journals, 39.26 % documents are from conference proceedings, 12.36% documents are from book series, 0.65% documents are from books and 0.22% documents are from trade journal. Thus, journal and conference proceedings contribute to 87% of the total documents (454 documents are published and 7 articles are in press).

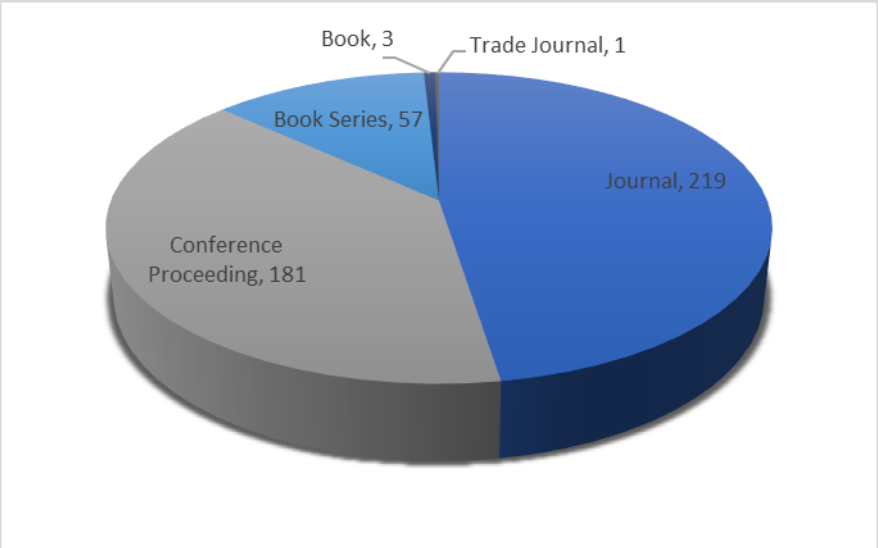

Fig 3: Sources of the Documents

The articles are from 20 different subject areas. The Top 10 subject areas are listed in Table 2. The majority of the articles are from Computer Science (378 articles) and Engineering (177) domain, while Chemical engineering (3), arts and humanities (1) contribute the least.

Table 2: Subject Areas

Sr. No	Subject Area	No. of Documents
1	Computer Science	378
2	Engineering	177
3	Mathematics	79
4	Materials Science	36
5	Physics and Astronomy	27
6	Medicine	21
7	Decision Sciences	19
8	Social Sciences	17
9	Multidisciplinary	11
10	Neuroscience	10

3.2. Most Important Journals and Conferences

A total of 218 articles are published in 129 journals. The journals which have contributed at least 4 articles are considered as relevant journals and are shown in Figure 4. IEEE Access, and Multimedia Tools and Applications Journals have contributed maximum articles (14 articles each).

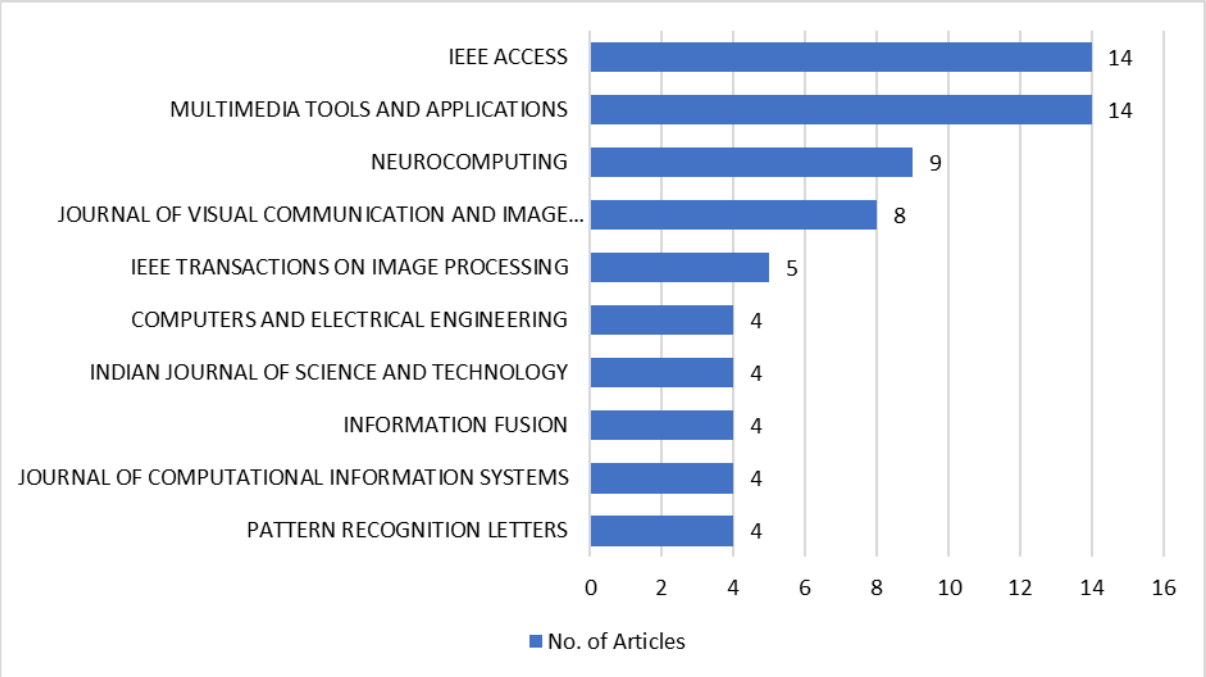

Fig 4: Most Relevant Journal Sources

Total 147 conferences have contributed 231 articles. The conferences contributing at least 3 articles have been considered relevant. Figure 5 shows the top 10 most relevant conferences. “Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)” have contributed maximum papers (31 articles).

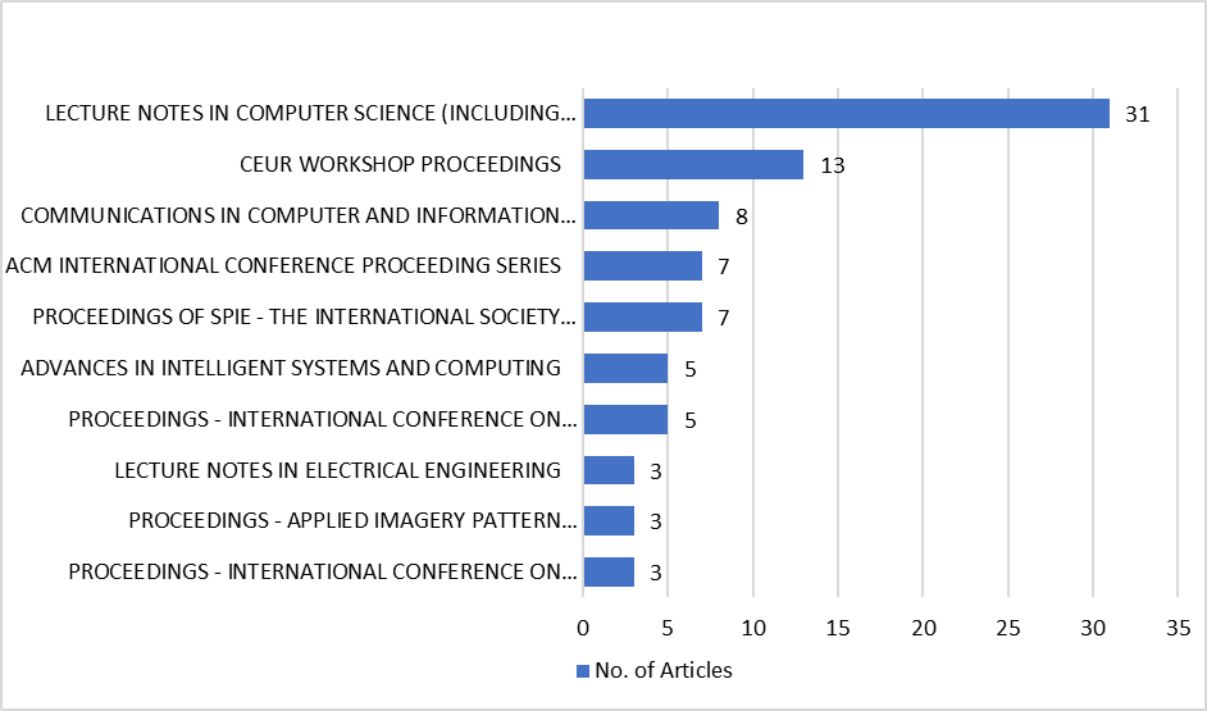

Fig 5: Most relevant Conference Sources

3.3. Growth of Sources/Journals

Figure 6 indicates the growth of the top 5 sources. IEEE Access, and Multimedia Tools and Applications have published a significant number of articles. The growth of "Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)" was constant and consistent in the initial years. Since 2016, the number of articles published by IEEE Access has increased exponentially.

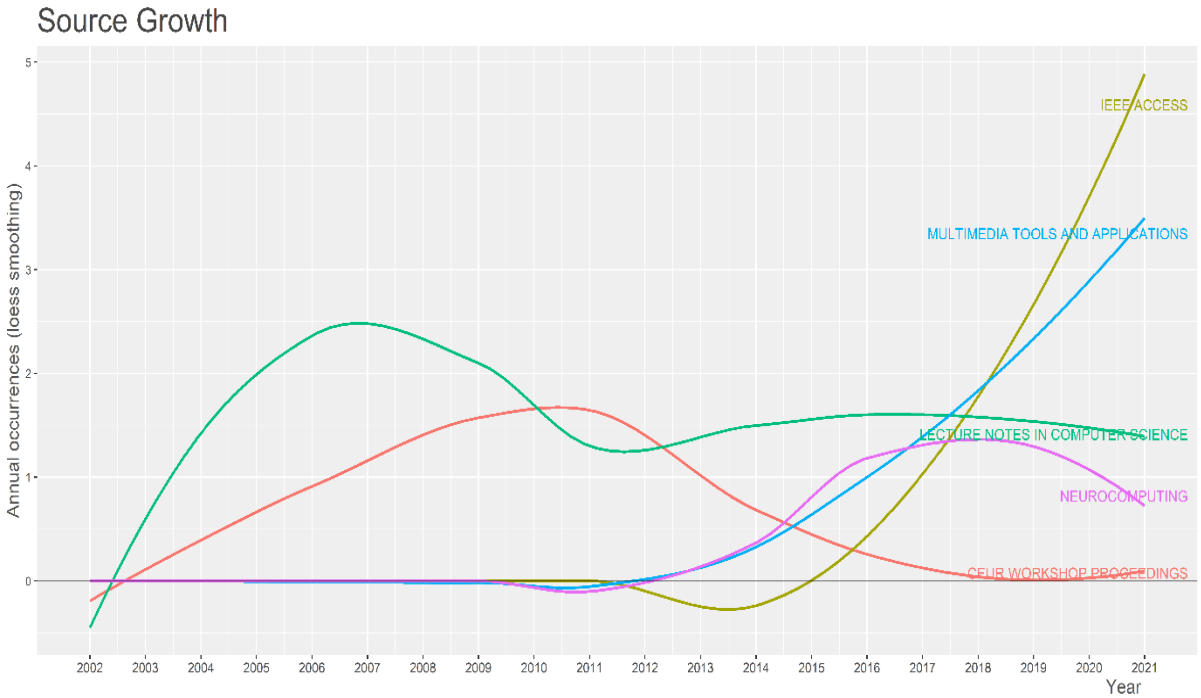

Fig 6: Top 5 Most Relevant Sources and their Growth (Image Source: Biblioshiny)

3.4. Significant Contributing Authors

After identifying the most contributing sources, the next step is to identify the most relevant authors. 1016 authors have published articles in this domain. There are 16 single-authored research articles. There is an average of 2.2 authors per document. 73% of the authors have contributed only 1 article, which indicates low average productivity. 37 authors have published at least 5 articles. Table 3 highlights the most relevant authors who have at least 9 articles, h-index, g-index, total citations (TC), documents published (NP), and the year of Ist article production (PY_Start). Although Liu Y has published the maximum number of articles (16), Rahman M.M. has the highest h-index (9).

Table 3: Most Contributing Authors and Different Index

Authors	Articles	h_index	g_index	m_index	TC	NP	Py_Start
Liu Y	16	5	6	0.333	58	15	2007
Li Y	15	6	12	0.429	145	15	2008
Wang Y	15	6	10	0.462	119	15	2009
Rahman M.M	14	9	14	0.529	304	14	2005
Tian Q	13	6	13	0.353	368	13	2005
Wang J	11	5	8	0.625	66	11	2014
Bhattacharya P	10	6	10	0.353	170	10	2005
Cen Y	9	4	6	0.667	40	7	2016
Desai B C	9	6	9	0.353	168	9	2005
Li H	9	3	6	0.375	46	9	2014
Li Z	9	3	6	0.75	43	9	2018
Wang X	9	4	6	0.333	47	9	2010
Zhang L	9	4	8	0.25	95	8	2006

Figure 7 highlights the cumulative citations annually. Total 461 documents have been published and cited 4027 times.

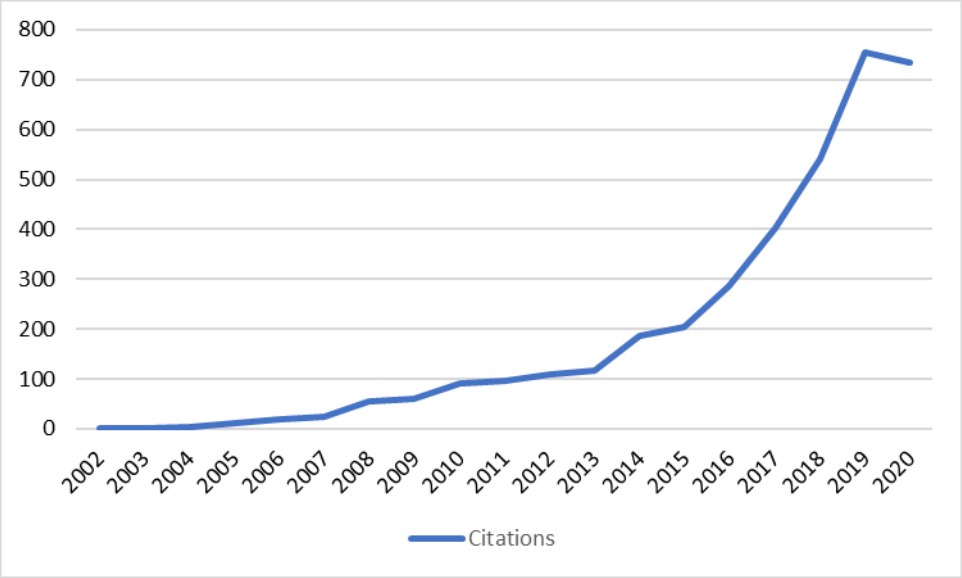

Fig 7: Documents Cited Annually

Table 4 highlights the most globally cited authors. Authors having at least 50 global citations are considered here. The global citations are calculated by excluding local citations from total citations. Total 13 authors have at least 50 citations with Tian Q having the highest global citation count. Liu Y has published the maximum number of articles (16) but has only 50 global citations.

Table 4: Most Global Cited Authors

Author	Total Citations	Local Citations	Global Citations
Tian Q	368	7	361
Rahman MM	304	2	302
Bhattacharya P	170	2	168
Desai BC	168	0	168
Li Y	145	20	125
Wang Y	119	5	114
Zhang L	95	0	95
Feng L	74	12	62
Zhang J	65	6	59
Liu S	66	11	55
Zhang H	56	2	54
Zhang Q	55	2	53
Liu Y	58	8	50

Table 5 represents the top 10 most global cited documents. Out of 4027 total citations, 1150 citations (28.6 %) are for the top 10 documents. The article by Hong C, in IEEE Transactions on Industrial Electronics, 2015 has the highest global citation count of 188.

Table 5: Top 10 Most Global Cited Document

Paper	Total Citations	TC Per Year	Normalized Tc
Hong C, 2015, IEEE Transactions on Industrial Electronics	188	26.8571	7.2308
Zheng L, 2014, Proc IEEE Computer Society Conference Computer Vision Pattern Recognition	156	19.5	6.8604
Zhang S, 2015, IEEE Transactions on Pattern Analysis and Machine Intelligence	131	18.7143	5.0385
Zhang S, 2012, Lecture Notes Computer Science	129	12.9	6.9355
Zheng L, 2014, IEEE Transactions on Image Processing	120	15	5.2772
Rahman Mm, 2011, IEEE Transactions on Information Technology in Biomedicine	101	9.1818	7.7692
Liu P, 2017, Information Sciences	97	19.4	8.4902
Song J, 2017, Proc IEEE International Conference on Computer Vision	78	15.6	6.8271
Rahman MM, 2008, Computerized Medical Imaging and Graphics	77	5.5	11.7174
Liu P, 2017, IEEE Transaction on Image Processing	73	14.6	6.3895

3.5. Significant affiliations and funding agencies

Table 6 represents the most relevant affiliations of authors. There are a total of 322 affiliations. But authors from only 13 universities and organizations have published at least 7 articles. The highest number of articles (24) have been published by the authors of Dalian University of Technology, China.

Table 6: Most Relevant Affiliations

Sr. No	Affiliations	Articles
1	Dalian University of Technology	24
2	Concordia University	18
3	Jilin University	15
4	Univ. of Science and Tech. of China	12
5	Univ. of Engineering and Tech.	10
6	Bahauddin Zakariya University	7
7	Beihang University	7
8	Guilin University of Electronic Technology	7
9	Institute for Infocomm Research	7
10	National University of Singapore	7
11	Ningbo University	7
12	Tianjin University	7
13	Yunnan Normal University	7

Figure 8 shows the top 10 funding agencies out of the total 146 funding agencies that have funded the research in this domain. National Natural Science Foundation has funded the highest number of articles (79), which is by far higher than the remaining agencies.

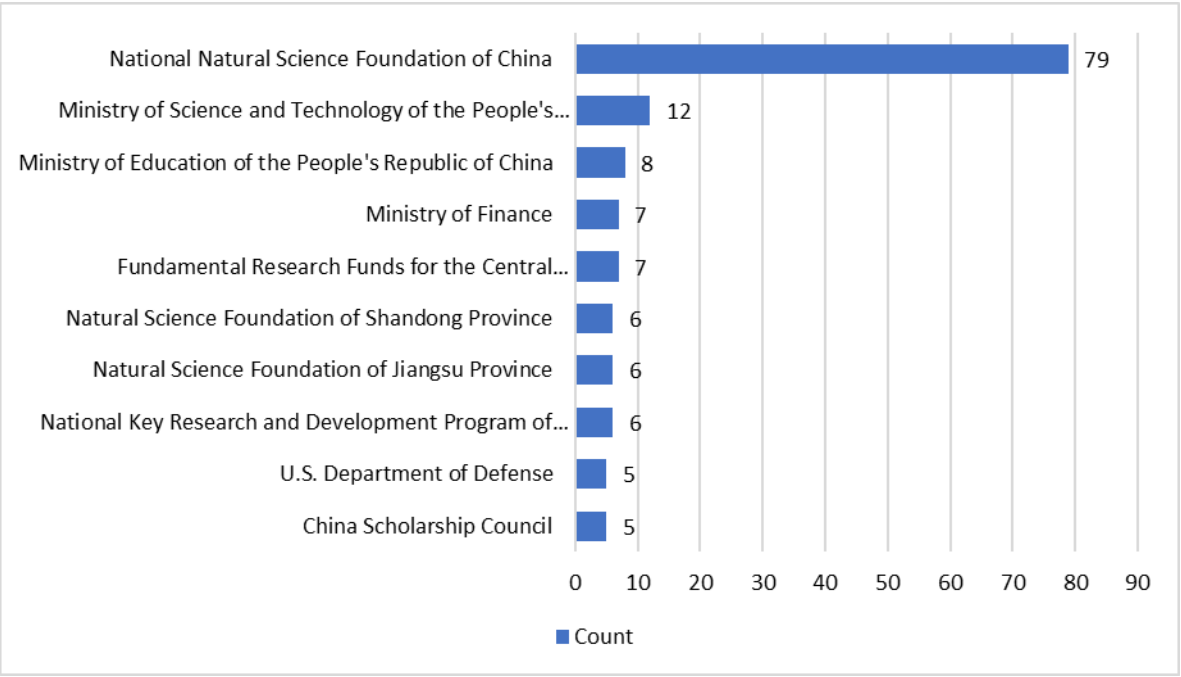

Fig 8: Top 10 Significant Funding Agencies

3.6. Countries of Authors and Collaborations

Table 7 represents the top countries out of the total 37 countries in terms of the frequency of papers published. Countries publishing at least 10 articles are listed in Table 207. China has the highest frequency of publishing articles as compared to other countries. This may be due to good funding support.

Table 7: Countries and Total Production

Rank	Region	Frequency
1	China	413
2	India	114
3	USA	53
4	Canada	30
5	Pakistan	29
6	France	25
7	UK	20
8	Australia	19
9	Singapore	15
10	Saudi Arabia	13
11	Tunisia	13
12	Malaysia	11

Figure 9 highlights the Countries' scientific production. The highly productive regions and less productive regions are marked with dark shades and light shades respectively. Major work in the domain of "image retrieval and feature fusion" is found in Asia especially in Easter and Southern Asia followed by North America.

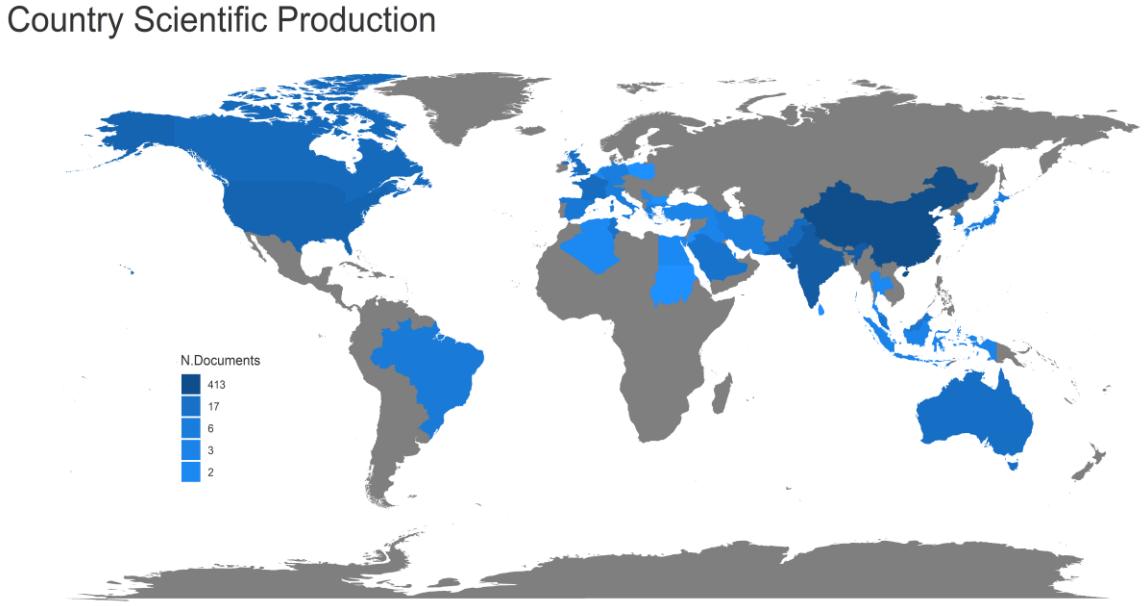

Fig 9: Graphical Representation of Country Scientific Production (Image Source: Biblioshiny)

Table 8 presents the countries and the collaboration among countries. Here, countries with a minimum of 5 publications are considered. The table also lists the inter-country collaboration

i.e. Multiple Country Publications (MCP) and intra-country collaboration i.e. Single Country Publications (SCP). The MCP_ratio indicates the ratio of multiple countries' collaborated articles to the total number of articles. From Table 8 and Figure 10, it is evident that China ranks first in the case of total articles and has the highest number of single country publications based on corresponding authors' countries. Korea is ranked at 8th position in terms of total articles published but has the highest MCP ratio as compared to other countries. Thailand and Algeria have contributed only one article each. These articles are Multiple Country Publications and thus have MCP_ratio as 1.

Table 8: Countries and Collaboration Index

Country	Articles	Freq	SCP	MCP	MCP_Ratio
China	146	0.48667	125	21	0.1438
India	38	0.12667	36	2	0.0526
Canada	17	0.05667	15	2	0.1176
USA	15	0.05	14	1	0.0667
France	8	0.02667	8	0	0
Singapore	8	0.02667	6	2	0.25
United Kingdom	8	0.02667	5	3	0.375
Korea	6	0.02	1	5	0.8333
Pakistan	5	0.01667	2	3	0.6
Tunisia	5	0.01667	3	2	0.4

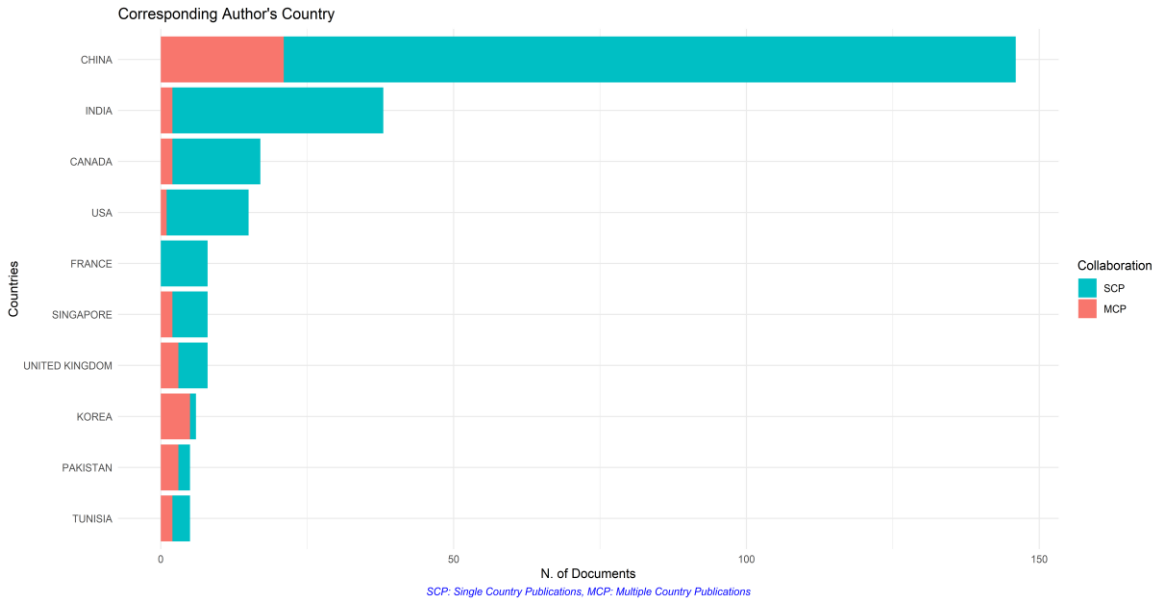

Fig 10: Countries and Collaboration Index (Graphical Representation) Image Source: Biblioshiny

3.7. Keywords Analysis

Keyword analysis helps to search the articles related to the field of interest in the databases. It is useful in finding future research directions based on research trends, over and under-researched keywords, and areas.

There are 2,322 keywords in the field of “image retrieval and feature fusion”. The keywords are identified using the keyword plus search method. The most frequent 50 words are

highlighted in Figure 11 using word cloud and the top 10 most frequent keywords with their occurrences are highlighted in Table 9.

Table 9: Most Frequent Keywords

Sr. No.	Words	Occurrences
1	Image Retrieval	314
2	Content Based Retrieval	149
3	Image Fusion	144
4	Content Based Image Retrieval	81
5	Feature Extraction	74
6	Information Retrieval	71
7	Semantics	71
8	Image Processing	69
9	Search Engines	69
10	Color	65

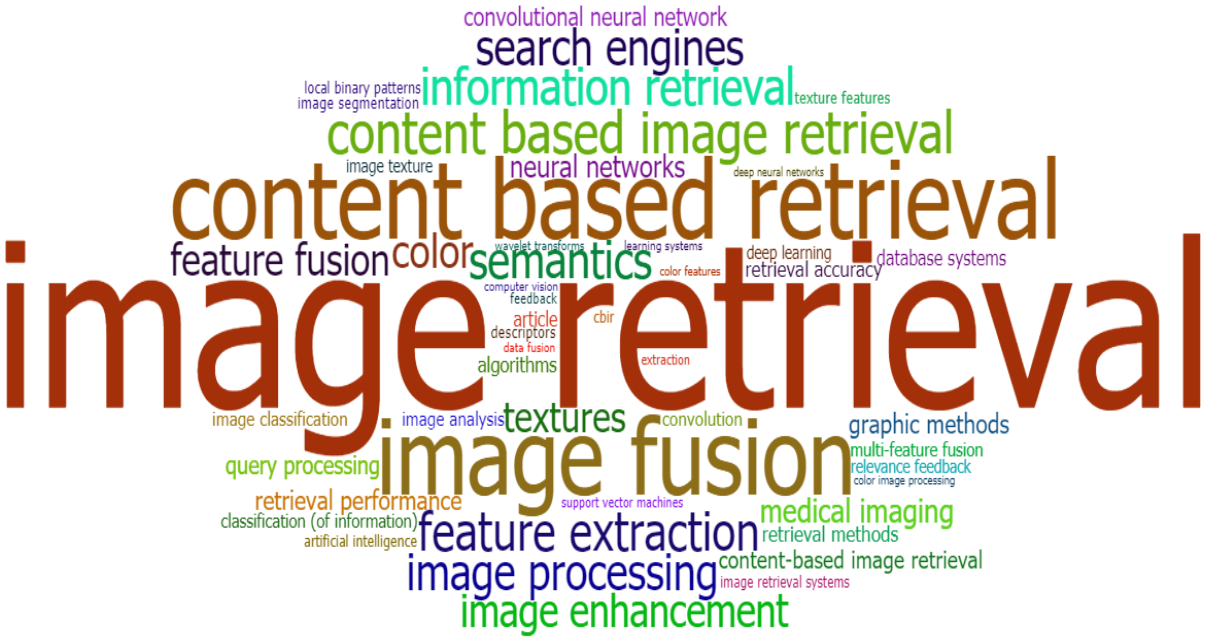

Fig 11: Most Frequent Words Cloud

4. Conclusion

The article presents the bibliometric analysis of the research articles published on image retrieval and feature fusion. The paper focuses on the who, what, where, how much research is carried out on feature fusion-based image retrieval. 13455 research papers have been published on image retrieval in Scopus. 461 research articles are based on feature fusion. The feature fusion-based image retrieval work majorly started from the year 2002. However, since 2016, nearly 50 papers are published every year. Almost 93% of the work is published in the English language. Around 50% of the work is published in journals, with major contributions from the computer science domain. China, followed by India has contributed the highest number of research articles. There are 16 single-authored research articles and the average collaboration index is 2.26. 73% of the authors have contributed only 1 article, which indicates low average

productivity. The top 13 most relevant affiliations are from universities and organizations in China, Canada, Pakistan, and Singapore. The most relevant keywords to search the existing literature other than image retrieval are content-based retrieval, image fusion, and content-based image retrieval.

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