COLLNET Journal of Scientometrics and Information Management
ISSN : 0973 – 7766 (Print) 2168 – 930X (Online)
Vol. 17(1) June 2023, pp. 23–38
DOI : 10.47974/CJSIM-2021-0103

Mapping global research on expert systems

Bisma Bashir
Fayaz Ahmad Loan

Purpose: The purpose of the study is to conduct a scientometric analysis of expert systems literature indexed in the Science Citation Index Expanded (SCIE) of the Web of Science database for a period of ten years (2011-2020).

Design/Methodology: The study collected data from the Science Citation Index Expanded (SCIE) of the Web of Science (WoS) database from 2011-2020. The synonymous, broader and related terms of Expert Systems were selected from the Dewey Decimal Classification Scheme and Sears List of Subject Headings. A string of these terms was employed to retrieve data in the advanced search mode of the database. The harvested data was analyzed using scientometric techniques. Besides, the Microsoft Excel and VOSviewer software were used to represent and map the research productivity on expert systems.

Findings: The results indicated inconsistent fluctuations in the annual number of publications from 396 in 2011 to 463 in 2020 and a decline in the number of citations from 8344 in 2011 to 520 in 2020. Further, it is divulged that China, the USA, and Spain are the three top countries contributing to expert system research published 16.36%, 14.96%, and 8.95% of literature respectively. While analysing institutional performance, the results revealed that most of the institutions are from China (6), followed by Iran (4), Spain (3) and India (2) /Malaysia (2) respectively. Further, by clustering the network map for keywords co-occurrence, it was found that expert systems, fuzzy logic, knowledge-based systems, machine learning, and artificial intelligence are the most common keywords and hence the hot topics of research in the area.

Practical implications: The findings of the study may help researchers, information scientists and technologists to identify the research progress in the field of expert systems. Besides, it will help librarians to know the hot topics of research, prominent publications and prolific authors in expert systems. This will be helpful in the collection development of expert systems and artificial intelligence in libraries and information centres.

Bisma Bashir*
Centre of Central Asian Studies
University of Kashmir, Srinagar
India

bismabashir53@gmail.com

Fayaz Ahmad Loan#
University Librarian
Islamic University of Science and Technology, Kashmir
Jammu & Kashmir
India

and

Centre of Central Asian Studies
University of Kashmir
Srinagar
Jammu & Kashmir
India

fayazlib@yahoo.co.in

* (Corresponding Author)

© Taru Publications

Research limitations: The database studied for the work does not represent the total literary output available on expert systems as data in other databases like Scopus, Compendex, IEEE Xplore, arXiv, etc. haven't been harvested.

Originality/Value: The study is based on current literature on expert systems and will highlight new research trends in the said field.

Keywords: *Expert systems, Knowledge-based systems, Intelligent Systems, Scientometrics, Bibliometrics.*

1. Introduction

Expert system, also known as a "knowledge-based system", is one of the most successful branches of artificial intelligence. It enables a computer programme to apply expertise to help with various issues, including identifying malfunctions and designing new equipment (Buchanan & Smith 1988). According to Rastogi (2016), "expert systems make use of a knowledge base of a specific domain and apply that knowledge to the facts of the particular scenario at hand". In Encyclopaedia Britannica, Zwass (2016) defines an "expert system" as a computer programme that employs artificial intelligence approaches to address issues within a specialised domain that typically needs human competence. It provides top-notch experience, includes subject-specific knowledge, uses heuristics, forward or backward reasoning, uncertainty, and explanatory capabilities (Tripathi, 2011). Expert systems are not only useful to users who lack specialised knowledge, but they may also supplement (Oyedeji, Osifeko, Folorunsho, Abolade, & Ade-Ikuesan, 2019) or even replace human experts (Ahmed et al., 2019). As a result, the strength of an Expert System (ES) should be in its capacity to emulate the human decision-making process (Kim, Oh & Pedrycz, 2017). In order to achieve feats of apparent intelligence, an expert system depends on two things, i.e., a knowledge base and an inference engine. A knowledge base is an organised compilation of facts concerning the domain of the system. An inference engine, on the other hand, interprets and assesses the facts in the knowledge base to give an answer. Typical tasks of expert systems include classification, diagnosis, monitoring, design, scheduling, and planning for specialised jobs.

The first expert system was developed in 1965 by Edward Feigenbaum and Joshua Lederberg of Stanford University in California, U.S.A. (Gwass, 2016). In recent years, expert systems have captured the interest of professionals and researchers in several fields, such as science, engineering, business, and medicine. This interest can be attributed to the expert system's potential to assist diverse organisations involved with solving real-world challenges (Rastogi, 2016). Due to the growing research interest and the significance of this field, it is essential to gauge the sharply increasing literature on expert systems. One of the intriguing lines of investigation can be through the scientometric approach. The scientometric analysis is a basic but effective method for the evaluation of scientific production (Wallin, 2005). It is an important approach to assessing, and analysing the research developed by different actors: countries, universities, research centres, research groups, journals, and, in general, scientists (Martínez, Cobo, Herrera,

and Herrera-Viedma, 2015). Thus, in light of the developing significance and interest in expert systems throughout the world, the scientometric assessment in the said field has been carried out to gain insight into the prominent journals, institutions, and countries.

Review of Literature

The metric studies have been carried out in diverse subject fields by different authors worldwide, like Information Systems (Hassan and Loebbecke, 2017), Mathematics (Behrens and Luksch, 2011), Computer Science (Bakri and Willett, 2011), Biotechnology (Dalpé, 2002; Bajwa and Yaldram, 2013), Library and Information Science (Siddique, Rehman, Khan, & Altaf, 2021) and so on. However, only a few studies are related to expert systems and allied fields. According to a survey of expert system (ES) business application papers published between 1977 and 1993, a growing amount of ES research is being undertaken for a wide variety of business operations (Wonga and Monacob, 1995).Using a literature survey of papers from 1995 to 2004, Liao (2005) analysed the trend of approaches employed in the development of expert systems (ES). Based on an analysis of 166 papers from 78 academic journals gathered from five online databases of ES applications, the study divulges that ES methodologies change constantly and acquire a new understanding in ES methodologies, and eleven categories have been developed until the period of study, namely rule-based systems, intelligent agent systems, knowledge-based systems, fuzzy expert systems, neural networks, system architecture, object-oriented methodology, case-based reasoning, database methodology, ontology, and modelling, as well as their implementations in a variety of research and problem domains. Blanco-Mesa, Merigo, and Gil-Lafuente (2017) used a bibliometric method to review the important contributions in the field of fuzzy decision-making. According to the findings, the United States was the traditional leader in this sector, with the most significant researchers. However, in recent years, this field has received more attention from Asian authors, who are beginning to lead the field. Zhang, Chen, Lu and Zhang (2017) conducted a bibliometric study to detect the hot topics of Knowledge-based systems from 1991 to 2016 and identified expert systems, machine learning, data mining, decision making, optimization, and fuzzy logic as the six main research areas of Knowledge-based systems. Niu, Tang, Xu, Zhou, and Song (2016) evaluated the global research on Artificial intelligence from 1990–2014 and found that the United States ranks first in producing the maximum single-country and collaborative articles. Shrivastava and Mahajan (2016)analysed the research output of India in the field of artificial intelligence and found that a total of 6,529 papers were published in the field of artificial intelligence in India from 1968-2014. The average citation per paper was 3.06 and the average number of authors per paper was three. The most frequent keyword was found to be “Artificial Intelligence”, followed by “Algorithms”. Liu, Kong, Xia, Bai, Wang, Qing, and Lee (2018) presented the anatomy of artificial intelligence spanning over the first 16 years of the 21st Century and found an increase in the number of publications and a growing trend in collaboration over the years. Gao, Jia, Zhao, Chen, Xu, Geng and Song (2019) investigated the tendency and topics of artificial intelligence using a bibliometric method and found

China (4854, 39.46%), the United States (2371, 19.27%) and the United Kingdom (1142, 9.28%) occupy the top three positions respectively. Lei and Liu (2019) conducted a bibliometric study to research the development of artificial intelligence. While analysing the distribution of publications by countries and the distribution of research fields, it was found that the United States ranked first place with the highest number of published articles that accounted for 20.03% of total world production. It was further divulged that the research hotspot of artificial intelligence research mainly focuses on machine learning. Hu, Wang and Deng (2020) sought to explore the trend and status of international collaboration in the field of artificial intelligence. They found that 84.8% of papers in the field of AI are collaborative papers. The network analysis showed that the USA, UK, France, and Spain led global collaboration research at the country level, while Vietnam, Saudi Arabia, and the United Arab Emirates had a high degree of international participation. Dhamija and Bag (2020) examined a total of 1,854 articles retrieved from the Scopus database for the years 2018-2019. The findings show that cluster analysis focuses on dominant themes for current and future artificial intelligence researchers, such as artificial intelligence and optimization, operational performance and machine learning, and the Internet of things and reverse logistics. Loan, Bisma, and Nasreen (2021) conducted a bibliometric analysis of the international journal "Applied Artificial Intelligence (AAI). The journal articles were scrutinized in terms of authorship patterns, degree of collaboration, productive and influential institutions and authors, hot topics, and so on. According to the findings, 94% of the published items were articles. The growth of these articles could be seen in the journal's productivity throughout time. The journal has grown from a mere 23 articles to around 50-70 research papers annually. The journal's contributors came from reputable institutions in 74 different nations. The percentage of articles with a single author has dramatically dropped in favour of frequent cooperation. When examining output by country, the USA, Italy, and India were the highest contributors to the journal. Furthermore, the Austrian Research Institute in Australia scored first among productive institutions in the field of artificial intelligence, while the Massachusetts Institute of Technology in the United States received the most citations (484) and proved to be more influential. Riahi, Saikouk, Gunasekaran, and Badraoui (2021) investigated the present status of research on AI applications in the supply chain using a systematic literature review along with bibliometric analysis. A review of 136 research publications published between 1996 and 2020 in the Scopus database was performed. In the supply chain, reinforcement learning was prioritized above the other two machine-learning methods (supervised and unsupervised). Kirtil and Aşkun (2021) used a bibliometric technique to track the progress of AI in the tourism field. The Scopus database yielded a total of 102 publications. The most prolific authors, collaborations, and institutions were identified, and research hotspots were found using a co-occurrence network and the most common author keywords. Thematic evolution analysis was used to depict the progress of AI. According to the findings, interest in AI has increased since 2017, and average citations imply that publications are frequently cited. Fosso Wamba and Queiroz (2021) did a bibliometric assessment of AI in digital health and found that the United States, China, and the United Kingdom ranked in the top three in

terms of the number of citations received per country. The study also revealed that robotics and prediction models were two of the most common themes, backed by machine learning, deep learning, natural language processing, artificial neural networks, and big data techniques. Bawack, Wamba, Carillo, and Akter (2022) did a bibliometric evaluation of AI in e-commerce. According to the study, most AI research in e-commerce is focused on recommender systems. Further, the main research themes were identified as sentiment analysis, trust, personalization, and optimization. The study also positions Chinese institutions as leaders in this field of study. The study also positions Chinese institutions as leaders in this field of study.A good number of metric studies have been conducted on artificial intelligence. The "expert systems" is one of the prominent fields of research in the field of artificial intelligence. However, no comprehensive study has been conducted to measure and map its growth in the last decade. The current study is an effort to bridge this research gap.

Research Design

a) *Objectives*

The objectives of the study include:

1. To investigate the annual growth of publications and citations.
2. To determine the relative growth rate (RGR) and doubling time (Dt) of articles on expert systems.
3. To highlight the prominent countries, institutions, and organizations contributing to expert systems research.
4. To identify the prolific journals publishing articles on expert systems
5. To identify the high-frequency keywords and hot topics in research.

b) *Methodology*

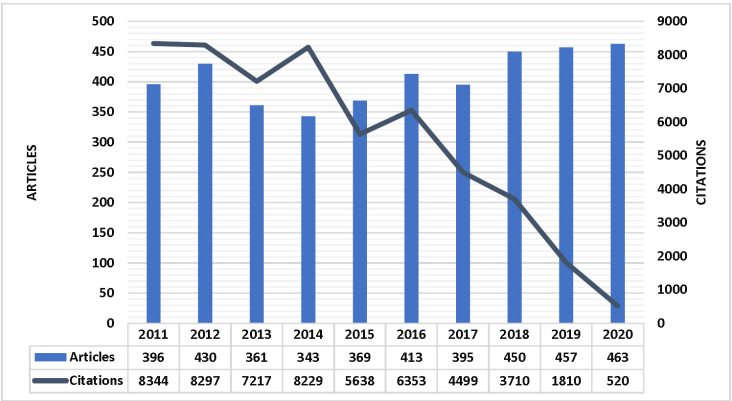
The study collected the data from the Science Citation Index Expanded (SCIE) of the Web of Science (WoS) database and confined publications to research articles in the English language from 2011-2020. The synonymous, broader and related terms of Expert Systems were selected from the Dewey Decimal Classification Scheme and Sears List of Subject Headings. The string of search terms employed was "Expert System* OR Intelligent System* OR Fuzzy Expert System* OR Knowledge based System* OR Knowledge-based System* OR Decision Support System*" The asterisk (*) mark was used to retrieve the plural forms of search terms as well. A total of 4077 records were retrieved, tabulated, mapped, and analysed to reveal findings. The Microsoft-Excel and VOS viewer software was used for data analyses and mapping the research productivity on expert systems respectively. VOSviewer is a software tool for constructing and visualizing bibliometric networks. These networks for instance include journals, researchers, or individual publications (VOSviewer, 2021).

Data Analysis

1. *Evolution of Publications and Citation Score*

The dynamics of literature production presented in Figure 1 shows inconsistent fluctuations in research productivity on expert systems. With 463 publications, the year 2020 was the most productive, followed by the year 2019 with 457 publications. However, the year 2014 experienced a decrease of 343 publications (Figure 1). Overall, the expert system literature shows a positive trend. The findings are similar to an earlier study conducted by Liu, Kong, Xia, Bai, Wang, Qing, and Lee on artificial intelligence in 2018 and found an increase in the number of publications and a growing trend in collaboration over the years.

In terms of citations, there are 54617 total citations for these 4077 publications. Since 2010 the number of citations garnered each year has declined from 8344 in 2011 to 520 in 2020, indicating that these publications are new in the literature and have not got more opportunities for citations (Figure 1).



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Articles	396	430	361	343	369	413	395	450	457	463
Citations	8344	8297	7217	8229	5638	6353	4499	3710	1810	520

Figure 1

Total publications and total citations on Expert systems

2. *RGR and Dt of Articles on Expert Systems*

RGR is a metric used to assess the growth in the number of articles per unit of time and is determined using Mahapatra's formula (as cited in Chitra &Jeyshankar, 2012) as follows:

$$RGR = \frac{W2 - W1}{t2 - t1}$$

Where, W1= Log_e (natural log of the initial count of contributions), W2 = Log_e (natural log of the final count of contributions), t1= the unit of initial time, and t2= the unit of final time.

Table 1

RGR and Dt of Articles

Year	Publication Count	Cumulative	Natural Log	RGR	Average RGR	DT	Average DT
2011	369	396	5.981	0	0.233	0	3.208
2012	430	826	6.716	0.735		0.943	
2013	361	1187	7.079	0.363		1.909	
2014	343	1530	7.333	0.254		2.728	
2015	369	1899	7.549	0.216		3.208	
2016	413	2312	7.746	0.197		3.518	
2017	395	2707	7.903	0.157		4.414	
2018	450	3157	8.057	0.154		4.500	
2019	457	3614	8.192	0.135		5.133	
2020	463	4077	8.313	0.121		5.727	

RGR= Relative Growth Rate, DT= Doubling Time

Doubling time is the time required for articles to become double the existing amount. It is calculated based on a formula given by Mahapatra (as cited in Chitra & Jeyshankar, 2012) as follows:

$$Dt = \frac{\ln 2}{RGR}$$

Table 1 represents the RGR and Dt of articles on expert systems. The data shows that the relative growth rate of world output decreases gradually from 0.735to 0.121 in ten years (2011-2020). While the doubling time (Dt) correspondingly increases from 0.943 to 5.727 in this period. Further, the average growth rate and doubling time of expert system literature are 0.233 and 3.208 respectively.

From the analysis, it is clear that there exists an inverse proportionality between RGR and DT.

3. *Most Productive Countries*

A total of 112 countries have contributed globally to the research of expert systems during 2011-2020. The analysis of the 20 most productive countries in terms of the publication count (PC) reveals that China has occupied the first position contributing 667 (16.36%) articles followed by the USA (14.96%), Spain (8.95%), India (7.70%), and England (6.28%) respectively (Figure 2). The findings are in tune with the earlier study conducted by Blanco-Mesa, Merigo and Gil-Lafuente in 2017. The results of their study indicated that the USA was the traditional leader in the field of expert systems with the most significant contribution. However, during the last few years, this field is receiving more attention from Asian authors.

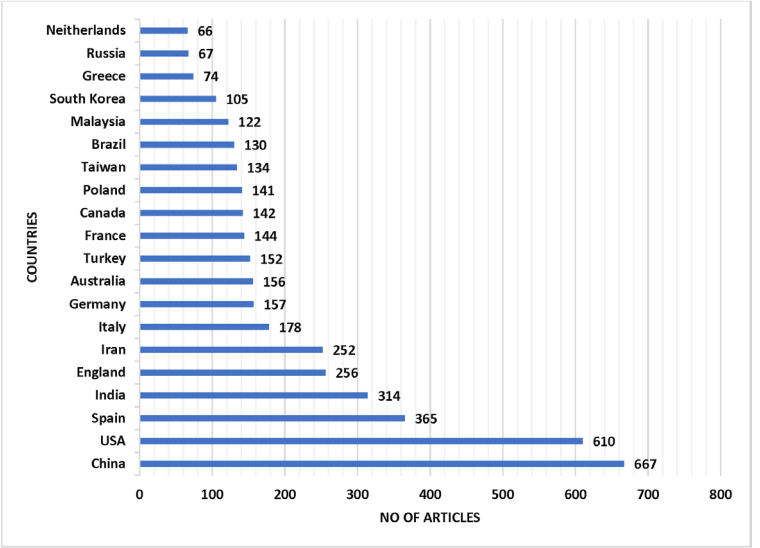


Figure 2

Most productive Countries

4. *Most Productive Institutions*

Table 2 lists the 20 most productive institutions/organizations in the area of expert systems. The results reveal that most of the institutions are from China (6), followed by Iran (4), Spain (3) and India (2) /Malaysia (2) respectively. The institutions from developed countries like Russia, France, Germany, Italy, and Japan haven't marked their presence in the top 20 institutions having greater research publications on expert systems.

Table 2

The 20 most productive institutions based on the number of articles

Organizations/Institutions	Countries	No of Articles
Islamic Azad University	Iran	62
Amirkabir University of Technology	Iran	38
University of Tehran	Iran	37
Chinese Academy of Sciences	China	35
University of Malaya	Malaysia	34
University of Manchester	England	34
University of Seville	Spain	33
Ohio University	USA	30
Indian Institute of Technology	India	28

Contd...

Universidad Complutense de Madrid	Spain	28
National Institute of Technology	India	26
Tsinghua University	China	26
Hong Kong Polytechnic University	China	25
Shanghai Jiao Tong University	China	23
Huazhong University of Science and Technology	China	21
University of Belgrade	Serbia	21
Universiti Teknologi Malaysia	Malaysia	21
Fuzhou University	China	20
TarbiatModares University	Iran	20
Universidad de Granada	Spain	20

5. *Preferred Sources of publication*

Figure 3 provides the list of the top 20 journals that have produced 18 or more publications during the period of study. The *Expert systems with applications*(England) topped the list with 649 publications, followed by *Knowledge-based systems*(Netherlands) with 101 publications, *IEEE Access*(USA) with 75 publications, *Applied soft computing*(England) with 48 publications and *International journal of advanced manufacturing technology*(UK) with 43 publications topped the list and ranked second to fifth respectively. Expert Systems with Applications is a peer-reviewed, international journal that focuses on the

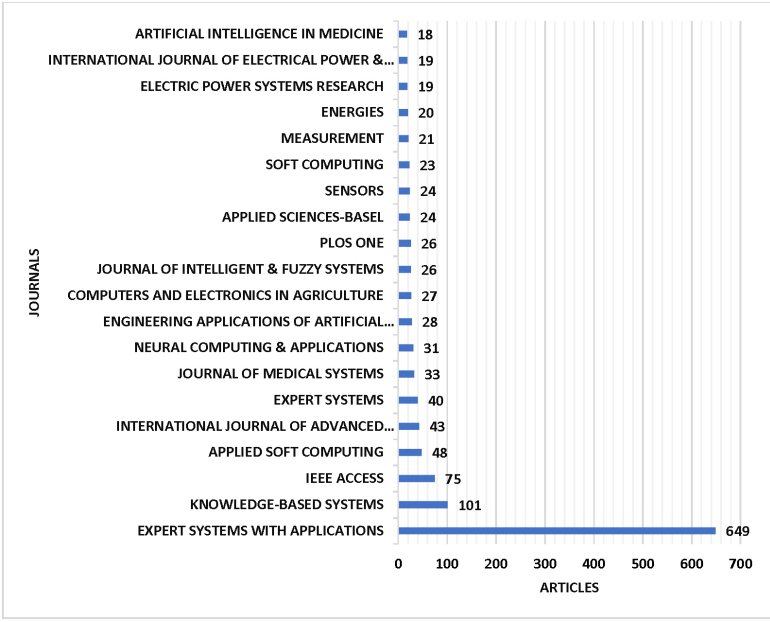


Figure 3

Most preferred sources of publication

exchange of information about expert and intelligent systems used in business, government, and academic settings all over the world. The journal has contributed the most papers on expert systems since it releases two issues in a single month.(Expert Systems with Applications,2021).The study also reveals that among the top twenty sources of publications, eight journals are published from the Netherlands, five from England, three from the USA, two from Switzerland, and one from Germany, and Egypt respectively.

6. *Keyword Analysis*

Keywords are used to draw attention to the core idea of a given publication and to help readers understand the main research contexts. The co-occurrence of keywords, on the other hand, reveals highly active areas of a study. As a result, the keyword

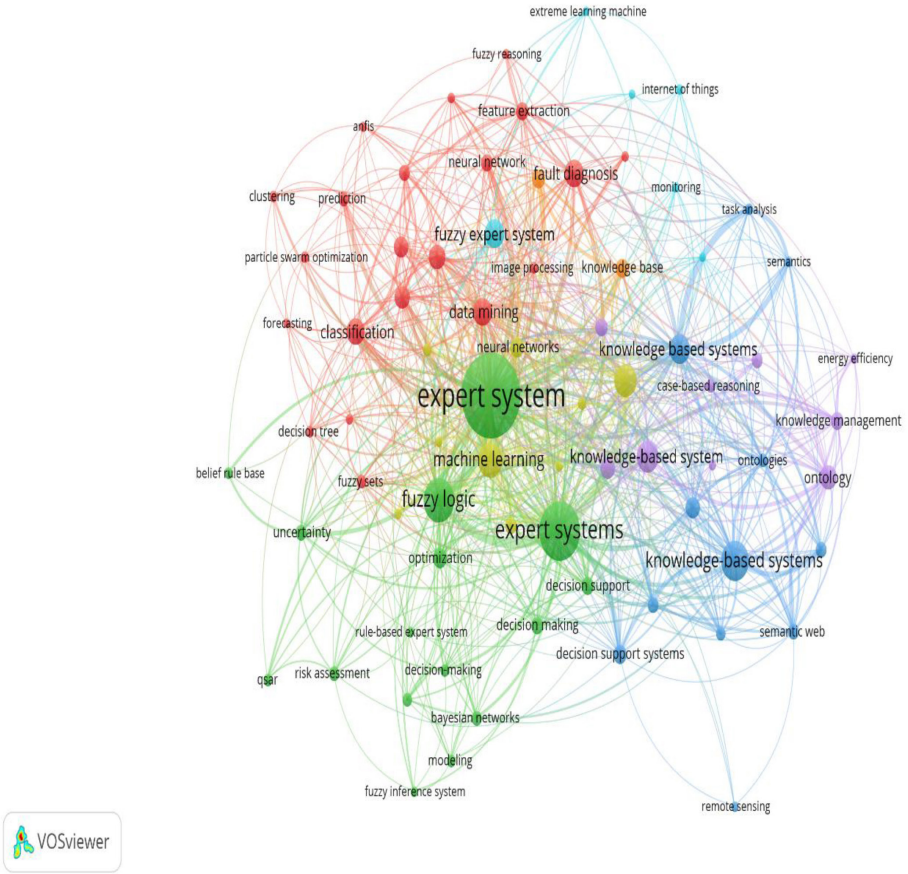


Figure 4

The size of the keyword represents its proportional contribution to the data set, the thickness of the lines represents the strength of collaboration between the two keywords, and the colour of the node represents the cluster to which a particular keyword belongs).

co-occurrence analysis technique has been employed using the VOSviewer software to demonstrate the keywords with a high frequency. The results indicate that the most common keywords as well as the hot themes of research within the field include expert systems, fuzzy logic, knowledge-based systems, machine learning, and artificial intelligence. As illustrated in Figure 4, seven clusters of keywords reflect different fields of knowledge. These clusters are shown in blue, green, saffron, red, purple, cyan, and yellow. These clusters are trespassing, which demonstrates that there are no clearly defined boundaries between or among the clusters of expert systems.

Similar keywords are scattered in singular and plural forms like *Expert System& Expert Systems, Knowledge-based System,* and *Knowledge-based Systems*. Therefore, to see more specifically the leading keywords appearing in the area of expert systems, table 3 represents an actual position. The keywords *Expert system + Expert systems* together occupy the first position figuring 797 times followed by *Knowledge based System + Knowledge based Systems+ Knowledge-based system* and *Knowledge-based Systems* figuring 342 times and *Artificial Neural Networks + Neural Networks* 113 times respectively (Table 3). Zhang, Chen, Lu and Zhang (2017) also conducted a bibliometric study to detect the hot topics of Knowledge-based systems from 1991 to 2016 and identified expert systems, machine learning, data mining, decision making, optimization, and fuzzy logic as the six main research areas of Knowledge-based systems and most of these keywords are still hot areas of research.

Table 3
Most Common Keywords

Rank	Keyword	Occurrences	Rank	Keyword	Occurrences
1	Expert System(s)	797	11	Classification	73
2	Knowledge-based System(s)	342	12	Genetic Algorithm	57
3	Fuzzy Logic	173	13	Decision Support System	53
4	Machine Learning	118	14	Knowledge Representation	51
5	Artificial Neural Networks	113	15	Feature Selection	50
6	Artificial Intelligence	105	16	Optimization	47
7	Fuzzy Expert System	86	17	Decision Support	43
8	Fault Diagnosis	80	18	Decision Making	41
9	Data Mining	78	19	Case-based Reasoning	41
10	Ontology(ies)	77	20	Knowledge Base	39

Discussion

The study revealed inconsistent fluctuations in research productivity on expert systems. Out of the total research output (4077), the year 2020 witnessed the most publications (463), while the year 2014 witnessed the least (343) publications. However, recently from 2017-2020, the volume of research on the expert system, substantially increased, suggesting an increased focus on expert systems research worldwide. This increased research productivity can be attributed to an exponential increase in the number of scholarly publications especially journals; more attention of the scientific community in this field; increased networking and collaboration of authors and institutions in this domain; and increased focus from governments, and specialized agencies on expert systems research. This field has a lot of potential, and it is also expected to grow even more in the future. It has been widely accepted by practitioners to use expert systems in the decision-making process. Institutions, organisations, governments, and other funding agencies need to gear up to provide all kinds of support to the scientists conducting research in this domain.

According to the article distribution by countries, China, USA, and Spain are on top of the list, which indicates that these countries are the most active regions in expert systems research. Blanco-Mesa, Merigo, and Gil-Lafuente (2017) reported that the United States was the traditional leader in the field of fuzzy logic systems, contributing the most significant research. However, in recent years, this topic has received more attention from Asian authors, who are beginning to take the lead in the field. The current study's findings also revealed that China has dethroned the United States from first place in expert system research. According to a recent bibliometric assessment of AI undertaken by Bawack, Wamba, Carillo, and Akter (2022), Chinese institutions are also leaders in artificial intelligence research.

The principal and novel outcome of the current study is that India is also making progress in this area and now holds the fourth position. However, the research has a worldwide reach and will be beneficial to everyone. Despite being among the top 20 most productive nations, none of the institutions from Italy, Germany, Australia, Turkey, France, Canada, Poland, Taiwan, Brazil, South Korea, Greece, and Russia were among the top 20 most productive institutions.

Among the 20 institutes, six were from China, four were from Iran, three were from Spain, two from Malaysia and India, and one from the USA, England, and Serbia respectively. The results will benefit the academic and research institutions worldwide to understand the progress and development of research in expert systems in general and the role of these institutions in particular. The funding agencies can identify and support the institutions conducting research in these domains in a more judicial way.

The most productive journals belonged to the Netherlands. However, of the 20 most preferred journals, Expert Systems with Applications published in England topped the list, with 649 publications. Expert Systems with Applications is a peer-reviewed international journal aimed at disseminating information on expert and intelligent systems

used in businesses, governments, and academic institutions throughout the globe. The goal of the journal is to publish articles that cover the design, development, testing, implementation, and/or management of expert and intelligent systems and also offer helpful advice for the setup and administration of these systems. Articles related to expert and intelligent systems technology are published in the journal. Additionally, it publishes content on how these technologies are used in a variety of fields, including finance, accounting, marketing, auditing, law, medicine, engineering, chemistry, economics, human capital, business, archaeology, energy, defence, etc. Additionally, the journal releases two issues a month, which signifies its commitment to publishing articles on expert systems. The journal doesn't only have quantity but quality as well. Its impact factor is 5.452, CiteScore 11.0, Source Normalized Impact per Paper (SNIP) 3.139, and Scimago Journal Rank (SJR) 1.494 (Expert Systems with Applications, 2021).Other theme-based journals like *Knowledge-Based Systems* and *Expert Systems* contributed fewer articles because the scope of these journals isn't limited to expert systems only but publish articles on all other sub-field of artificial intelligence as well.

By clustering the network map for keyword co-occurrence, it was found that expert system/s, fuzzy logic, knowledge-based system/s, machine learning, and artificial intelligence are the most frequently used terms and thus the hot themes of research within the area. These keywords result in a variety of clusters, each of which criss crosses, which therefore reveal that there are no water-tight, borders that separate the clusters of expert systems. However, it is clear that neither the authors nor the publishers use a controlled mechanism, such as a thesaurus, to assign keywords to the articles, as both singular and plural keywords of the same term (expert system and expert systems) have been assigned to them. Standardized vocabulary control yields better results in the information storage and retrieval process.

Conclusion

According to the study, China, the United States, Spain, India, and England are the top nations for expert systems research. China has displaced the United States as the leader in expert system research. Besides, Iran and India are also gaining momentum in this field. The hotspots of the study are highlighted using keywords. According to the findings, the most popular keywords and thus the most popular study areas include expert systems, fuzzy logic, knowledge-based systems, machine learning, and artificial intelligence. Expert systems have attracted the attention of researchers and practitioners in academia and the IT industry worldwide. The research status in this domain will be intensively investigated by researchers across disciplines, institutions, and countries with time. Scientometrics, as an important area of research evaluation, will aid researchers to examine the development of this area of research at regular intervals. However, this is the quantitative representation of research on expert systems; more qualitative studies are required to yield better results.

References

[1] Ahmed, A., Al-Masri, N., Abu Sultan, Y. S., Akkila, A. N., Almasri, A., Mahmoud, A. Y., ... & Abu-Naser, S. S., Knowledge-based systems survey (2019). Retrieved from: http://dstore.alazhar.edu.ps/xmlui/handle/123456789/465.

[2] Bajwa, R. S., & Yaldram, K., Bibliometric analysis of biotechnology research in Pakistan. *Scientometrics*, 95, 529-540 (2013).

[3] Bakri, A., & Willett, P., Computer science research in Malaysia: a bibliometric analysis. *Aslib Proceedings,* 63(2/3), 321-335 (2011, March). Doi https://doi.org/10.1108/00012531111135727.

[4] Bawack, R. E., Wamba, S. F., Carillo, K. D. A., & Akter, S., Artificial intelligence in E-Commerce: a bibliometric study and literature review. *Electronic markets*, 32(1), 297-338 (2022). Doi: 10.1007/s12525-022-00537-z.

[5] Behrens, H., & Luksch, P., Mathematics 1868–2008: a bibliometric analysis. *Scientometrics*, 86(1), 179-194 (2011). Doi: 10.1007/s11192-010-0249-x.

[6] Blanco-Mesa, F., Merigó, J. M., & Gil-Lafuente, A. M., Fuzzy decision making: A bibliometric-based review. *Journal of Intelligent & Fuzzy Systems*, 32(3), 2033-2050 (2017). Doi:10.3233/JIFS-161640.

[7] Buchanan, B. G., & Smith, R. G., Fundamentals of expert systems. *Annual review of computer science*, 3(1), 23-58 (1988). Doi: 10.1146/annurev.cs.03.060188.000323.

[8] Chitra, V., & Jeyshankar, R., Growth of Literature in Neuroscience: A Scientometric study (1972-2011). *Journal of Advances in Library and Information Science*, 1(4), 201-210 (2012). Retrieved from: https://www.jalis.in/pdf/pdf4/Jeyshankar.pdf.

[9] Dalpé, R., Bibliometric analysis of biotechnology. *Scientometrics*, 55(2), 189-213 (2002). Doi: 10.1023/a:1019663607103.

[10] Dhamija, P., & Bag, S., Role of artificial intelligence in operations environment: a review and bibliometric analysis. *The TQM Journal, I*(4), 869-896 (2020). Doi: 10.1108/TQM-10-2019-0243.

[11] Expert Systems with Applications. Retrieved on August 3, 2022 (2021). from: https://www.sciencedirect.com/journal/expert-systems-with-applications.

[12] Fosso Wamba, S., & Queiroz, M. M., Responsible artificial intelligence as a secret ingredient for digital health: Bibliometric analysis, insights, and research directions. *Information Systems Frontiers*, 1-16 (2021). Doi: 10.1007/s10796-021-10142-8.

[13] Gao, F., Jia, X., Zhao, Z., Chen, C. C., Xu, F., Geng, Z., & Song, X., Bibliometric analysis on tendency and topics of artificial intelligence over last decade. *Microsystem Technologies*, *27*, 1545-1557 (2021). Doi: 10.1007/s00542-019-04426-y.

[14] Hassan, N. R., & Loebbecke, C. Engaging scientometrics in information systems. *Journal of Information Technology*, 32(1), 85-109 (2017). 10.1057/jit.2015.29.

[15] Hu, H., Wang, D., & Deng, S., Global collaboration in artificial intelligence: Bibliometrics and network analysis from 1985 to 2019. *Journal of Data and Information Science*, 5(4), 86-115 (2020). Doi: 10.2478/jdis-2020-0027.

[16] Kim, E. H., Oh, S. K., & Pedrycz, W., Reinforced rule-based fuzzy models: Design and analysis. *Knowledge-Based Systems*, 119, 44-58 (2017). Doi: 10.1016/j.knosys.2016.12.003.

[17] Kirtil, I. G., & Aşkun, V., Artificial intelligence in tourism: a review and bibliometrics research. *Advances in Hospitality and Tourism Research*, 9(1), 205-233 (2021). Doi: 10.30519/ahtr.801690.

[18] Lei, Y., & Liu, Z., The development of artificial intelligence: a bibliometric analysis, 2007-2016. In *Journal of Physics: Conference Series*, Vol. 1168, No. 2, p. 022027 (2019, February). IOP Publishing. Doi: 10.1088/1742-6596/1168/2/022027.

[19] Liao, S. H., Expert system methodologies and applications—a decade review from 1995 to 2004. *Expert systems with applications*, 28(1), 93-103 (2005). Doi: 10.1016/j.eswa.2004.08.003.

[20] Liu, J., Kong, X., Xia, F., Bai, X., Wang, L., Qing, Q., & Lee, I., Artificial intelligence in the 21st century. *IEEE Access*, *6*, 34403-34421 (2018). Doi: 10.1109/ACCESS.2018.2819688.

[21] Loan, F. A., Bashir, B., & Nasreen, N., Applied artificial intelligence: A bibliometric study of an International Journal. *COLLNET Journal of Scientometrics and Information Management*, 15(1), 27-45 (2021). Doi: 10.1080/09737766.2021.1938742.

[22] Martínez, M. A., Cobo, M. J., Herrera, M., & Herrera-Viedma, E., Analyzing the scientific evolution of social work using science mapping. *Research on social work practice*, *25*(2), 257-277 (2015). Doi: 10.1177/104973151452210.

[23] Niu, J., Tang, W., Xu, F., Zhou, X., & Song, Y., Global research on artificial intelligence from 1990–2014: Spatially-explicit bibliometric analysis. *ISPRS International Journal of Geo-Information*, 5(5), 66 (2016). Doi: 10.3390/ijgi5050066.

[24] Oyedeji, A. O., Osifeko, M. O., Folorunsho, O., Abolade, O. R., & Ade-Ikuesan, O. O., Design and implementation of a medical diagnostic expert system. *Journal of Engineering Science* 10(2), 103-109 (2019). Retrieved from: https://www2.kuet.ac.bd/JES/images/files/v102/12_JES_239_28-11-2019.pdf.

[25] Rastogi, P., The Designing and Applications of Expert Computer Systems in the Sciences. *International Journal of Latest Trends in Engineering and Technology, 7(*2), 104-110 (2016). Doi: 10.21172/1.72.517.

[26] Riahi, Y., Saikouk, T., Gunasekaran, A., & Badraoui, I., Artificial intelligence applications in supply chain: A descriptive bibliometric analysis and future research directions. *Expert Systems with Applications,* 173, 114702 (2021). Doi: 10.1016/j.eswa.2021.114702.

[27] Siddique, N., Rehman, S. U., Khan, M. A., & Altaf, A., Library and information science research in Pakistan: A bibliometric analysis, 1957–2018. *Journal of librarianship and information science,* 53(1), 89-102 (2021). Doi:10.1177/0961000620921930.

[28] Shrivastava, R., & Mahajan, P., Artificial intelligence research in India: A scientometric analysis. *Science & Technology Libraries,* 35(2), 136-151 (2016). Doi: 10.1080/0194262X.2016.1181023.

[29] Tripathi, K. P., A review on knowledge-based expert system: concept and architecture. *IJCA Special Issue on Artificial Intelligence Techniques-Novel Approaches & Practical Applications*, 4, 19-23 (2011). Retrieved from: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=19f89f1b19b558389e9c70b75403063376cb8e3d.

[30] VOSViewer, VOSviewer: Visualizing Scientific Landscapes. Retrieved September 03 (2021), from: https://www.vosviewer.com/.

[31] Wallin, J. A., Bibliometric methods: pitfalls and possibilities. *Basic &Clinical Pharmacology &Toxicology,* 97(5), 261-275 (2005). Doi: 10.1111/j.1742-7843.2005.pto_139.x.

[32] Wonga, B.K. & Monacob, J.A., Expert system applications in business: A review and analysis of the literature (1977–1993). *Information & Management,* 29(3), 141-152 (1995). Doi: 10.1016/0378-7206(95)00023-P.

[33] Zhang, Y., Chen, H., Lu, J., & Zhang, G., Detecting and predicting the topic change of Knowledge-based Systems: A topic-based bibliometric analysis from 1991 to 2016. *Knowledge-Based Systems,* 133, 255-268 (2017). Doi: 10.1016/j.knosys.2017.07.011.

[34] Zwass, V., Expert system. Encyclopedia Britannica. Retrieved September 3, 2021 (2016) from: https://www.britannica.com/technology/expert-system.