Global Research Trends in the Application of Advanced AI Tools: A Bibliometric Perspective on Fuzzy Logic-based Studies

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Abstract

This study aims to determine the trend of published studies on the application of advanced artificial intelligence tools in the field of Fuzzy Logic. In this study, where documents published in the SCOPUS database were analyzed, the bibliometrix technique, one of the bibliometric analysis methods, was preferred. In the study where 232 documents were examined, it was determined that the published documents were between the years 1990 and 2025 and that the documents were published in 201 sources. It was determined that most of the published documents were published in the article document type. When the most cited studies at the global and local level were examined, it was seen that the most cited publication at the global level was "MELLIT A, 2008, PROG ENERGY COMBUST SCI". It was determined that the most cited studies at the local level were "BOSE BK, 2017, PROC IEEE" and "MELLIT A, 2008, PROG ENERGY COMBUST SCI". It was determined that the most trending topic in the published documents was "neural networks" and then "expert systems". It is believed that the results obtained from the research will shed light and guide researchers who will work in this field.

Keywords

Fuzzy Logic, AI, AI Tools, Bibliometric Analysis, Bibliometrix

1. Introduction

Nowadays, smart technologies and data-driven decision-making processes have become a necessity. For this reason, the integration of advanced artificial intelligence (AI) tools into many sectors is increasing. With these tools, fuzzy logic has come to the fore in many areas, from the healthcare sector to industrial automation systems, to manage uncertainty and make many complex decisions. To give an example from the studies, fuzzy logic and Analytical Hierarchy Process (AHP) were applied in early-stage Alzheimer's diagnosis and allowed the evaluation of uncertain human behaviors [1]. In addition, in another study, fuzzy logic contributed to strategic planning in collaborative cobot applications, both technical and social risk assessment [2]. Bibliometric studies have determined that fuzzy logic is important by emphasizing its strategic role together with technological transformations in studies related to Industry 4.0 [3]. In addition, fuzzy logic artificial intelligence tools and many innovative applications can be used in many different fields, such as power electronics and motion control. Comparative studies for cloud computing reveal the superior performance of fuzzy logic over artificial neural networks (ANN) for resource planning [4]. In addition, in project management, artificial intelligence applications ranging from neural networks to optimization algorithms improve resource optimization of real-time decision-making mechanisms [5]. This study was carried out with the aim of "Global Research Trends in the Application of Advanced Artificial Intelligence Tools: A Bibliometric View of Fuzzy Logic-Based Studies".

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1.1. Related Research

Nowadays, the use of generative artificial intelligence in higher education is increasing day by day. The qualitative development made by [6] investigated how ChatGPT can be used in pedagogical applications. ChatGPT provides benefits in many different areas such as personalized learning, automatic evaluation, content production, translation, and research support. All uses require human supervision for ethical reasons and the risk of misuse. In addition, it is an important tool for educators. Another study [7] 8 students and 3 teachers who participated in the research conducted with a phenomenological pattern in the language teaching and learning process of ChatGPT. Research findings show that ChatGPT may provide benefits in language education, but it also brings with it some difficulties.

In their study, [8] based on the thematic analysis of 50 studies conducted between 2016 and 2022. According to artificial intelligence (AI) literacy education in secondary education, Project-based learning is the most common pedagogical approach; hardware, software, and unplugged tools were used. Students' cognitive, affective, and ethical developments were evaluated. In addition, teaching methods, contents, and measurement tools were analyzed, and suggestions were made to educators. [9] offers an innovative approach in which Bloom's Taxonomy is reversed to integrate artificial intelligence-supported learning into programming education. With artificial intelligence tools such as WebSim.ai, the focus is on students' ability to understand and analyze AI-generated solutions. Thus, students start with production and progress to deep understanding using Reverse Bloom's Taxonomy. [10] This study offers an innovative curriculum content integrated into an advanced computer engineering graduation project with the role of artificial intelligence tools in software development. Students gain skills in dealing with errors in development with artificial intelligence.

[11] investigated the relationship between the widespread use of Artificial Intelligence (AI) tools in terms of their effects on critical thinking and the mediating role of cognitive load transfer. As a result of the survey and interviews conducted with 666 participants, it was seen that constant use of AI tools negatively affects critical thinking skills. [12] investigated the role of ChatGPT in solving physics problems and improving educational practices with the integration of artificial intelligence (AI) tools into physics education. A systematic literature review analyzed with PRISMA found that AI tools support lesson planning, offer innovative teaching methods, and improve problem-solving skills.

In his study, [13] examined the GPT-4 Discovery Program carried out at the University of New Mexico Library Faculty and discussed the competency conditions required for adaptation to artificial intelligence in academic librarianship. The program increased participants' AI literacy and self-confidence through hands-on learning. Awareness in lifelong learning, ethics, and collaboration processes is emphasized, and strategies are presented.

[14] focuses on artificial intelligence applications in modern production and discusses how artificial intelligence improves quality, efficiency, and decision-making processes.

[15] aims to monitor the stress levels of workers with a chat bot that performs emotional analysis, video recordings that recognize emotions through facial expressions and voice, and personality tests, which include Human Digital Twin (HDT) and artificial intelligence technologies in order to increase the safety and well-being of workers in industrial environments such as oil and gas. [16]'s study examines the effects of advanced artificial intelligence tools such as ChatGPT, Gemini Advanced and Co-pilot in the field of health. AI; It contributes to personalized treatment, early diagnosis, optimization of clinical workflows, and medical research. In his study, [17] examined advanced Business Intelligence (BI) tools and data integration solutions to reduce increasing operational costs in the healthcare industry. BI tools have been shown to provide cost savings by identifying inefficiencies and improving processes through data-driven analysis. [18] examined the role of deep learning algorithms in combating human trafficking. Artificial intelligence-supported surveillance systems detect suspicious patterns, allowing victims to be rescued and criminal networks to be weakened. [19] examines Artificial intelligence (AI), cyber security, and security compliance processes; It states that it provides the ability to detect threats in real time, analyze data, and automate compliance tasks. [20] examined the role of artificial intelligence software in personalized marketing automation in SMEs and its impact on customer experience and sales, revealing that it increases customer interaction and loyalty thanks to machine learning, natural

language processing, and predictive analysis. In the study of [21], data management, open source softwar,e and hardware requirements were examined by examining artificial intelligence (AI) tools for academic research, emphasizing the role of RAG systems in document processing and reference provision. [22] examined the aspect of artificial intelligence (AI) in increasing resilience in different areas and shows that it strengthens resilience by providing rapid analysis, prediction, and support in areas such as disaster management, climate resilience, healthcare, cyber security, business continuity, urban sustainability, and psychological resilience.

To achieve the research purpose, the following questions were answered:

1. What is the distribution of publications in terms of main information, such as year, document type, etc.?
2. Which documents are cited most globally and locally?
3. What is the most trending topic?
4. What is the distribution of publications by year?
5. What are the most relevant sources?

2. Method

In this study, which was conducted to determine the trend towards the application of advanced artificial intelligence tools in the field of Fuzzy Logic, the SCOPUS database was used. SCOPUS was preferred because it is “a database that provides a comprehensive overview of global interdisciplinary scientific information covering the fields of science, technology, medicine, social sciences, arts and humanities”[1]. Additionally, the Scopus database was chosen because it provides easy access to researchers. For the literature search, the “article title, abstract, keywords” search option in the SCOPUS database was selected and the keywords TITLE-ABS-KEY (“Fuzzy Logic*" AND “Artificial Intelligence*" OR "Advanced AI Tools*") were used. All filters included in the data scan are given in Table 1. The literature search conducted by the researchers was completed on June 20, 2025. In this context, the analyzed data were limited to the studies indexed in SCOPUS until June 20, 2025. The data collected for the research were analyzed with bibliometrix[2], an open source tool that includes bibliometric analysis methods developed by [23]. In addition, the Biblioshiny[3] web application was used in the analysis of the data. This study provides a trend overview of trends in Fuzzy Logic and Artificial Intelligence, but it has some limitations. The analysis is limited to Scopus, and citations may influence the results. It is also limited to the specified keywords.

3. Findings

The study focused on general information about 232 documents, the most cited documents globally and locally, and trending topics.

3.1. Basic Information of Published Studies on the Application of Advanced Artificial Intelligence Tools in the Field of Fuzzy Logic

The main information for the 232 documents analyzed in the study is given in Table 1.

As seen in Table 1, the documents published on the application of advanced artificial intelligence tools in the field of Fuzzy Logic were carried out between 1990 and 2025. In the mentioned years, a total of 232 studies were published in 201 sources such as journals, books, and similar. 80 of the publications were published in the article document type, 14 were books, 35 were book chapters, 61 were conference papers, 7 were conference reviews, and 35 were reviews. From the findings, it was determined that the authors preferred to write their publications in the "article" type.

[1]Scopus https://www.scopus.com/home.uri
[2]Bibliometrix https://www.bibliometrix.org/home/index.php/layout/bibliometrix
[3]Biblioshiny https://www.bibliometrix.org/home/index.php/layout/biblioshiny

Table 1
Main Information About the Dataset

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1990:2025
Sources (Journals, Books, etc)	201
Documents	232
Annual Growth Rate %	9,37
Document Average Age	6,7
Average citations per doc	22,35
References	12227
DOCUMENT CONTENTS	
Keywords Plus (ID)	1913
Author's Keywords (DE)	778
AUTHORS	
Authors	713
Authors of single-authored docs	27
AUTHORS COLLABORATION	
Single-authored docs	30
Co-Authors per Doc	3,26
International co-authorships %	18,97
DOCUMENT TYPES	
article	80
book	14
book chapter	35
conference paper	61
conference review	7
review	35

3.2. Most Cited Documents Globally and Locally

The study also aimed to determine the citation status of documents published in the SCOPUS database. In this context, documents were examined according to their citation status both globally and locally. Table 2 provides the findings for the most cited documents globally.

Table 2
Most Global Cited Documents

Paper	DOI	Total Citations	TC per Year	Normalized TC
MELLIT A, 2008, PROG ENERGY COMBUST SCI	10.1016/j.pecs.2008.01.001	776	43,11	1,92
MELLIT A, 2009, RENEWABLE SUSTAINABLE ENERGY REV	10.1016/j.rser.2008.01.006	364	21,41	3,39
BOSE BK, 1994, PROC IEEE	10.1109/5.301690	301	9,41	2,90
BOSE BK, 2017, PROC IEEE	10.1109/JPROC.2017.2756596	223	24,78	1,00
PIMENOV DY, 2023, J INTELL MANUF	10.1007/s10845-022-01923-2	212	70,67	9,26
CHENG C-H, 2010, INF SCI	10.1016/j.ins.2010.01.014	188	11,75	5,35
HANSON III CW, 2001, CRIT CARE MED	10.1097/00003246-200102000-00038	166	6,64	1,99
KAUR S, 2020, IEEE ACCESS	10.1109/ACCESS.2020.3042273	155	25,83	6,76
CARRILLO-PEREZ F, 2022, J ESTHETIC RESTORATIVE DENT	10.1111/jerd.12844	126	31,50	10,40
MOHAGHEGH SD, 2005, JPT J PET TECHNOL	10.2118/89033-JPT	123	5,86	2,00

As seen in Table 2, the top 10 most cited studies on the application of advanced artificial intelligence tools in the field of Fuzzy Logic are, respectively; "MELLIT A, 2008, PROG ENERGY COMBUST SCI", "MELLIT A, 2009, RENEWABLE SUSTAINABLE ENERGY REV", "BOSE BK, 1994, PROC IEEE", "BOSE BK, 2017, PROC IEEE", "PIMENOV DY, 2023, J INTELL MANUF", "CHENG C-H, 2010, INF SCI", "HANSON III CW, 2001, CRIT CARE MED", "KAUR S, 2020, IEEE ACCESS", "CARRILLO-PEREZ F, 2022, J ESTHETIC RESTORATIVE DENT" and "MOHAGHEGH SD, 2005, JPT J PET TECHNOL". It is seen that these studies, which are cited globally and are extremely valuable in the field, started to be published in 2008 and continued until 2023. It was determined that the most cited researcher globally is "MELLIT A" with 2 different documents. It is recommended that researchers who will conduct future studies in this field read the documents published by these authors. In addition, it can be said that the first 10 most cited

documents globally will guide researchers and shed light on their work. The analysis of the most cited documents locally is given in Table 3.

Table 3
Most Local Cited Documents

Document	DOI	Year	Local Citations	Global Citations	LC/GC Ratio (%)	Normalized Local Citations	Normalized Global Citations
BOSE BK, 2017, PROC IEEE	10.1109/JPROC.2017.2756596	2017	5	223	2,24	1,00	1,00
MELLIT A, 2008, PROG ENERGY COMBUST SCI	10.1016/j.pecs.2008.01.001	2008	5	776	0,64	2,00	1,92
GARIA P, 2023, INT CONF POWER ENERGY, ENVIRON INTELL CONTROL, PEEIC	10.1109/PEEIC59336.2023.10451368	2023	2	43	4,65	18,00	1,88
MELLIT A, 2009, RENEWABLE SUSTAINABLE ENERGY REV	10.1016/j.rser.2008.01.006	2009	2	364	0,55	4,00	3,39
BOSE BK, 1994, PROC IEEE	10.1109/5.301690	1994	2	301	0,66	3,00	2,90
CHOPRA P, 2023, LECTURE NOTES DATA ENG COMMUN TECH	10.1007/978-981-99-1767-9_41	2023	1	9	11,11	9,00	0,39
KAUR S, 2020, IEEE ACCESS	10.1109/ACCESS.2020.3042273	2020	1	155	0,65	17,00	6,76
DANDE P, 2018, TUBERCULOSIS	10.1016/j.tube.2017.09.006	2018	1	84	1,19	7,00	2,30
BAHIRAEI M, 2019, POWDER TECHNOL	10.1016/j.powtec.2019.05.034	2019	1	109	0,92	5,00	3,17
MOHAGHEGH SD, 2011, ARTIFICIAL INTELLIGENCE: APPROACHES, TOOLS, AND APPLICATIONS		2011	1	4	25,00	4,00	2,67

When the most cited documents at the local level were examined, it was determined that the studies were distributed between the years 2008 and 2023, and "BOSE BK, 2017, PROC IEEE" and "MELLIT A, 2008, PROG ENERGY COMBUST SCI" shared the first place with 5 citations.

3.3. Distribution of Trending Topics

The findings obtained from the analysis conducted to determine trending topics in the documents published on the application of advanced artificial intelligence tools in the field of Fuzzy Logic are given in Table 4.

Table 4
Trend Topics

Term	Frequency	Year (Q1)	Year (Median)	Year (Q3)
decision support systems	6	1994	1997	2015
fuzzy sets	13	2000	2002	2009
knowledge based systems	7	1998	2002	2011
machine tools	5	2005	2005	2010
neural networks	28	2006	2010	2016
fuzzy control	5	2008	2011	2011
computer vision	6	2006	2012	2016
expert systems	20	2000	2013	2021
bayesian networks	5	2011	2014	2021
problem solving	5	2011	2014	2018

As seen in Table 4, the most frequently used word in published documents on advanced artificial intelligence tools in the field of Fuzzy Logic was determined as "neural networks" ($f = 28$). Another word most frequently used by the authors in the studies was determined as "expert systems" ($f = 20$). Other trending topics in the studies were; "fuzzy sets" ($f = 13$), "knowledge based systems" ($f = 7$), "decision support systems" ($f = 6$), "computer vision" ($f = 6$) and "machine tools", "fuzzy control", "bayesian networks" and "problem solving" with 5 frequencies, respectively.

3.4. Distribution of Publications by Year

The distribution of published documents on the use of advanced artificial intelligence tools in the field of Fuzzy Logic by year is given in Table 5.

As seen in Table 5, the first studies on the use of advanced artificial intelligence tools in the field of Fuzzy Logic began in 1990 ($n = 1$). While no publications were found in 1991, only one publication was found in the SCOPUS database in 1992 and 1993. An examination of the findings revealed that the 2020s were the most productive years, quantitatively. While 17 documents were published in the

Table 5
Annual Production

Year	Articles
1990	1
1991	0
1992	1
1993	1
1994	3
1995	0
1996	0
1997	1
1998	1
1999	2
2000	3
2001	2
2002	2
2003	1
2004	0
2005	2
2006	2
2007	2
2008	2
2009	4
2010	6
2011	4
2012	3
2013	9
2014	5
2015	4
2016	3
2017	1
2018	7
2019	5
2020	17
2021	23
2022	27
2023	27
2024	38
2025	23

SCOPUS database in 2020, 23 were published in 2021, 27 in 2022 and 2023, 38 in 2024, and 23 in 2025. This number is expected to increase towards the end of 2025. The results indicate that interest in the use of advanced artificial intelligence tools in the field of Fuzzy Logic has gained significance since 2020.

3.5. Most Relevant Sources

The distribution of the most productive sources in this field, which include documentation on the use of advanced artificial intelligence tools in the field of Fuzzy Logic, is given in Table 6.

As seen in Table 6, the source that published the documents on the use of advanced artificial intelligence tools in the field of Fuzzy Logic the most was determined as "LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS)" ($n = 6$). The other most productive sources, quantitatively, are "LECTURE NOTES IN NETWORKS AND SYSTEMS" ($n = 5$), "ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING" ($n = 3$), "HELIYON" ($n = 3$), "LECTURE NOTES ON DATA ENGINEERING AND COMMUNICATIONS TECHNOLOGIES" ($n = 3$), "APPLIED SCIENCES (SWITZERLAND)"

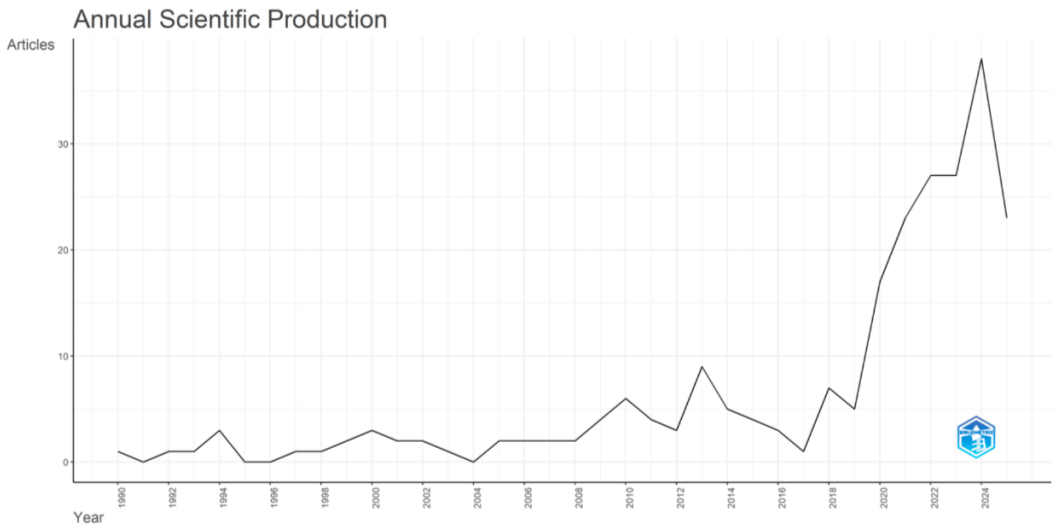

Figure 1: Annual Scientific Production

Table 6
Most Relevant Sources

Sources	Articles
LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS)	6
LECTURE NOTES IN NETWORKS AND SYSTEMS	5
ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING	3
HELIYON	3
LECTURE NOTES ON DATA ENGINEERING AND COMMUNICATIONS TECHNOLOGIES	3
APPLIED SCIENCES (SWITZERLAND)	2
ARTIFICIAL INTELLIGENCE: APPROACHES, TOOLS, AND APPLICATIONS	2
DYNA (COLOMBIA)	2
EAI/SPRINGER INNOVATIONS IN COMMUNICATION AND COMPUTING	2
ENGINEERING APPLICATIONS OF ARTIFICIAL INTELLIGENCE	2

($n = 2$), "ARTIFICIAL INTELLIGENCE: APPROACHES, TOOLS, AND APPLICATIONS" ($n = 2$), "DYNA (COLOMBIA) ($n = 2$)", "EAI/SPRINGER INNOVATIONS IN COMMUNICATION AND COMPUTING" ($n = 2$) and "ENGINEERING APPLICATIONS OF ARTIFICIAL INTELLIGENCE" ($n = 2$). The distribution of the most productive sources by year is visualized in Figure 2.

4. Discussions and conclusions

This study aims to determine the trend of published studies on the application of advanced artificial intelligence tools in the field of Fuzzy Logic. In this study, where documents published in the SCOPUS database were analyzed, the bibliometrix technique, one of the bibliometric analysis methods, was preferred. In the study where 232 documents were examined, it was determined that the published documents were between the years 1990 and 2025 and that the documents were published in 201 sources. It was determined that most of the published documents were published in the article document type. When the most cited studies at the global and local level were examined, it was seen that the most cited publication at the global level was "MELLIT A, 2008, PROG ENERGY COMBUST SCI". It was determined that the most cited studies at the local level were "BOSE BK, 2017, PROC IEEE" and "MELLIT A, 2008, PROG ENERGY COMBUST SCI". It was determined that the most trending topic in the published documents was "neural networks" and then "expert systems". These findings demonstrate the importance of AI in energy systems and sustainability studies. These findings are consistent with studies

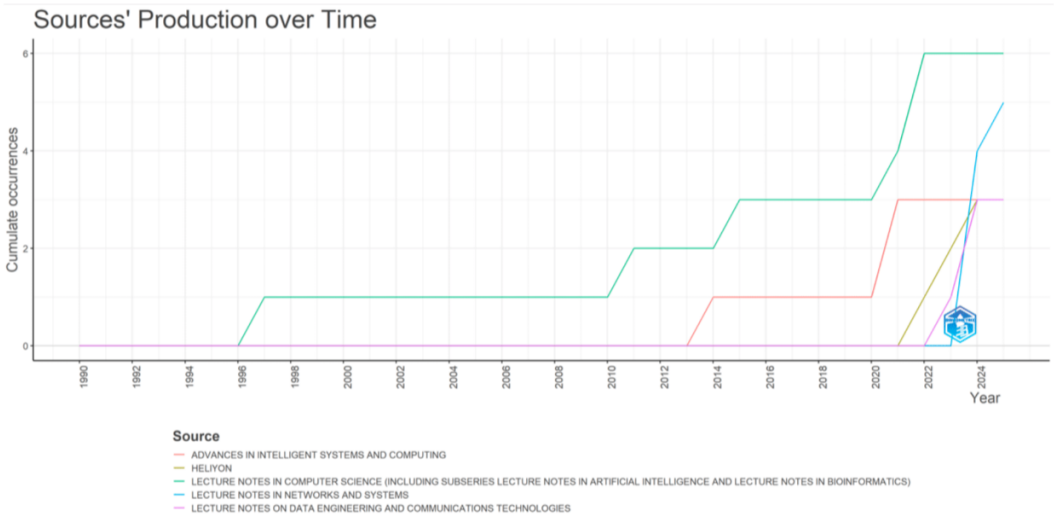

Figure 2: Sources' Production over Time

that demonstrate the capacity of AI to address uncertainty in complex environments in studies such as Industry 4.0 [3] and collaborative robotics [2]. The frequent use of terms such as "neural networks" and "expert systems" together suggests that FL is often used in hybrid models and is compatible with areas such as cloud computing [4] and project management [5]. Consequently, Fuzzy Logic is important for supporting data-driven decision making. This suggests that future research should focus on hybrid integration, scalability, and ethical studies.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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