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*Research article*

## **Classification and detection of Covid-19 based on X-Ray and CT images using deep learning and machine learning techniques: A bibliometric analysis**

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**Abstract:** During the COVID-19 pandemic, it was crucial for the healthcare sector to detect and classify the virus using X-ray and CT scans. This has underlined the need for advanced Deep Learning and Machine Learning approaches to effectively spot and manage the virus's spread. Indeed, researchers worldwide have dynamically participated in the field by publishing an important number of papers across various databases. In this context, we present a bibliometric analysis focused on the detection and classification of COVID-19 using Deep Learning and Machine Learning techniques, based on X-Ray and CT images. We analyzed published documents of the six prominent databases (IEEE Xplore, ACM, MDPI, PubMed, Springer, and ScienceDirect) during the period between 2019 and November 2023. Our results showed that rising forces in economy and technology, especially India, China, Turkey, and Pakistan, began to compete with the great powers in the field of scientific research, which could be seen from their number of publications. Moreover, researchers contributed to Deep Learning techniques more than the use of Machine Learning techniques or the use of both together and preferred to submit their works to Springer Database. An important result was that more than 57% documents were published as Journal Articles, which was an important portion compared to other publication types (conference papers and book chapters). Moreover, the PubMed journal “Multimedia Tools and Applications” tops the list of journals with a total of 29 published articles.

**Keywords:** Covid-19; X-Ray images; computed tomography scan; classification; detection; machine

learning; deep learning

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## 1. Introduction

In late 2019, the world witnessed one of the most severe health disasters that affected all countries [1–6]. Spotted in Wuhan City, Hubei Province, China, Covid-19 is a respiratory disease that is caused by the new coronavirus SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2) [7–10]. Coronavirus is a pathogenic disease that starts by attacking the respiratory tract and then directs itself into the cells using an enzyme called furin and impairs the immune system [10]. The primary signs and symptoms of COVID-19 include fever (38 °C or higher), dry cough, dyspnea, sore throat, tiredness, pains, and, in certain cases, diarrhea. Loss of taste and smell is reported as Covid-19 symptoms. Respiratory problems are observed in those developing more severe forms, and these can result in hospitalization in critical care as well as death [7,11–13]. The World Health Organization declared, on February 11, 2020, this new disease to be a pandemic after it took a few weeks to spread rapidly throughout the world [7]. While writing this review, the accumulated positive cases is 698,035,072, including 6,940,130 deaths, and 669,603,810 recovered [14] (Last updated: November 20, 2023, 17:56 GMT).

Faced with this complicated situation, many precautions have been taken to minimize the spread of Covid-19: Washing hands with soap frequently, using hydroalcoholic solution, keeping social distance (2 meters), covering mouth while sneezing, and wearing a mask [7,15,16]. The precautions taken did not stop there. Rather, movement between cities and countries was prevented, and a lockdown was imposed [17,18]. Due the demand to effective solutions of this disease and after deep research in laboratories, researchers developed Covid-19 vaccines. Indeed, different types of vaccines are available: BNT162 (Pfizer BioNTech, USA), ChAdOx1 (AstraZeneca, UK), mRNA1273 (Moderna, USA), Ad26.COVS-2 (Johnson & Johnson, USA), BIBP-CorV (Sinopharm, China), CoronaVac (Sinovac, China), and Sputnik V (Gamaleya, Russia) [19–22].

Considered a gold standard to detect Covid-19, Reverse Transcription-Polymerase Chain Reaction (RT-PCR) can detect the virus's genetic material, offering high accuracy. However, the need for specialized equipment and well-trained personnel and the time to confirm the patients as well as its expensiveness are the considerable obstacles of its use for testing in this pandemic [10,23]. To overcome this issue, medical images analysis is used massively in this field and allows doctors and specialists to make accurate diagnoses and eliminate the need for laborious manual review processes [24]. Indeed, X-Ray and CT (Computed Tomography) images are the most used in processing of medical images. The utilization of these images required a very good expertise to detect Covid-19 which is taking a lot of time [8]. So, the necessity of new techniques allowing the detection of the virus effectively with minimal time is crucial. Hence, the combination of Deep Learning and Machine Learning methods with X-Ray and CT images is one of the solutions that helps to beat this problem [25]. In fact, Machine Learning and Deep Learning have recently played a major role for automated medical diagnostics by providing new solutions overcoming the shortcomings of the classical methods. Therefore, developing automated analysis system based on X-Ray and CT images using Machine Learning and Deep Learning techniques, that allow to detect the anomalies in the images, helped physicians and healthcare professionals to make accurate decision and save a lot of time [26].

We aim to focus on classification and detection of Covid-19 using X-Ray and CT images through Deep Learning and Machine Learning techniques. Based on a qualitative and quantitative analysis of published documents on this field and the use of new technologies to improve the diagnosis of Covid-19, we highlight the role of Deep Learning and Machine Learning methods on recognizing Covid-19 from medical images. Data analysis is used to get more insights from the data to determine some information's such as: The distribution of published papers in all used databases, and the most used techniques in the contributions. The participation of each country in terms of the number of published documents was considered as well as the type of publication. The rest of this paper is organized as follows. In Section 2, we describe the methodology of the bibliometric analysis employed, along with the tools used for this analysis. Section 3 delves into various aspects of bibliometric analysis, including the techniques used, annual trends, types of publications, geographic dispersion, leading authors, and predominant journals. Finally, Section 4 provides a detailed breakdown analysis for each database.

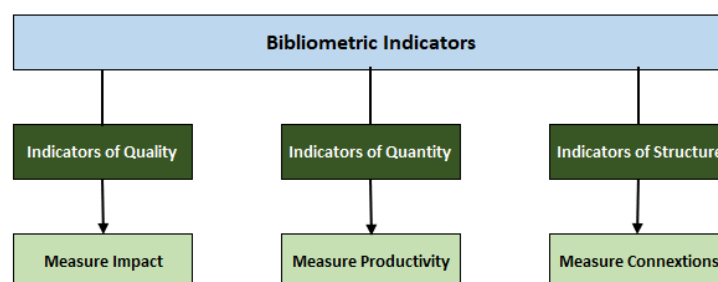
## 2. Bibliometric analysis

### 2.1. Choice of databases

The first and the most important step in any bibliometric analysis is the selection of the relevant databases which pertain to the objectives of the study [27]. The scope of bibliometric analysis is limited by the type of accessible information [28]. It is therefore imperative that the information sources be trusted and adapted to conduct such an analysis and make the most efficient decisions [29]. For our study, we used six well known databases: IEEE Xplore, ACM, MDPI, PubMed, Springer, and ScienceDirect.

### 2.2. Indicators

Once the databases have been selected, the second step is to pick out the appropriate indicators for evaluating the resulting samples. The published papers articles showcase a range of bibliometric measures [29]. We can distinguish three different types of bibliometric indicators: (1) Quality Indicators, which can measure the impact, (2) Quantity Indicators that allow us to measure the productivity, and (3) Structural Indicators that measure the connection [30]. Figure 1 shows the types of bibliometric indicators. In our study, we focused on quantity indicators.



**Figure 1.** Bibliometric indicator types.

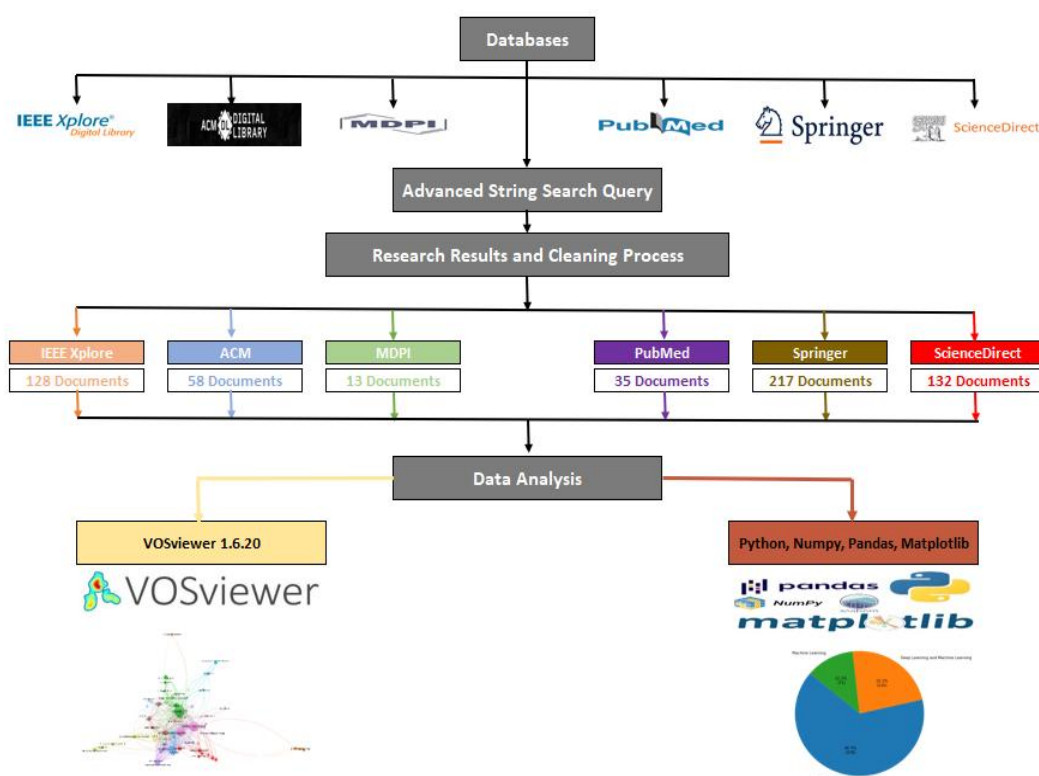
### 2.3. Advanced research

Our purpose of this study is to investigate the research area of classification and detection based on X-Ray and CT images using Deep Learning and Machine Learning techniques. We conducted our review using IEEE Xplore, ACM, MDPI, PubMed, Springer, and ScienceDirect databases. In our bibliometric analysis, we covered the most prevalent areas of knowledge, the prolific authors, the journals and the most publications, the most productive countries, the number of citations, the trends of publications, document types, and countries or territories of origin. To carry out our research, we used the same advanced search string for all the selected databases:

**(“Covid” OR “Covid19” OR “Covid 19” OR “Covid-19” OR “Coronavirus” OR “Corona Virus”) AND (“Classification” OR “Image Classification”) AND (“Detection” OR “Image Detection”) AND (“Deep Learning” OR “Deep Neural Networks” OR “DL” OR “Convolutional Neural Network” OR “CNN”) AND (“X-Ray” OR “X-Ray Image” OR “CT” OR “Computed Tomography”) AND (“Machine Learning” OR “Machine Learning Algorithms” OR “ML”)**

The methodology followed in our bibliometric analysis is described in Figure 2. First, it begins with selecting the databases (IEEE Xplore, ACM, MDPI, PubMed, Springer, and ScienceDirect). An advanced string search query is applied across these databases to gather research papers. Then, the results from this search undergo a cleaning process to refine the selection of documents. The specific counts of papers retrieved from each database are indicated: IEEE Xplore (128), ACM (58), MDPI (13), PubMed (35), Springer (217), and ScienceDirect (132). The bibliometric analysis software VOSviewer and Numpy, Pandas, and Matplotlib Python packages are used to conduct the data analysis and visualizations. The cleaning process involves eliminating duplicated documents and documents that do not address classification and detection of Covid-19 based on X-Ray and CT images.

After the cleaning process, we extracted the relevant information for each document and created an excel file to process the data analysis. In the excel file, we stored the following information: Title of the document, year of publication, first author, country (of the first author; in some documents, we found many authors with different countries), type of document (conference paper, journal article, and book chapter), publisher (title of conference or journal), database, number of citations (the last upgrade of number of citation was 6 November 2023), abstract, key words, and the technique used (Deep Learning, Machine Learning or Deep Learning and Machine Learning). The Excel file was used as a primary tool to conduct an initial analysis of the data, which helped us understand the dataset better. This preliminary analysis opened the point for more interpretation and advanced data visualization. With the help of Python and its powerful libraries such as Pandas, Numpy, and Matplotlib, we created detailed graphs and charts that helped us visualize our findings and understand complex patterns within the data more effectively.



**Figure 2.** Methodology of bibliometric analysis diagram.

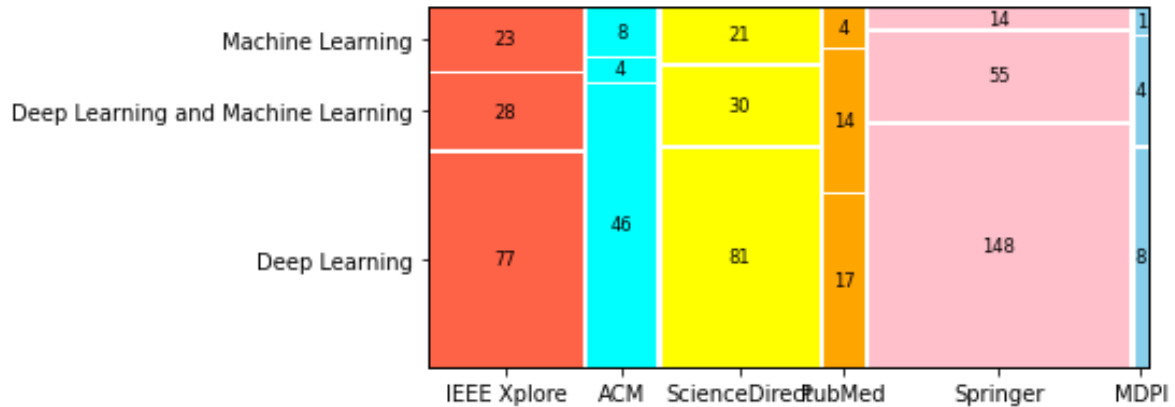
### 3. Comprehensive bibliometric synthesis

The research resulted in 139, 80, 15, 39, 239, and 161 documents in IEEE Xplore, ACM, MDPI, PubMed, Springer, and ScienceDirect, respectively. The cleaning process consists of removing duplicated and documents that do not exactly address the classification and detection of Covid-19 based on X-Ray and CT images using Deep Learning and Machine Learning. The total number of documents, after the cleaning process, for the databases IEEE Xplore, ACM, MDPI, PubMed, Springer, and ScienceDirect is 128, 58, 13, 35, 217, and 132 documents, respectively. Figure 3 shows the distribution of total documents of each database over the years.

We used VOSviewer version 1.6.20 as bibliometric analysis software due to its efficiency in analyzing clustered search results. Indeed, VOSviewer is a software tool designed for creating and visualizing networks within bibliometric data. Such networks include journals, researchers, or individual publications, and are formed through various relationships such as citation, bibliometric coupling, co-citation, or co-authorship relations. It also provides text mining capabilities, allowing us to construct and visualize the patterns of the networks of important terms drawn from a body of scientific literature [31,32]. VOSviewer analyzes the text within abstracts and titles of published papers by segmenting the paragraphs into individual words and phrases and connecting them with the citation data of the corresponding papers. The outcomes are presented as a density map or term bubbles. As we can see in the figure below (Figure 4), the density map highlights key areas of research related to Covid-19, including terms like "Covid-19", "deep learning," and "machine learning" as central nodes. These nodes are surrounded by related terms such as "classification",



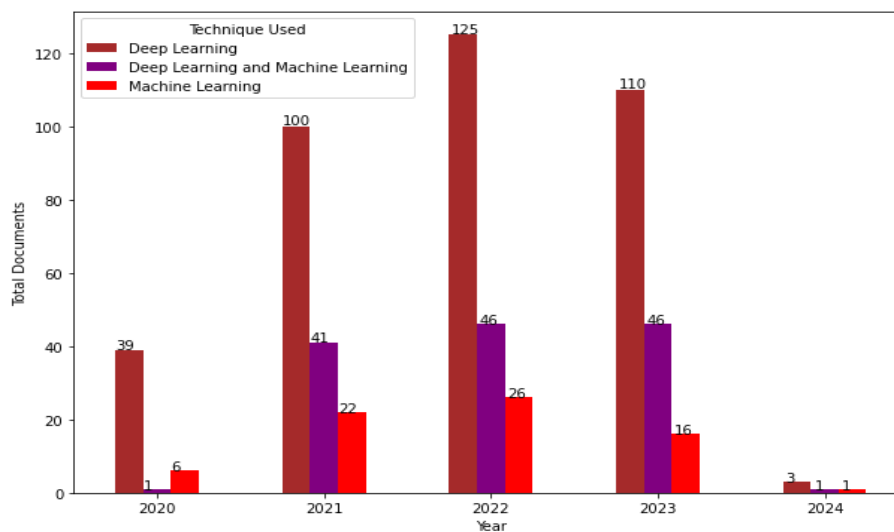




**Figure 6.** Distribution of techniques used.

### 3.2. Annual trends in technique application

Since the beginning of the Covid-19 pandemic in 2020, academic publications about the virus have increased significantly, especially those using Deep Learning and Machine Learning methods. Indeed, the trend shown by Figure 7 presents the yearly distribution of total documents categorized by the utilized techniques from 2020 to 2024. Deep Learning techniques demonstrated its presence with 39 documents, and a significant increase in 2021 (100 documents), 2022 (125 documents), 2023 (110 documents), and 6 documents have already been published as of 2024, even though we are in 2023. A modest count of 6 documents for Machine Learning in 2020 had a low increase for 2021, 2022, and 2023 with 22, 26, and 16 documents, respectively. During the observed period, the combination of Deep Learning and Machine Learning remains relatively stable, indicating a consistent integration of these two approaches in research practices. As the years progressed, the adoption of Deep Learning and Machine Learning continued to grow. This continual increase underlines the critical role that Deep Learning and Machine Learning have played in understanding and combating the Covid-19 pandemic through innovative research and analysis.

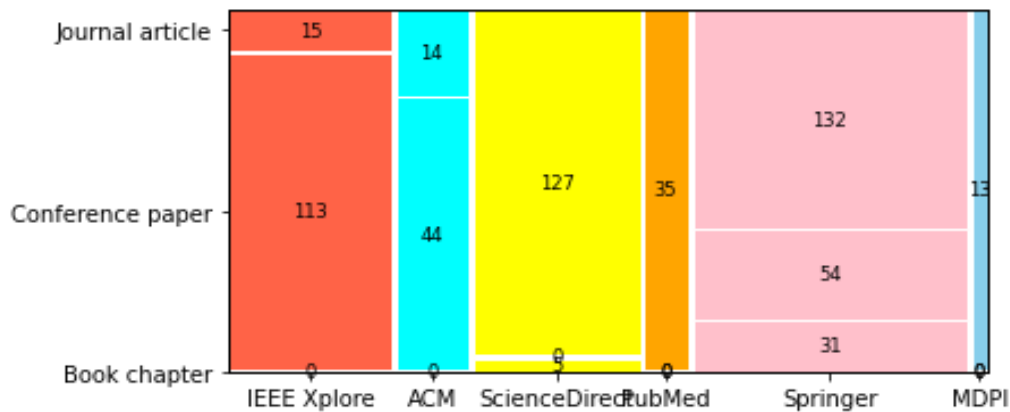


**Figure 7.** Total documents for each technique used per year.



### 3.3. Publication type distribution

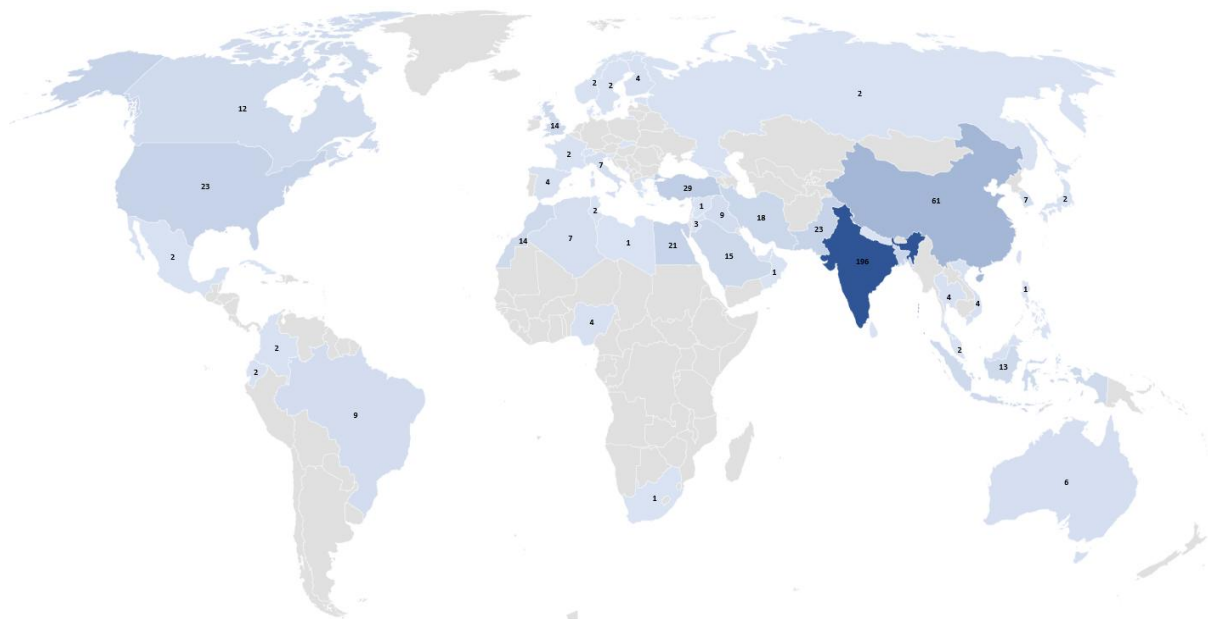
In our study, we carefully paid attention to the type of document, distinguishing three major categories: Conference paper, journal article, and book chapter. We were able, through this classification, to analyze and understand the dissemination patterns and academic impact of each type of publication within the research environment. Regularly, authors present their initial findings in conference papers and their detailed contributions to the body of knowledge in journal articles, while comprehensive insights into specific areas of study are typically reserved for book chapters. Figure 8 represents the distribution of different publication types. As we can see, with 337 (57.7%) of all publications being journal articles, they make up the majority and play a major role in publishing research findings. Conference papers contain 211 (36.1%) of the publications, which is a notable proportion, indicating their significance as a platform for showcasing preliminary research findings and promoting academic discussion. Although they are fewer in number, book chapters make up 6.2% (36) of the publication because they provide more in-depth analysis and discussion on field-related topics. This distribution demonstrates the variety of channels that the academic community uses to publish research findings.



**Figure 8.** Distribution of type of publication.

### 3.4. Geographic dispersion of research contributions

We take the first author's country into account to determine the country of origin for the research contribution in our study. Geographic dispersion of documents across the globe is illustrated in Figure 9. India tops the countries with an impressive count of 196 documents, highlighting its robust research in the topic. Followed by China in second with 61 contributions, illustrates the volume of its academic output. Other notable contributions come from Turkey with 29 papers, and Pakistan and the USA, each contributed with 23 papers. Other noteworthy contributions come from Egypt and Bangladesh, with 21 documents each. A substantial representation of Middle Eastern nations come from Iran and Saudi Arabia with 18 and 15 articles, respectively. Morocco from north Africa contributed 14 documents. The rising forces in economy and technology have challenged the established powers' traditional dominance in the field of global research and are making significant contributions. These emergent forces are leading the way in both academic and practical advances because of their remarkable agility and innovation.



**Figure 9.** Geographic dispersion of documents worldwide.

### 3.5. Leading authors in the field

The top 5 authors who have made major contributions to the corpus of documents are the focus of this analysis. We explore the specifics of their contributions, looking at the geographical context of their affiliations as well as the volume of published works they have contributed. The number of papers published, the esteemed journals that have published their work, and the corresponding databases are used to gauge their impact. This allows us to recognize the depth of their academic impact and the size of knowledge they contribute to the forefront of their respective fields.

As mentioned in Figure 10, K. Shankar from India has published four important journal articles in three years. Shankar's research papers received 18 and 38 citations in 2021 when they were published in "ACM Transactions on Internet Technology" [32] and "Applied Soft Computing" [33], respectively, both published by ACM and ScienceDirect. His work continued to garner attention in "Multimedia Systems" [34] published by Springer the following year. Shankar's 2023 publication in "Cognitive Neurodynamics" [35] was also published by Springer. All these articles, which have appeared in respectable journals and databases, have accumulated 118 citations.

The Pakistani author Imran Ahmed published two articles in 2022: "Interdisciplinary Sciences: Computational Life Sciences" [36] published by Springer, and one in "Virtual Reality & Intelligent Hardware" [37] hosted on ScienceDirect. Imran made another significant contribution in 2023 when he published an article in "Computing" [38], which was also published by Springer. The total citation of Imran reached 63 citations.

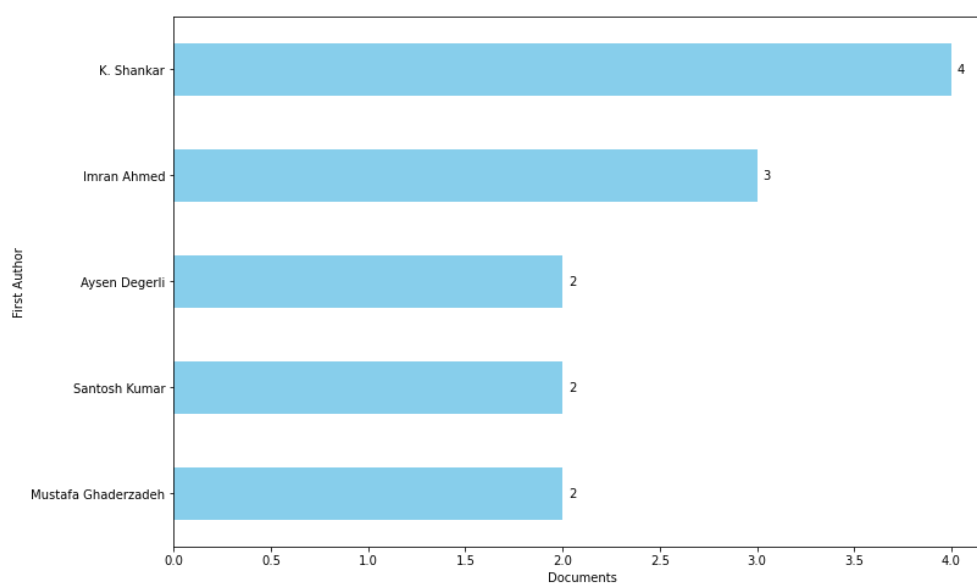
Santosh Kumar, an Indian researcher, published two journal articles in 2022, having a total of 36 citations. One article was published in "Computer Methods and Programmes in Biomedicine" [39] which is indexed in PubMed Database. His second work was featured in "Computers and Electrical Engineering" [40] on ScienceDirect.

The Iranian author Mustafa Ghaderzadeh had a remarkable year in 2021. His research was published as a conference paper by ACM and presented at the 5th International Conference on Medical and Health Informatics in 2021 [41]. Furthermore, he published an article in the "Journal of

Medical Internet Research" [42] that was indexed in PubMed. He received a total count of 59 citations.

In 2023, Aysen Degerli, from Finland, made a significant contribution by publishing one journal article in "Health Information Science and Systems" [43] indexed in Springer with 76 citations. In 2022, he published a conference paper in the IEEE International Conference on Image Processing (ICIP), which is indexed in the IEEE Xplore database and earned 9 citations [44].

The prominence of the rising academic forces is demonstrated by the four leading authors who are from India, Pakistan, and Iran. Indeed, this is demonstrated by showcasing the increasing intellectual talent of their respective nations. These researchers have highlighted an academic ascendancy trend in regions that have been strongly pushing the boundaries of innovation and research.



**Figure 10.** Top 5 leading authors in the field.

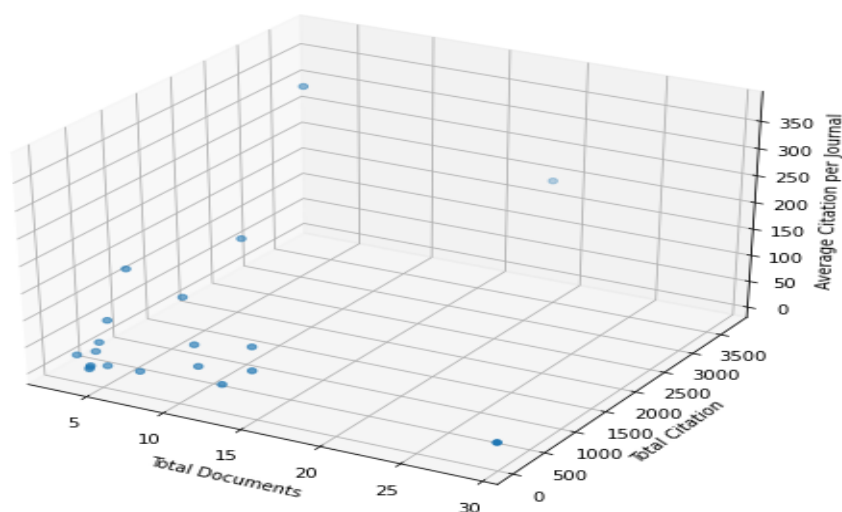
### 3.6. Predominant journals in the literature

A comprehensive overview of the 20 most productive journals in this study with details of corresponding databases, total citations, and average citation per journal is presented in Table 1. The analysis showcases that "Multimedia Tools and Applications" (29 documents), "Computers in Biology and Medicine" (19 documents), and "Expert Systems with Applications" (13 documents) are the most top three journals within their corresponding databases (PubMed for the first journal and ScienceDirect for the two others). These articles earned total citations of 237, 3711, and 399, respectively. With their large number of citations, they established a standard for scholarly impact. A more thorough analysis identifies a trend of significant contributions on several platforms, including ScienceDirect, Springer, and IEEE Xplore. This trend across databases demonstrates how research publications are dynamic and how journals bear witness to how academic discourse is changing. These results highlight the critical role that highly regarded journals play in promoting knowledge advancement among the international research community.

**Table 1.** Top 20 Journals ranked by productivity in the study.

Journal Title	Database	Total Documents	Total Citation	Average Citation per Journal
Multimedia Tools and Applications	PubMed	29	237	8.17
Computers in Biology and Medicine	ScienceDirect	19	3711	195.32
Expert Systems with Applications	ScienceDirect	13	399	30.69
Applied Soft Computing	ScienceDirect	12	632	52.67
Biomedical Signal Processing and Control	ScienceDirect	12	181	15.08
Journal of Ambient Intelligence and Humanized Computing	Springer	10	290	29.00
Scientific Reports	Springer	9	462	51.33
Applied Intelligence	Springer	8	1422	177.75
IEEE Access	IEEE Xplore	7	2637	376.71
Informatics in Medicine Unlocked	ScienceDirect	7	757	108.14
Neural Computing and Applications	Springer	7	106	15.14
SN Computer Science	Springer	5	78	15.60
ACM Transactions on Multimedia Computing, Communications, and Applications	ACM	4	132	33.00
Computers and Electrical Engineering	ScienceDirect	4	29	7.25
Computer Methods and Programs in Biomedicine	PubMed	4	615	153.75
Procedia Computer Science	ScienceDirect	4	39	9.75
Neurocomputing	ScienceDirect	4	48	12.00
Pattern Recognition	ScienceDirect	4	314	78.50
Soft Computing	Springer	4	185	46.25
Knowledge-Based Systems	ScienceDirect	3	74	24.67

From Figure 11, we can notice that there is no clear trend indicating a direct proportionate relationship between the number of documents published and average citations. This implies that more publications do not necessarily lead to a higher average citation count per document.

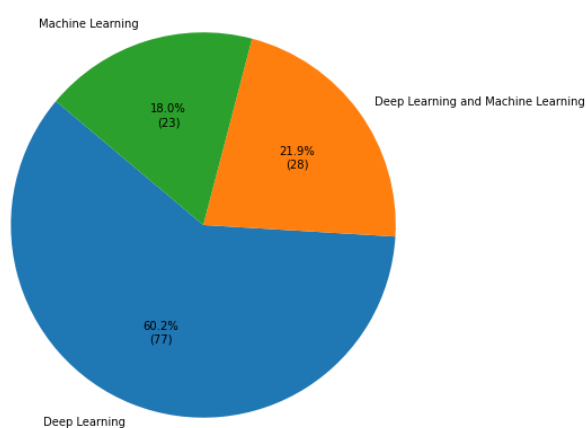


**Figure 11.** A 3D scatter plot for journal metrics.

## 4. Database-specific bibliometric insights

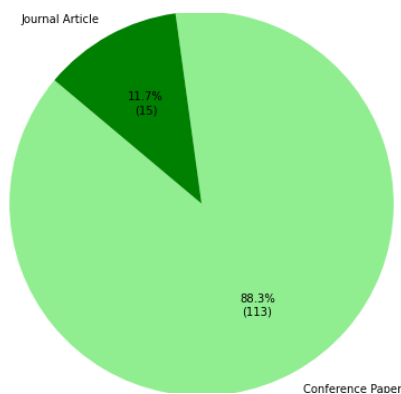
### 4.1. IEEE Xplore

The total documents that have been published in IEEE Xplore database is 128 documents. As depicted in Figure 12, most published papers used Deep Learning techniques, accounting for 77 documents of research, which is showing its significant role in studies. Machine Learning techniques and the combined use of Deep Learning and Machine Learning are almost in the same range with 23 and 28 documents, respectively.



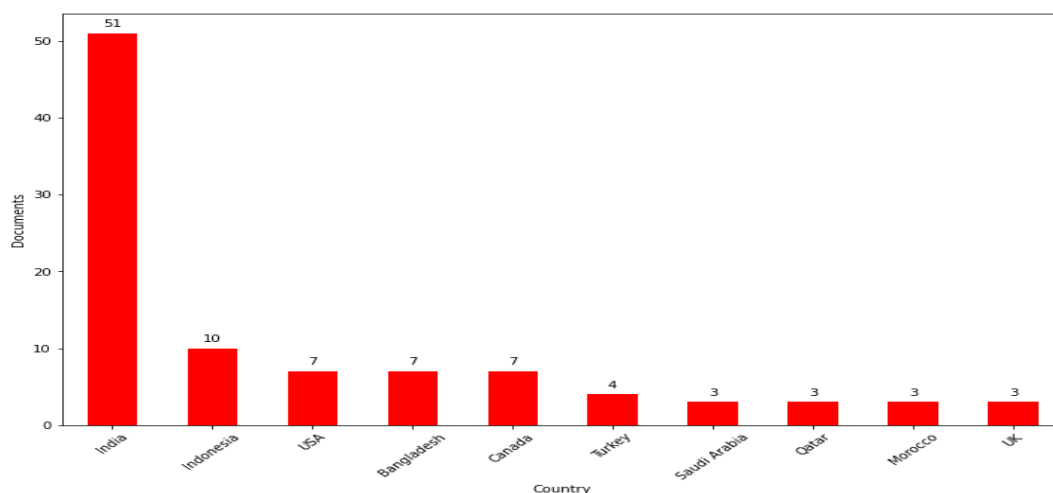
**Figure 12.** Distribution of techniques used for the IEEE Xplore database.

For the distribution of publication type in IEEE Xplore, as shown in Figure 13, the first remark that we can raise is the absence of book chapters. Only conference papers, which are predominant, with 113 documents, and journal articles with 15 documents and are published. This distribution clearly highlights conference proceedings within the IEEE community, reflecting the typical patterns of academic distribution in the field.



**Figure 13.** Distribution of publication type for the IEEE Xplore database.

The graph in Figure 14 represents the top 10 contributing countries to the IEEE Xplore database. India is in the lead with a substantial 51 documents, underscoring the country's significant research output. Indonesia came in second with 10 publications, while the USA, Bangladesh, and Canada each contributed 7 documents. With four publications, Turkey follows closely in demonstrating its scholarly presence. Notable contributors include Saudi Arabia, Qatar, Morocco, and the UK, each of which has three publications in the database.



**Figure 14.** Top 10 Countries contributed to publication for IEEE Xplore database.

For the IEEE Xplore Database, all authors have published one single document in the IEEE Xplore database. Indeed, Abbas Mazrouei Sebdani, from Iran, published a conference paper [45] on the 5th International Conference on Pattern Recognition and Image Analysis (IPRIA) in 2021. He proposed two classification algorithms of Covid-19 using Machine Learning. In 2020, the south Korean researcher, Abdul Waheed, has published a journal article [46] where he proposed a method to generate synthetic chest X-ray (CXR) images by developing an Auxiliary Classifier Generative Adversarial Network (ACGAN). Using a deep unsupervised framework to classify lung diseases from chest CT and X-ray images, Pooja Yadav (India) published in IEEE Access [47]. Oussama El Gannourm, from Morocco, presented a Deep Learning based system for the diagnosis of COVID19 disease at the IEEE 2nd International Conference on Electronics, Control, Optimization, and Computer Science (ICECOCS) [48]. Using Deep Learning and Machine Learning, a framework

named CovFrameNet., which consist of a pipelined image pre-processing method and a deep learning model for feature extraction, classification, and performance measurement, has been published by Olaide Nathaniel Oyelade from South Africa on IEEE Access [49].

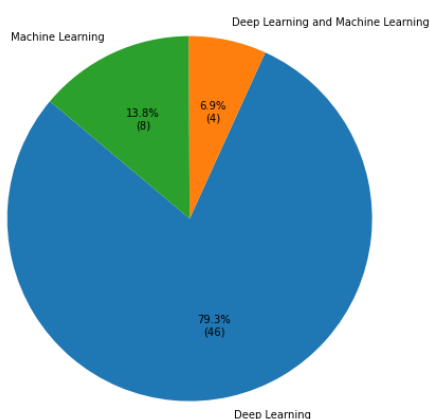
According to Table 2, "IEEE Access" is the prominent journal in IEEE Xplore with a total of 7 documents and an impressive total of 2637 citations. Followed by "IEEE Journal of Biomedical and Health Informatics", "IEEE Transactions on Engineering Management", and "IEEE Transactions on Medical Imaging" participating with 2 documents each with total citations of 72, 33, and 186, respectively. With only one document, "IEEE Transactions on Big Data" shows its weight in the field with 70 citations.

**Table 2.** Top 5 journals ranked by productivity for IEEE Xplore database.

Journal Title	Database	Total Documents	Total Citation	Average Citation per Journal
IEEE Access	IEEE Xplore	7	2637	376.71
IEEE Journal of Biomedical and Health Informatics	IEEE Xplore	2	72	36.00
IEEE Transactions on Engineering Management	IEEE Xplore	2	33	16.50
IEEE Transactions on Medical Imaging	IEEE Xplore	2	186	93.00
IEEE Transactions on Big Data	IEEE Xplore	1	70	70.00

#### 4.2. ACM

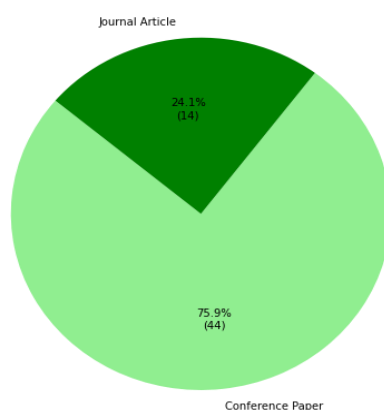
58 documents have been published in ACM database. Figure 15 illustrates that most documents used Deep Learning technique (46 documents) while Machine Learning and combined Deep Learning and Machine Learning techniques are less used accounting for 8 and 4, respectively. This makes us conclude the importance of Deep Learning techniques in ACM platform.



**Figure 15.** Distribution of techniques used for ACM database.

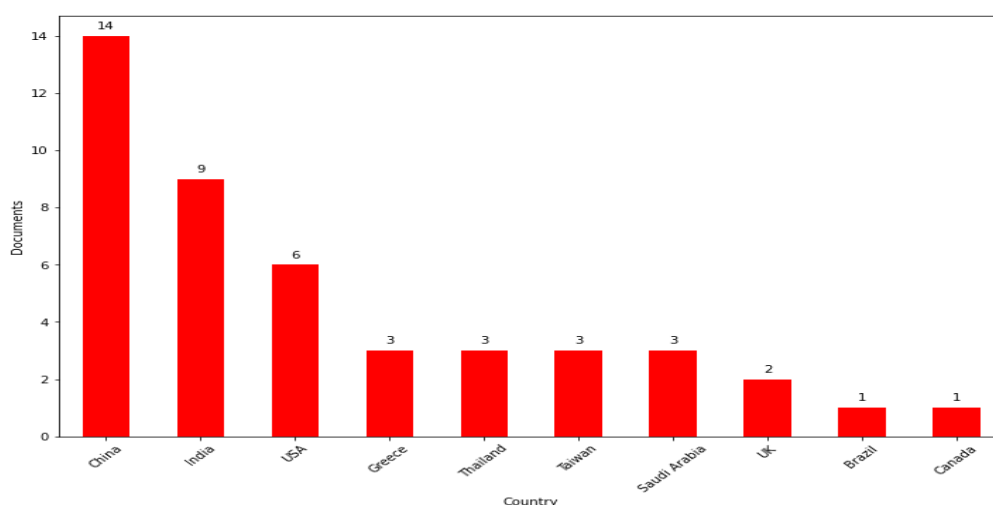
For the ACM database (Figure 16), only conferences articles and journal articles have been published with a dominance of conference articles around 76% (44 documents) and only 24% (14 documents) for journal articles. This distribution highlights the dual focuses of ACM database, which

are to contribute to the body of knowledge with journal articles and to promote the academic record through the conferences.



**Figure 16.** Distribution of publication type for the ACM database.

Figure 17 is demonstrating China's remarkable advantage with 14 documents. India comes in second with 9 documents, while the USA contributes 6 publications. Greece, Thailand, Taiwan, and Saudi Arabia participated with 4 documents. With 2 documents, the UK contributed to the publication, although Brazil and Canada marked their presence with 1 document. This data shows a geographically varied collection of contributions to the ACM database, illustrating the international scope and cooperative character of modern research initiatives among different countries.



**Figure 17.** The top 10 Countries that contributed to publications for the ACM database.

As for the ACM database, we do not have duplicated authors. Indeed, the paper of Abhishek Kumar, from India, was published for the 13 Indian Conference on Computer Vision, Graphics, and Image Processing (ICVGIP) [50]. He presented a comparative analysis of the most well-known CNN models to classify X-Ray images. The 12th ACM Conference on Bioinformatics, Computational Biology, and Health Informatics was an opportunity for the Georgian Tarun Naren [51] to publish his work where he developed a new variant of Model-Agnostic Meta-Learning (MAML) algorithm, named MAML++, in order to classify X-Ray images. From Vietnam, Pham Ngoc Ha [52] in 2023, participated in the 8th International Conference on Intelligent Information Technology and published



his paper. He used Vision transformer architecture to extract data characteristics and classify images. In 2020, a system for automatic detection of COVID-19 from CXR images using machine learning techniques was proposed by Phongsathorn Kittiworapanya [53] on the Eleventh International Conference on Computational Systems-Biology and Bioinformatics. The year 2023 was when Robert Hertel [54] published a hit paper in ACM Computing Surveys. He presented an in-depth review of deep learning techniques on the purpose of diagnosis and prognosis of COVID-19 patients.

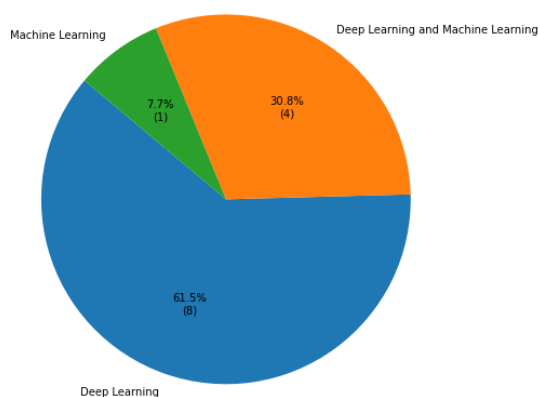
Table 3 presents the top 5 Journals Ranked by Productivity for ACM database. Indeed, "ACM Transactions on Multimedia Computing, Communications, and Applications" stands out as the most productive journal in the ACM database with 4 papers and 132 citations overall, followed by "ACM Transactions on Management Information Systems" having 3 publications and a total of 47 citations. Publishing 2 documents, "ACM Transactions on Internet Technology" and "IEEE/ACM Transactions on Computational Biology and Bioinformatics" got overall citations of 33 and 957, respectively. "ACM Computing Surveys" has completed the list of the top five productive journals with one contribution totaling five citations.

**Table 3.** Top 5 Journals ranked by productivity for ACM database.

Journal Title	Database	Total Documents	Total Citation	Average Citation per Journal
ACM Transactions on Multimedia Computing, Communications, and Applications	ACM	4	132	33.00
ACM Transactions on Management Information Systems	ACM	3	47	15.67
ACM Transactions on Internet Technology	ACM	2	33	16.50
IEEE/ACM Transactions on Computational Biology and Bioinformatics	ACM	2	957	478.50
ACM Computing Surveys	ACM	1	5	5.00

#### 4.3. MDPI

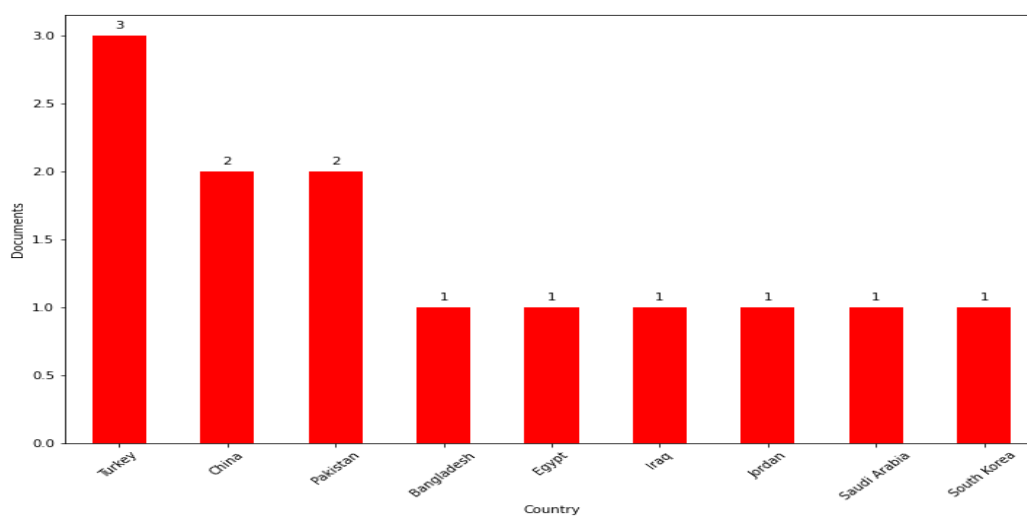
Participating with only 13 documents in this study, MDPI possesses the smallest collection of documents. The distribution of published documents (Figure 18) according to the techniques used is that more than 61% (8 documents) of the techniques used are Deep Learning, and the mixture of Deep Learning and Machine Learning is highlighted in four documents (30.8%). The use of Machine Learning was used only in one document.



**Figure 18.** Distribution of techniques used for the MDPI database.

Journal articles make up 100% of the publications and are the only contributor. The complete dominance of journal articles across all 13 documents in the dataset suggests that the ACM database places a high value on formal, peer-reviewed articles. The focused nature of this collection is highlighted by the absence of other publication types like conference papers or book chapters.

The top 10 nations that have contributed to the MDPI database are shown in Figure 19. Turkey leads the count with 3 documents. Following with 2 contributions, China and Pakistan show that they are actively involved in academic publishing within MDPI. Additionally, Bangladesh, Egypt, Iraq, Jordan, Saudi Arabia, and South Korea, contributed one document each.



**Figure 19.** The top 10 Countries that contributed to publications for the MDPI database.

There was one contribution per author from the MDPI database. Indeed, Ali Tariq Nagi [55], from Pakistan, has a paper that involves an evaluation of the performance of deep learning models for COVID-19 diagnosis using chest X-ray images from a dataset containing the largest number of COVID-19 images ever used in the literature. The Iraqi, Awf Ramdhan [56] proposed an approach that uses image cropping methods and a deep learning technique that classifies three public datasets. In [57], Bayan Alsaaidah from Jordan conducted a comprehensive review of Deep Learning and Machine Learning methods for detection and classification of Covid-19. Using Deep Learning techniques, a computer-aided diagnostic system for chest X-ray and CT images for Covid-19

classification was developed by Heba M. Emara [58] from Egypt. A Turkish researcher, Jawad Rasheed [59], proposed a computer vision and artificial-intelligence-based hybrid approach aid in efficient detection and control of the COVID-19 disease.

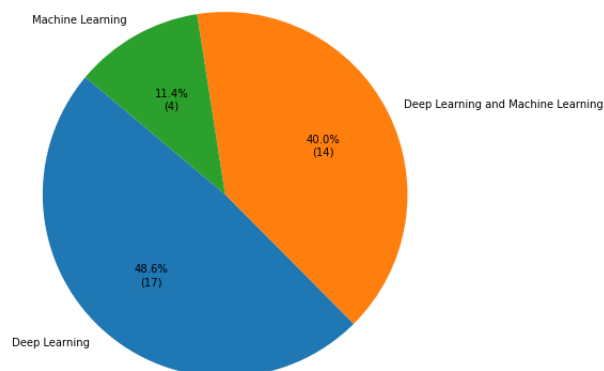
The top 5 Journals Ranked by Productivity for the MDPI database are presented in Table 4. With 3 published documents, "Diagnostics" leads the 5 productive journals in the MDPI database, and having 10 citations, was followed by "Applied Sciences" and "Sensors" with a count of 2 documents and an overall of citation of 33 and 27, respectively. "Bioengineering" with 15 citations and "Cancers" had 6 citations as their publications, with one document each.

**Table 4.** Top 5 Journals ranked by productivity for the MDPI database

Journal Title	Database	Total Documents	Total Citation	Average Citation per Journal
Diagnostics	MDPI	3	10	3.33
Applied Sciences	MDPI	2	33	16.50
Sensors	MDPI	2	27	13.50
Bioengineering	MDPI	1	15	15.00
Cancers	MDPI	1	6	6.00

#### 4.4. PubMed

In this study, 35 documents were selected in the PubMed database. Figure 20 displays the distribution of techniques used. Having almost 50% (17 documents), Deep Learning was used as a technique for detection and classification of Covid-19 in the PubMed database. Deep Learning and Machine Learning were utilized jointly with a count of 14 documents (40%). The use of Machine Learning as a technique appeared only 4 times with a percentage of 11.4%. This brings us to the superiority of the use of Deep Learning techniques in the PubMed database.

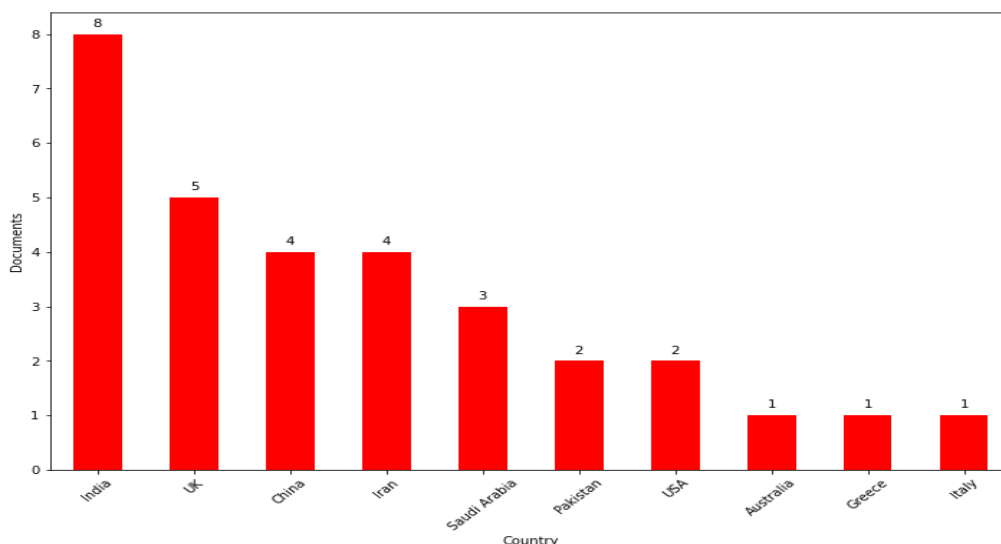


**Figure 20.** Distribution of techniques used for the PubMed database.

Same as for the ACM database, only journal articles were published in the PubMed database. With the absence of other publication types, such as book chapters or conference papers, we can underline that peer-reviewed articles are the focused nature of the PubMed database.

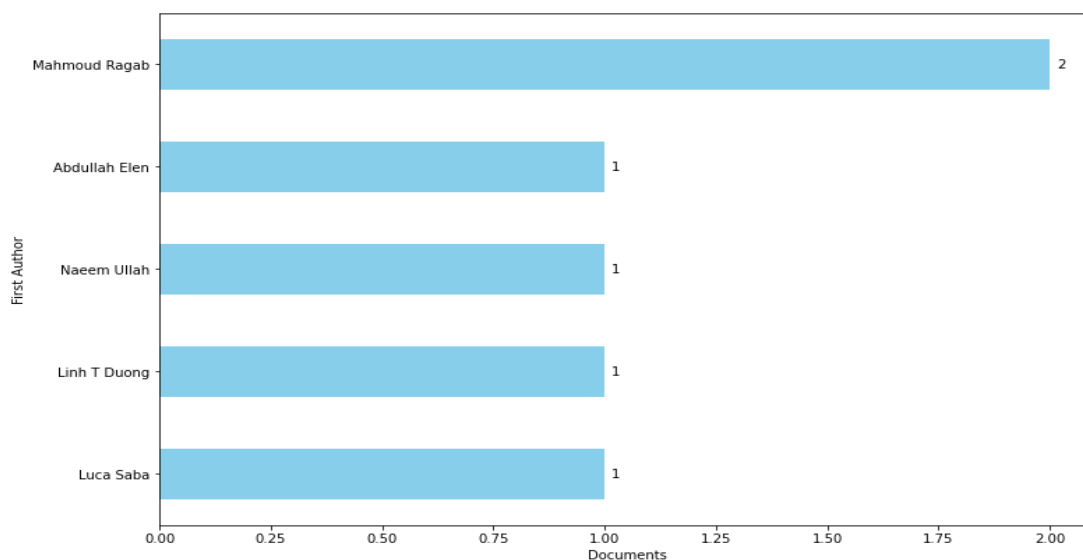
Leading the top 10 countries that contributed to publication, India published 8 documents, followed by the UK with 5 publications. Three published documents were the participation of China

and Iran each. Not far from them is South Africa, with 3 published documents. Other countries include Pakistan and the USA with 2 publications, and Australia, Greece, and Italy contributed with 1 document each. Figure 21 displays the top 10 Countries that contributed to publications for the PubMed database.



**Figure 21.** The top 10 Countries that contributed to publications for the PubMed database.

As displayed in Figure 22, from Saudi Arabia, Mahmoud Ragad published 2 journal articles in 2021 and 2022. In his first paper [60], he presented an artificial intelligence-based ensemble model for detection and classification (AIEM-DC) that aims to accurately detect and classify the COVID-19 using an ensemble of DL models. In [61], Mahmoud Ragad proposed a new Quantum Seagull Optimization Algorithm with a DL-based COVID-19 diagnosis model, named the QSGOA-DL technique to detect and classify COVID-19 with the help of CXR images. Abdullah Alen, from Turkey, proposed a Residual Convolutional Neural Network (ResCNN) used as a deep learning method, with the assistance of machine learning algorithms and extracted features from images [62]. An effective COVID-19 detection and classification approach using the Shufflenet CNN by employing three types of images (chest radiograph, CT-scan, and ECG-trace images) was proposed by the Pakistani Naeem Ullah [63]. The main idea of Linh T Duong, from Vietnam, in [64] is exploiting cutting-edge Machine Learning techniques for the detection of Covid-19 from chest X-ray (CXR) and lung computed tomography (LCT) images. From Italy, Luca Saba [65] presented a comparative study between Deep Learning and Machine Learning algorithms for the detection of Covid-19 based on radiological computed tomography (CT) lung scans.



**Figure 22.** Leading authors in the field of the PubMed database.

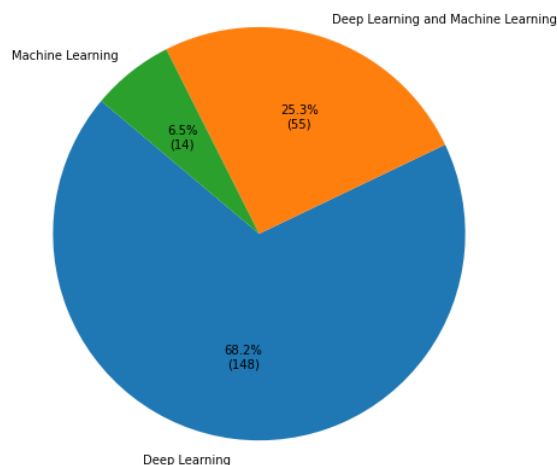
Table 5 displays the 5 most productive journals in the PubMed database. With 3 documents, "Diagnostics (Basel)" ranks first with 29 citations, followed by "Computational Intelligence and Neuroscience" with 2 published papers, which got 8 citations. "Mathematical Biosciences and Engineering", "Journal of Healthcare Engineering", and "Journal of Medical Internet Research" have participated in this field by publishing 1 article each with total citations of 8, 10, and 59, respectively.

**Table 5.** Top 5 Journals ranked by productivity for the PubMed database.

Journal Title	Database	Total Documents	Total Citation	Average Citation per Journal
Diagnostics (Basel)	PubMed	3	29	9.67
Computational Intelligence and Neuroscience	PubMed	2	8	4.00
Mathematical Biosciences and Engineering	PubMed	1	8	8.00
Journal of Healthcare Engineering	PubMed	1	10	10.00
Journal of Medical Internet Research	PubMed	1	59	59.00

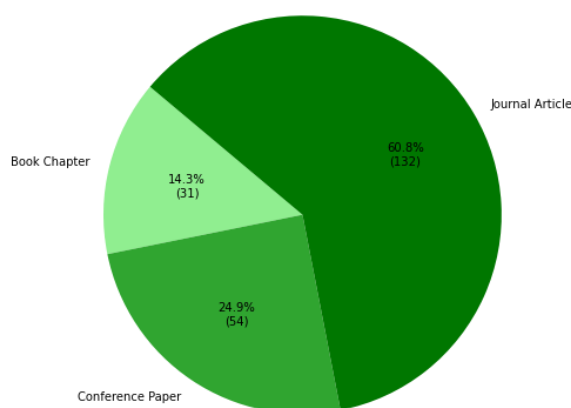
#### 4.5. Springer

Springer is the database that has the highest number of documents in this study by contributing 217 documents. With 148 journal articles, Deep Learning dominated the techniques used in Springer database with a percentage of 68.2%. Merged Deep Learning and Machine Learning techniques have been used in 55 documents, achieving 25.3% of all documents. Moreover, the use of Machine Learning techniques occurred only in 14 documents (6.5%). This distribution used techniques that signify the research trends and priorities within the Springer database. Figure 23 shows the distribution of techniques used for the Springer database.



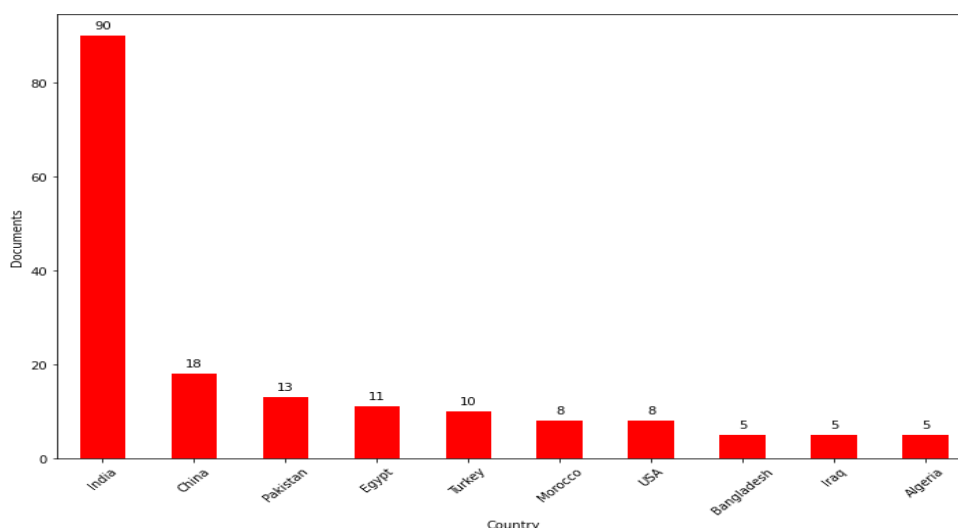
**Figure 23.** Distribution of techniques used for the Springer database.

With a percentage of 60.8% (132 documents), the publication type of published documents in Springer are journal articles with a huge part (see Figure 24). A considerable number of types of publications are conference papers, accounting for 54 documents or 24.9%. Book chapters got a significant part of publication type with 31 documents (14.3%). This means that Springer is a database that opens all the opportunities to researchers to publish their works.



**Figure 24.** Distribution of publication type for the Springer database.

As we can see in Figure 25, Indian researchers lead the top 10 countries that contributed to publication with a very high number of documents (90 publications). This carries us to India's superiority in the field of scientific research in recent years. With a very big gap between India, China came second with 18 documents, followed by Pakistan, Egypt, and Turkey in the same range of published documents, with a count of 13, 11, and 10 documents, respectively. Morocco and the USA marked their presence with 8 publications each. Furthermore, Bangladesh, Iraq, and Algeria have participated with 5 documents each.



**Figure 25.** The top 10 countries that contributed to publications in the Springer database.

The top 5 researchers in Springer participated with 2 documents each. Indeed, an Indian researcher, K. Shankar, who came first with publications [66], presented a new metaheuristic-based fusion model for COVID-19 diagnosis using chest X-ray images using Weiner filtering for preprocessing, grey level co-occurrence matrix for feature extraction, and artificial neural network for classification. In 2023, an automated COVID-19 diagnosis process using Convolutional Neural Network (CNN) with a fusion-based feature extraction model (FM-CNN) was developed in his second paper [67]. In 2021, Sourabh Shastri, from India, designed a nested ensemble model using deep learning methods based on long short-term memory (LSTM) [68]. A CheXImageNet model has been introduced for detecting Covid-19 disease using digital images of Chest X-ray with the help of an openly accessible dataset in his second paper [69]. The work done by the Pakistani Kainat Khoro in [70] was a review of ML and DL-based techniques for early detection of Covid using chest X-rays. A comparison study of 9 state-of-the-art CNN architectures through a transfer learning approach for detection of Covid-19 was presented in his second work [71]. Siddharth Gupta, from India, presented pre-trained CNN models (VGG16 and VGG19) that were used for transfer learning and several machine learning classifiers for the classification of images, such as Covid19 [72]. In [73], he employed DL-based automated techniques (VGG16, VGG19, and Inception V3) to process the chest X-ray images for the detection of Covid-19. The Indian author Ebenezer Jangam [74] proposed a stacked ensemble of heterogeneous pre-trained computer vision models where 4 pre-trained DL models were considered (VGG19, ResNet101, DenseNet169, and WideResNet502). His second work [75] was about a novel multi-class classification framework that can minimize either false positives or false negatives, and is useful in computer aided diagnosis or computer aided detection, respectively.

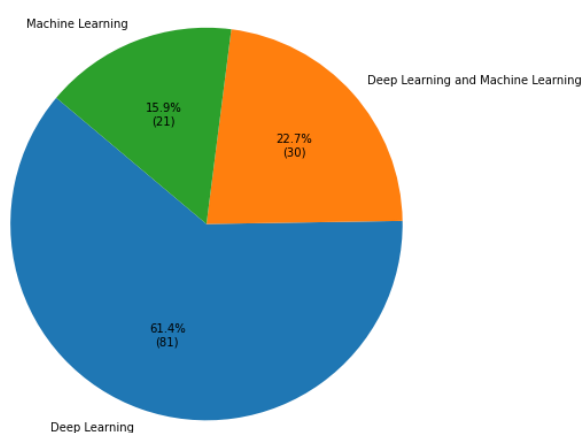
Publishing 28 documents with a total citation of 222 citations, "Multimedia Tools and Applications" came out on top of the productive journal in Springer (see Table 6). With a considerable difference of 18 documents, "Journal of Ambient Intelligence and Humanized Computing" took the second rank, with 290 citations. "Applied Intelligence" and "Scientific Reports" have published 8 documents each with 1422 and 462 citations respectively. Six publications and 106 citations allowed "Neural Computing and Applications" to be in the top 5 productive journal in Springer.

**Table 6.** Top 5 Journals ranked by productivity for the Springer database.

Journal Title	Database	Total Documents	Total Citation	Average Citation per Journal
Multimedia Tools and Applications	Springer	28	222	7.93
Journal of Ambient Intelligence and Humanized Computing	Springer	10	290	29.00
Applied Intelligence	Springer	8	1422	177.75
Scientific Reports	Springer	8	462	57.75
Neural Computing and Applications	Springer	6	106	17.67

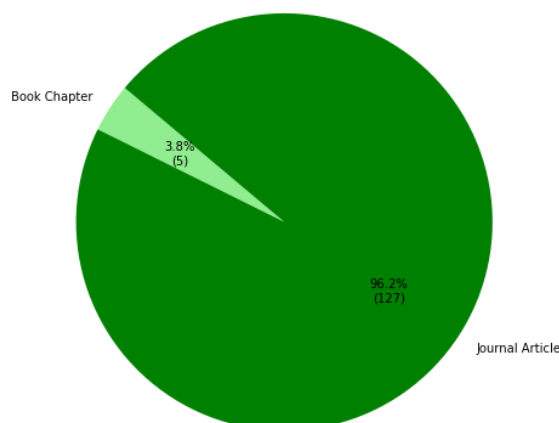
#### 4.6. ScienceDirect

With 132 collected documents, ScienceDirect comes in second of all the databases concerned in this study. From Figure 26, we can conclude that Deep Learning techniques are the most used with a total count of 81 documents, which is almost a huge portion of all technique used. The use of Deep Learning and Machine Learning together appeared in 30 (22.7%) papers while Machine Learning as type of technique occurred in 21 (15.9%) documents.

**Figure 26.** Distribution of techniques used for ScienceDirect database.

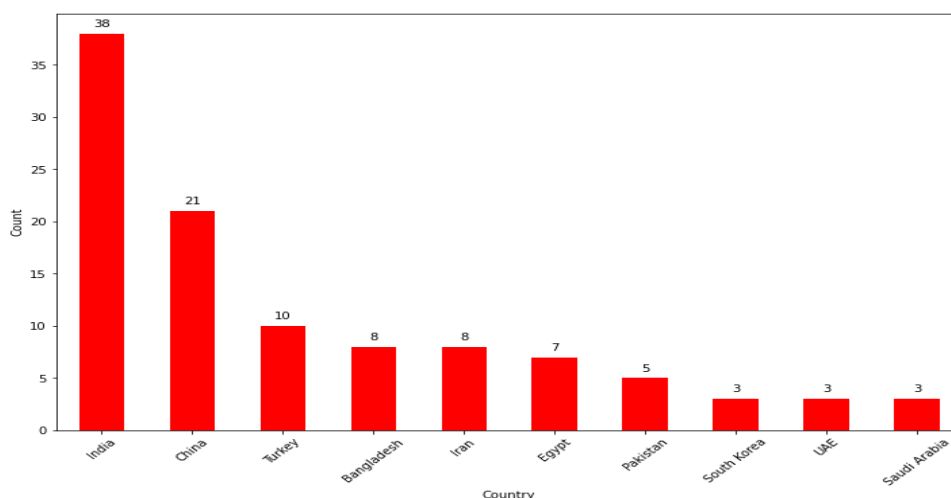
As illustrated in Figure 27, more than 96% (127 papers) of documents published in ScienceDirect are journal articles. This shows the total dominance of this type of publication, and it is the main way for researchers to publish their works in ScienceDirect. Even though they are less in number, book chapters make up 3.8% of all publications (5 documents).





**Figure 27.** Distribution of publication type for ScienceDirect database.

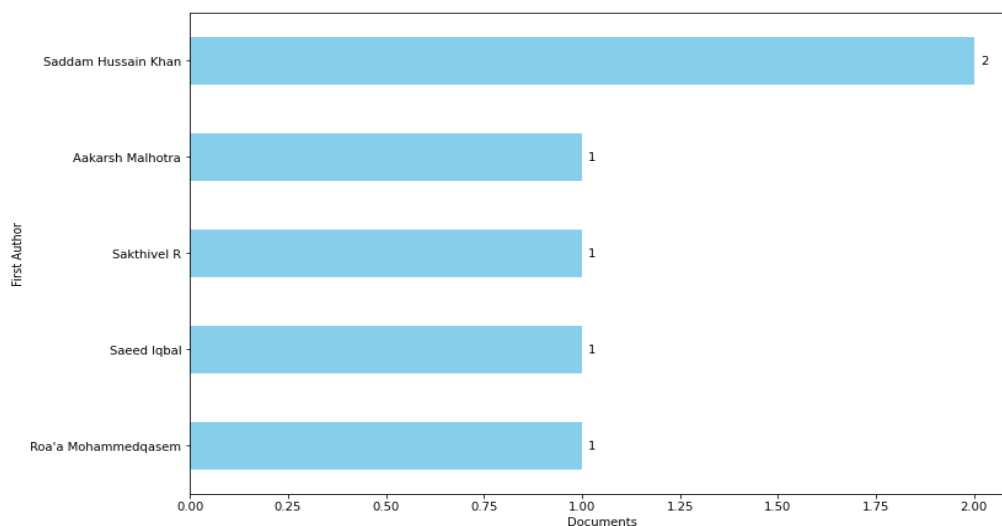
Like almost all the databases, India tops the 10 countries that contributed to publications in ScienceDirect with 38 documents, which confirms its dominance in this study. India is followed by China, with a significant gap accounting for 21 published papers. Turkey maintained its presence among the countries contributing to publication in this database. Bangladesh and Iran contributed 8 documents, while Egypt and Pakistan h 7 and 5 times, respectively. South Korea, UAE, and Saudi Arabia insisted on being included among the countries with 3 documents each. Figure 28 displays the top countries that contributed to the publications for the ScienceDirect database.



**Figure 28.** The top 10 countries that contributed to publications for the ScienceDirect database.

The year 2021 was a special year for the Pakistani Saddam Hussain Khan when he published two papers (Figure 29). In [76], he proposed two new deep learning frameworks: Deep Hybrid Learning (DHL) and Deep Boosted Hybrid Learning (DBHL) for effective COVID-19 detection in X-ray dataset. He developed, in his second work [77], two novel custom CNN architectures (COVID-RENet-1 and COVID-RENet-2) for COVID-19 specific pneumonia analysis. The Indian researcher, Aakarsh Malhotra [78], presented a COVID-19 Multi-Task Network (COMiT-Net), which is an automated end-to-end network for COVID-19 screening and that can perform semantic segmentation of the regions of interest to make the model explainable. Originally from India, Sakthivel R [79] built an efficient hardware architecture based on an ensemble deep learning model

to identify the COVID-19 using chest X-ray (CXR) records. Saeed Iqbal [80] suggested a technique allowing a class balancing algorithm to understand and detect lung disease signs from chest X-ray and CT images. He used Deep learning techniques to train and evaluate images, enabling the extraction of basic visual attributes. Roa'a Mohammedqasem [81], from Turkey, proposed a real-time detection system based on the Internet of Things framework. The system can collect real-time data from users to determine potential coronavirus cases, analyze treatment responses for people who have been treated, and accurately collect and analyse the datasets.



**Figure 29.** Leading authors in the field for the ScienceDirect database.

As presented in Table 7, the journal "Computers in Biology and Medicine" came in the top 5 productive journals with 19 published documents and accumulating a total of 3711 citations. With 13 papers having 221 citations, "Expert Systems with Applications" ranked in second place, followed by "Biomedical Signal Processing and Control" and "Applied Soft Computing" with 12 and 11 documents and receiving 181 and 622, respectively. "Informatics in Medicine Unlocked" announced its position within the productive journals with 7 documents accounting for a total of 757 citations.

**Table 7.** Top 5 Journals ranked by productivity for the ScienceDirect database.

Journal Title	Database	Total Documents	Total Citation	Average Citation per Journal
Computers in Biology and Medicine	ScienceDirect	19	3711	195.32
Expert Systems with Applications	ScienceDirect	13	221	17.00
Biomedical Signal Processing and Control	ScienceDirect	12	181	15.08
Applied Soft Computing	ScienceDirect	11	622	56.55
Informatics in Medicine Unlocked	ScienceDirect	7	757	108.14

## 5. Conclusions

In this review, we highlighted the use of Deep Learning and Machine Learning techniques to detect and classify Covid-19 using X-Ray and CT images. The bibliometric analysis carried out for

this study revealed a significant number of documents describing the importance of the use of Deep Learning in this field compared to Machine learning methods. Moreover, one conclusion we can draw from this study is the rising forces in economy and technology, especially India, China, Turkey, and Pakistan, which began to compete in the field of scientific research. Additionally, journal articles, as a publication type, dominated the type of publication compared to Conference Papers and Book Chapters. This means that authors prefer to publish their detailed contributions to the field of knowledge in journals than publish their initial findings in conference papers or their comprehensive insights into specific areas in Book Chapters. Furthermore, authors focused on the Springer database to submit their works for publication, which is explained by the high number of published documents in this database compared to other databases.

### Use of AI tools declaration

The authors declare that they have not used Artificial Intelligence (AI) tools in the creation of this article.

### Conflict of interest

The authors declare that there are no conflicts of interest in this paper.

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