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A Bibliometric Analysis of Deepfakes : Trends, Applications and Challenges

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Abstract

INTRODUCTION: The rapid progress in artificial intelligence (AI) over the past decade has ushered in a new era of transformative technologies. Deep learning has emerged as a potential tool, demonstrating remarkable capabilities in various applications. This paper focuses on one of the controversial applications of deep learning commonly known as deepfakes.
OBJECTIVES: The main objective of this comprehensive bibliometric survey is to explore the trends, applications and challenges of deepfakes over the course of last 4.5 years.
METHODS: In this research, a total of 794 documents published from 2019 to July 2023 were acquired from Scopus database. To conduct this bibliometric analysis, RStudio and VOSviewer tools have been used. In this current analysis, deepfake challenges, countries, sources, top 20 cited documents, and research trends in the field of deepfake have been included.
RESULTS: The analysis highlights a substantial increase in deepfake publications from January 2019 to July 2023. Out of the 8 document types identified 38% are article publications. In addition, from the journal articles it has been depicted that the journal source entitled "Advances in Computer Vision and Pattern Recognition" holds Q1 status with 8.3% publications in the deepfakes domain during the targeted year range. Moreover, the data visualizations reveal the growing international collaboration, with the USA as the most prolific country in deepfake research.
CONCLUSION: Despite numerous reviews on deepfakes, there has been a notable absence of comprehensive scientometric analyses. This paper fills this gap through a bibliometric study using the Scopus database as urderlying source. The analysis includes keyword analysis, leading research-contributing institutes, co-country collaboration, and co-keyword occurrence. The findings offer valuable insights for scholars, providing a foundational understanding including document types, prominent journals, international collaboration trends, and influential institutions and offering valuable guidance for future scholarly pursuits in this evolving field.

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1. Introduction

The rapid dissemination of information across various platforms, such as social media, television, and various online services contributes to the facilitation of timely communication. This has arisen concerns about the technology's potential for unethical usage, such as spreading false information or causing harm to individuals through the manipulation of digital media [1]. Artificial neural network (ANN)-based technologies are rapidly advancing that helped manipulate multimedia content using a machine learning approach called deep learning [2]. Deep learning (DL) approaches became famous in social media due to their ability to produce highly naturalistic videos and pictures of individuals expressing something in a way they never actually did [1].
Combining "Deep Learning" and "Fake" creates a

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new term "Deepfake". Face swapping, particularly in pictures and videos, or changing people's expressions is known as the "Deepfake approach" [3]. An example of a deepfake created using the open-source tool FaceFusion 2.5.0 is shown in the Figure 1, where the face of the source person is swapped with that of the selected target person's face.

Figure 1. Example of Deepfake

The '2023 State of Deepfakes Report' from 'Home Security Heroes,' a U.S.-based web security services company, points out that deepfake videos witnessed a fivefold growth since 2019 [4]. Deepfake technology received substantial attention in entertainment industry in 2021 as a result of a prominent occurrence. During that period, In a Cadbury ad campaign, the renowned Bollywood actor Shah Rukh Khan not only extends Diwali greetings but also acknowledge numerous local businesses by name. This is achieved through a deepfake representation of Khan that skillfully incorporating the names of small businesses chosen by Indians nationwide [5]. During the Russian invasion of Ukraine in 2022, a notable incident unfolded wherein Ukrainian President Volodymyr Zelenskyy was portrayed directing his troops to capitulate to the Russian forces [6]. Different series have implemented deepfakes on YouTube channels; for example; Deep Fake Neighbour Wars. This is a British comedy TV series that uses deepfake technology to create videos of celebrities engaging in inane conflicts [7]. Rashmika Mandanna and deepfakes are nowadays inextricably linked in India. She was captured heading into a lift dressed in a black yoga suit in a deepfake video that went viral online. However, it eventually emerged that the first video, which featured Zara Patel, a force in web entertainment, had been altered to look like Rashmika Mandanna using sophisticated technology. She addressed thoughts about these types of recordings and how these affect people's security in a statement that she posted on her popular social media platforms [8]. Although this technology is frequently employed for malevolent purposes with negative intentions, there are some positive applications for it as well, such as the legendary footballer David Beckham, who addressed in nine distinct tongues to raise awareness of a malaria campaign [9]. Deepfake videos are creating alarming situations for the general public. As technology develops and gets better, it becomes more and more challenging to differentiate between real and fake information [10]. Although there are ongoing efforts to create tools that can detect and stop deepfakes. Owing to the potential risks and privacy vulnerabilities, the study of deepfake detection has attracted a lot of interest from professionals and academics, which has resulted in the creation of several deepfake detection methods [11–13]. The novelty of this work is to provide the comprehensive analysis of the subject deepfakes. The analysis is based on various aspects such as key authors, participating countries and specific institutions who are active in this specified field. In this research, the primary source of data is Scopus. The data obtained from Scopus is utilized across various dimensions such as Co-keyword based searches, Co-country based searches, top document types, and top publication sources. The tools named VOSviewer and R-Studio are used to examine the collaborations between institutions, authors and countries.

1.1. Objectives

The objective of this bibliometric study is to assess the scopus database aiming to gain a deeper understanding for the following in the field of deepfakes.

(i) To study the research trends for detecting deepfakes.

(ii) To figure out top countries contributing research in the field of Deepfakes from 2019 to 2023, July.

(iii) To analyse the research trends based on abstract, titles, and keywords analysis.

(iv) To study the literature of top 20 global cited documents for deepfake detection.

(v) To evaluate top sources, authors, and institutions contributing in research.

(vi) To analyse the major challenges related to the area.

The primary objective of undertaking this study is to critically analyse and assess the current trajectory of research within this particular field, with a specific focus on discerning the potential future developments that are likely to emerge. Additionally, a key aim of this research is to identify and propose potential regulatory measures and legal frameworks that may be deemed necessary in order to effectively mitigate and address the negative repercussions that can arise as a result of the dissemination of misleading and fabricated information facilitated by the proliferation of deepfake technology. Moreover, there is not much of the existing literature targeting to the bibliometric analysis of deepfakes.

1.2. Research Questions

This work provides a bibliometric analysis of the current research in deepfake generation and detection from last 4.5 years. In the scope of this research, our objective is to utilize bibliometric analysis as a means to investigate pivotal research questions.

RQ1: What are the various applications of deepfakes?
RQ2: What are the various trends and challenges in the detection of deepfakes?
RQ3: What are the most relevant sources that work on the creation and detection of deepfakes?
RQ4: What are the most relevant countries working on deepfakes?
RQ5: Who is the most relevant author with affiliations between 2019 and 2023 ,July?
The primary focus of these research questions is to form the core of our investigation and direct our research into the scholarly output in this field. This analysis will help researchers, academicians, policy makers, and individuals to determine emerging trends in the field of deepfakes. The research will help buddy trying to make progress in the area of deepfakes.
To make it easier to understand and navigate, a structured approach is adopted in this analysis where Section 2 outlines the methodology of deepfakes. Section 3 reveals State-of-the-Art methods in deepfakes. Applications of deepfakes are explained in Section 4. In Section 5, the outcomes and corresponding discussion are provided. Section 6 provides the top 20 publication sources. Further, top 10 countries deploying deepfakes are presented in Section 7. Section 8 enlists the top 20 authors contributing most in the research of deepfakes. Section 9 entitles the conclusion of this review analysis which will further help the researchers to have more insight in the context of deepfakes.

2. Methodology

The methodology illustrates a systematic research approach to examine the academic literature as shown in figure 2.

This procedure originates with a description of research objectives and scope, followed by the gathering of related bibliographic data from the Scopus database. Data is analyzed and visualized by using the tools VOSviewer and RStudio, allowing the study of co-citation, bibliographic coupling, and co-authorship networks.

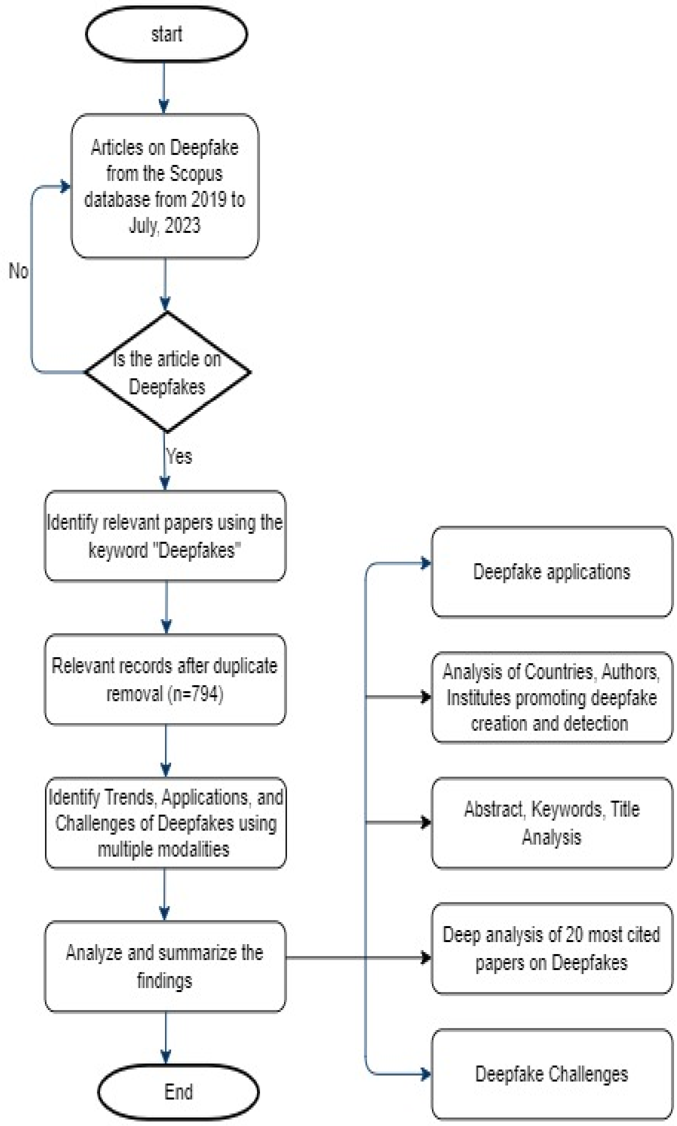


Figure 2. Methodological framework for data analysis

3. State-of-the-Art Methods in Creation and Detection of deepfakes

Advancements in deep learning have significantly enhanced the development of technology for facial modification. Some deep learning techniques that can be used for the creation and detection of deepfakes for images, videos, and audios are GANs, Convolutional Neural Networks (CNNs), and Recurrent Neural Networks (RNNs).
The most popular deep neural network model for detection is CNN. CNNs are deep learning classification neural networks that consist of multiple layers, each contributing unique features to the network. CNNs have gained popularity in deepfake detection due to their effectiveness in identifying and extracting critical image regions. They are particularly adapt

at recognizing frame areas with high spatial and temporal dependencies, such as facial regions or specific facial features. This capability enables the detection of inconsistencies between authentic images and deepfakes. While CNNs are utilized across various deepfake detection model, each model applies them in its unique manner. Another use of an artificial neural network that can learn characteristics from sequence data is the recurrent neural network (RNN). RNN stores information sequences from previous inputs in internal memory, making it useful in many fields like speech recognition and natural language processing [14–17].
The LSTM (Long Short-Term Memory) is a type of artificial RNN developed to successfully handle dependency over time. LSTM can maintain critical information throughout the data sequence by including a feedback connection. Its widespread use in domains dealing with time series data, such as processing, classification, and predictive modeling, has been widely recognized [18, 19]. The readers can find a review of current deepfake detection approaches in Table 1. This table also presents different pre-trained CNN models including VGG16 and ResNet50 for the classification of deepfake images and videos [20, 21].
GAN is one of the most challenging deep learning algorithms for the creation of deepfakes. GAN is build up using two neural network viz. a generator and discriminator. The generator can be used to create synthesized image same as real image and the discriminator is used to discriminate the created synthesized image as real or fake. The deep-fake manufacturing process based on GANs is dependent on the generator's capacity to deceive the discriminator. This produces deep fakes that closely resemble real videos, making them difficult to detect with the human eye [22]. A review of significant literature of deepfake using GAN is provided in Table 2.
In this research, the data of deepfake literature is retrieved from the Scopus database which ranges from the year 2019 to 2023. All the papers cited in the research have been published in various reputable journals, and this information is detailed in Table 5. The survey can guide future research endeavours by identifying gaps in knowledge and areas requiring further investigation, ultimately contributing to the advancement of techniques for deepfake detection and prevention.

4. Applications

RQ1: What are the various applications of deepfakes? The term deepfake is an intelligent use of artificial intelligence to craft remarkably realistic and sometimes highly misleading multimedia content has become prevalent. while some content is beneficial, but

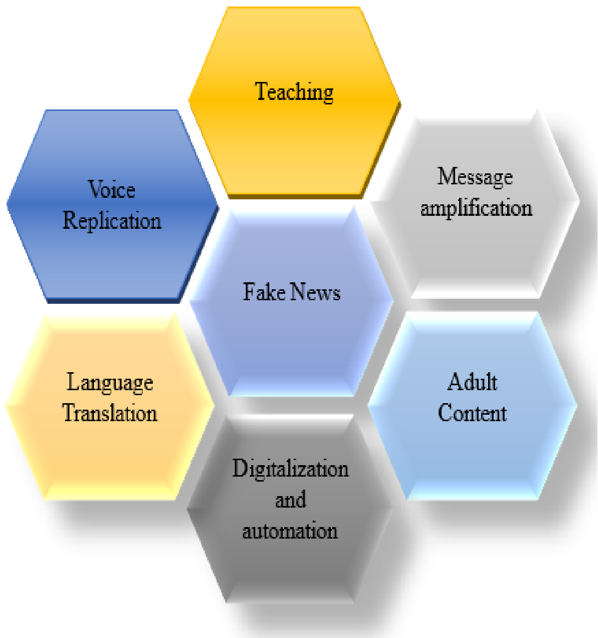


Figure 3. Deepfake applications

conversely, some applications pose ethical challenges. Figure 3 depicts some of the applications of deepfakes.

4.1. Fake News

Deepfakes can be used to create convincing fake news. In the world of politics, the fake news created in 2018 by Hollywood filmmaker Jordan Peele featured former US President Obama speaking about how fake news can be dangerous, as well as mocking the president of the moment, Trump[37].

4.2. Adult Content

The use of deepfake technology to produce explicit content incorporating the likeness of actual individuals without their authorization raises substantial ethical concerns.Victims of pornographic deepfakes frequently include celebrities, mainly because of their photos and videos are easily accessible. The utilization of law as a means for social reform, functioning as a tool of social engineering should enable the progression of developments within society[38].

4.3. Digitalization and automation

This technology is heavily used to create new works of art, engage audiences, and provide them with distinctive experiences. Salvador Dal's museum in St. Petersburg, Florida recently gave visitors the ability to connect more closely with his life and get to know him by using artificial intelligence. Deepfakes also shows

Table 1. Techniques and datasets used by various researchers for the detection

Reference / year	**Modality** Image	Video	**Method** Model	**Evaluation Dataset** FaceForensics++	Celeb-DF	DFDC	Other/ Custom	**Performance** ACC	AUC
[14] 2023	-	✓	Hybrid CNN	-	-	✓	-	95.75	-
[23] 2023	✓		SVM	-	-	-	✓	88.33	-
[15] 2023	-	✓	3D-CNN		-	-	-		
[16] 2023	-	✓	CNN	-	-	✓	✓	-	0.81
[17] 2023	-	✓	CNN	✓	-	-	-	-	94.7
[24] 2023	-	✓	MTCNN	✓	-	-	-	-	87.76
[25] 2023	-	✓	CNN	-	-	✓	-	99	-
[26] 2023	-	✓	CNN, LSTM	-	✓	✓	-	99.24	-
[27] 2022	-		CNN, LSTM	✓	✓	✓	-	91.21	-
[28] 2021	✓	-	Canny Edge Detection, Hough Transform	-	-	-	✓	-	94
[19] 2021	-	✓	Convolutional LSTM-based Residual Network (CLRNet)	✓	-	-	✓	93.86	-
[20] 2020	✓		Xception Networks	✓	✓	✓	-	-	75
[29]2020	✓	-	ResNet, Gram-Net	-	-	-	✓	80.55	-
[30] 2020	✓	✓	FakeSpotter	-	✓	-	-	-	66.8
[18] 2020	-	✓	LSTM	✓	-	-	-	94.29	-
[31] 2020	-	✓	CNN	✓	-	-	-	-	99
[21] 2019	✓	✓	VGG16, ResNet50, ResNet101, ResNet152	-	-	-	✓	-	84.5

Table 2. Techniques and datasets used by various researchers for the creation

Reference/year	**Modality** Image	Video	**Method** Model	**Database** CelebA-HQ	CelebA	Other	**Performance** FID	SSIM
[22] 2023	✓	✓	Deep Convolution GAN	-	✓	-	49.3	-
[26] 2023	-	✓	GAN	-	-	✓	9.17	-
[32] 2020	✓	-	GAN	-	-	✓	29.31	-
[33] 2020	✓	-	StarGAN v2	✓	-	-	23.9	-
[34] 2020	✓	-	Encoder-Decoder	-	-	✓	12.17	0.717
[35] 2019	-	✓	FSGAN	-	-	✓	-	0.51
[36] 2019	✓	-	STGAN	-	-	✓	-	0.948

Nicolas Cage acting in movies that he's never been in, like Indiana Jones or Terminator 2 [39].

4.4. Teaching

In the field of education, deepfake technology offers a diverse range of prospects. Over an extended period, educational institutions and instructors have incorporated various forms of media, including audio and video, in their classrooms. The integration of AI-generated synthetic media can reanimate historical figures, contributing to a more engaging and dynamic educational setting [39].

4.5. Message amplification

Deepfake technology can be used to produce extremely naturalistic videos, and pictures of individuals expressing something in a way they never actually did. In the year 2019, it was reported that the U.S. Democratic Party deep faked its chairman Tom Perez to highlight the possible threat of fakes to the 2020 presidential election [40, 41].

4.6. Voice Replication

Deepfake techniques can be used to replicate an individual's voice and make them say things they never spoke [42]. In 2019, scammers employed AI-based software to replicate the voice of a chief executive and execute a deceptive scheme, demanding a fraudulent transfer of USD 243,000. To counter such threats, it is crucial to possess the capability to identify deepfake audios [43, 44].

4.7. Language Translation

Deepfake technology can be utilized to dub movies into several languages by creating lip-synced audio and video in the targeted language [45]. In february 2023, two videos featuring Delhi BJP president Manoj Tiwari demonstrated the impact of deepfakes. These films showed him making a bilingual election offer in Haryanvi and English before the 2020 assembly elections. Both were fakes [46].

5. Results and Discussions

RQ2: What are the various trends and challenges in the detection of deepfakes?

5.1. Document types on deepfakes

There is a combined count of 794 research papers based on scopus indexing database dedicated to the subject of deepfake technology. As illustrated in figure 4, 379 papers are categorized as conference papers and 298 are journal papers. The remaining papers consist of a review, editorial, conference review, short reviews, editorials and book chapters [47].

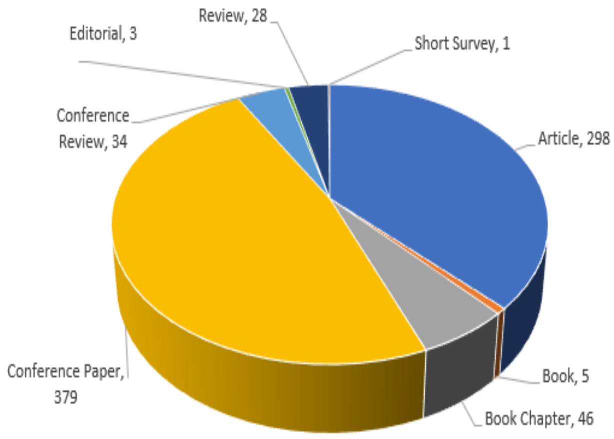


Figure 4. Documents types on Deepfakes

5.2. Publication variations on deepfakes

The data for last four and half years has been referred to carry the bibliometric analysis of publication variation. The count of publications has constantly increasing in the last three years from 2021 to 2023, July as shown in the figure 5. A lot of work is going on for the detection of deepfakes. According to the Gartner Hype Cycle that shows this work will last for at least 5 years. It offers a view of emerging technologies and applications over some time and can be used as a source of knowledge to guide deployment within the framework of the business objectives. It also minimizes the risk associated with technology investment decisions [48, 49].

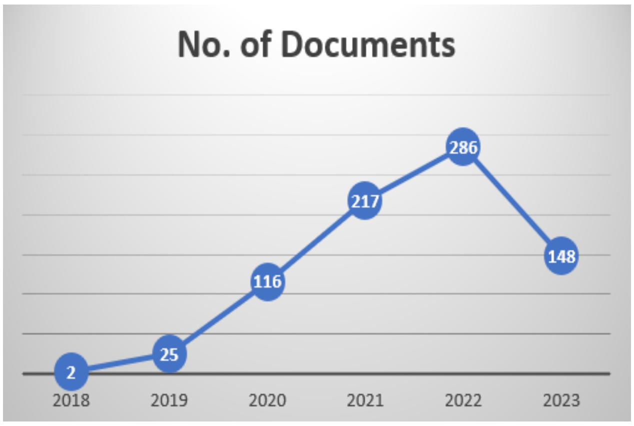


Figure 5. Publication swing on Deepfakes

5.3. Top 15 Institutes contributing documents on deepfakes

The table 3 demonstrates the leading 15 institutions that are providing content related to deepfakes. The table is arranged in decreasing order, commencing with 43 which is the highest number of articles. When examining the table based on continents, Asia emerges as the dominant region, with 12 institutes included in the top 15. Among a total of 15 universities, 9 of them are located in China. This implies that the majority of the work done is concentrated in China. Following Asia, the United States is the next country, with 2 institutes represented in the table, marking Europe as the third country in the rankings with one institute.

5.4. Abstract analysis of documents on deepfakes

Within the framework of a research paper, an "abstract" provides a summarized overview of the paper's content.

Figure 6. Top 50 abstract word spectrum

The primary aim of the abstract is to offer readers a rapid glimpse into the research and its significant discoveries, enabling them to assess the paper's relevance to their interests.

Frequently, it incorporates a set of keywords that assist other researchers in discovering the paper within databases and search engines[50].

In this section, we have analyzed the 50 most frequently utilized words obtained through abstracts utilized by various researchers in the past 4.5 years from the Scopus database, aiming to identify current recommendations and trends. The word cloud, arranged according to the occurrence of matching terms, is displayed in figure 6.

The articles focus on different aspects of deepfake detection, such as the use of artificial intelligence, machine learning, GAN approach and face manipulation methods. Some articles also discuss the ethical and philosophical implications of deepfakes, as well as the evolution and trends in deepfake technology [51].

5.5. Title Analysis of documents on deepfakes

In the realm of bibliometrics, title analysis involves the inspection and assessment of the titles of scholarly materials such as academic papers, articles, books, and similar works. Its purpose is to serve as a method for evaluating and comprehending the patterns, subjects, and distinctive attributes of research within a specific field or discipline. In this segment, we analyze the prevailing trends and standards by scrutinizing the 50 most frequently utilized words found in the titles of research publications from 794 that have been listed in the Scopus database over the past 4.5 years.

As depicted in the figure 7, the most commonly employed keywords in title analysis are deep learning, fake news, video detection and neural features. This cloud, presented in a visually structured format, aids readers in grasping the significance of each term and its position within the bibliometric dataset's hierarchy. This, in turn, facilitates the identification of the most critical topics and trends within the field [52].

Figure 7. Top 50 title word spectrum

5.6. Keywords and co-keyword analysis of documents on deepfakes

The analysis of keywords is another core element in bibliometric studies, which employ quantitative

Table 3. Top Institutes contributing documents on Deepfakes

Affiliation	Articles
Sungkyunkwan University, Seoul, South Korea	43
Universidad Autonoma De Madrid, Madrid, Spain	35
Nanyang Technological University, Singapore	31
University of Chinese Academy of Sciences , Beijing, China	31
Beijing University of Technology, China	28
Delhi Technological University, Delhi	28
Sun Yat-Sen University, Guangzhou, China	25
Beijing Jiaotong University, Beijing, China	23
Purdue University, United States	23
University of California, Los	22
Beijing University of Posts And Telecommunications, China	21
Institute Of Information Engineering, Beijing, China	20
Shanghai Jiao Tong University, china	20
Wuhan University, China	20
Institute of Automation, China	19

methods to assess and gauge the influence of scholarly literature in a particular domain or subject area. Through quantifying the frequency and simultaneous appearance of keywords, scholars can acquire valuable understandings regarding the progression of expertise within a specific domain [53]. Figure 8 presents the term ’deep learning’ stands out prominently having a frequency of 277.

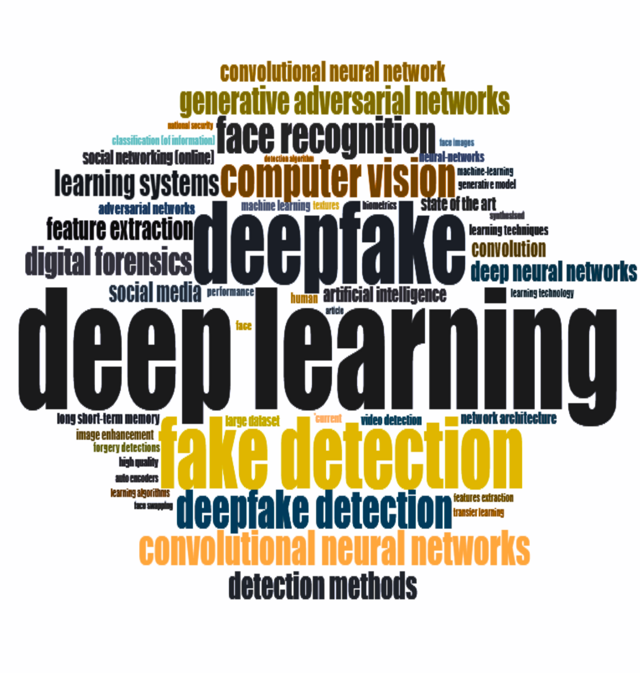


Figure 8. Top 50 keywords

Following closely with 188 occurrences, the term ’deepfake’ emphasizes the prevalence of research. The occurrence of the term ’fake detection’ 162 times highlights the focus of approaches to identify deceptive practices. There are terms associated with distinct technologies like ’convolutional neural networks’,’generative adversarial networks’, and ’long short-term memory’ in cloud showcasing a broad spectrum of approaches.On the whole, the word cloud reflects the diverse aspects of contemporary research in computer vision, digital forensics and associated disciplines presenting a glimpse into prevailing themes and technologies.

Keyword co-occurrence holds significant importance in the domains of bibliometric analysis and information retrieval. This concept pertains to the occurrence of two or more keywords or terms together within a document, which could be a research paper or an article. Analyzing the co-occurrence of keywords offers valuable perspectives on the connections between concepts, subjects, and ideas present within a collection of literature. As illustrated in figure 9 , in the context of a research topic deepfakes, the simultaneous presence of keywords such as "deepfake", "deep learning", "deepfake detection," and " artificial intelligence", implies a semantic linkage among them. In the following depicted figure maximum number of occurrences of the keyword “deepfakes” is 253 and the link strength is 175 which describes the degree of association or connection between different components in a network of scholarly publications [54].

5.7. Co-country Analysis

The figure 10 presents a co-country representation in which the major analysis unit is country. The figure details about the total link strength developed among

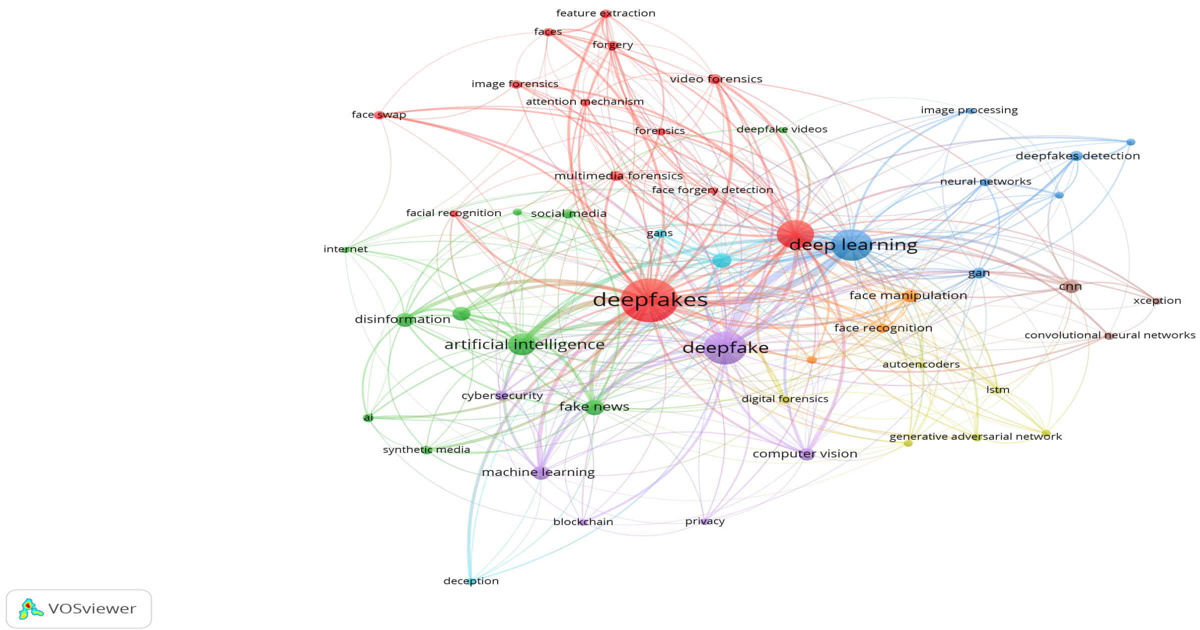


Figure 9. Co-keyword occurances on Deepfakes

different countries corresponding to the number of documents published in the field of deep fakes. The maximum link strength is developed by US with a total value of 84. India ranks third among 33 countries with a link strength of 39 and 124 total number of documents.

5.8. Top globally cited documents on deepfakes

This segment has focused on the 20 most referenced published documents in the field of deepfakes over the past 4.5 years. The ranking is presented in Table 4, arranged in descending order based on the corresponding citation index. The publication referenced in the initial row of the table, holds the highest citation score of 404 citations. This study presents a large-scale deepFake video dataset, Celeb-DF, containing 5,639 high-quality celebrities, demonstrating the escalated challenges posed by the current detection methods and datasets [55]. The authors referred in second row aimed that face editing in videos is a concern due to artefacts resembling computer vision issues. Simple visual artefacts like deepfakes and Face2Face can effectively expose manipulations, achieving Area Under Curve (AUC) values of up to 0.866 [56]. The authors investigates the possibility of creating a universal detector for distinguishing real images from CNN-generated ones, using a dataset of fake images from 11 CNN-based models [57]. In this survey techniques were reviewed for manipulating face images, including deepFake methods, and methods to detect them [58]. It discusses four types of facial manipulation techniques, the latest generation of deepfakes, and the future trends [59]. Recent advancements in multimedia content realism offer exciting applications in creative arts, advertising, and video games. However, it also poses security threats, requiring automated tools to detect fake media and analyses methods for visual media integrity verification [60]. The author analysed 84 online news articles to understand deepfakes, AI-generated videos, their benefits and threats, and potential solutions. The study suggested legislation, corporate policies, education, and technology development can combat these threats, providing cyber security and AI entrepreneurs with business opportunities [61]. The researchers revealed that deepfakes, created by AI, reduce trust in public discourse and contribute to uncertainty, undermining public discourse and online civic culture in democratic societies [62]. The study represented a framework using Ethereum smart contracts to trace the provenance and history of digital content, even when copied multiple times. The solution, focusing on video content, ensures authenticity by tracing content to a trusted source [63]. Deepfakes, powered by AI and machine learning, create fake content harder for humans to detect. Organisations must prepare for societal impact and implement the Real framework to manage risks [64]. This research brings attention to a drawback in generative convolutional deep neural networks, specifically prevalent GAN architectures, in

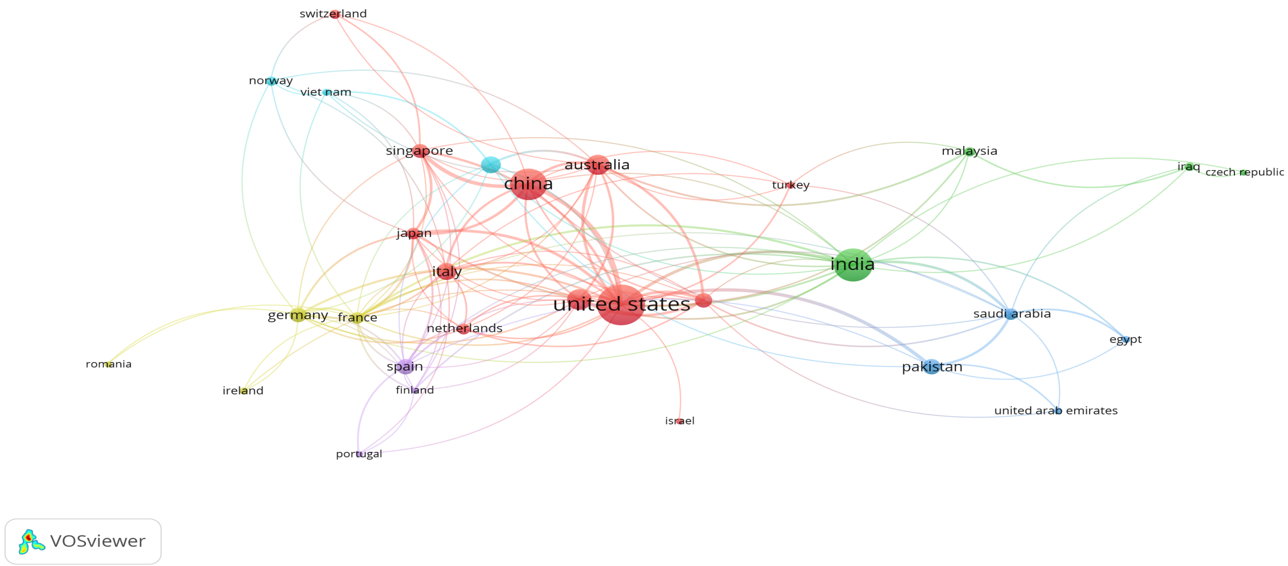


Figure 10. Co-Country Analysis

which mimicking the spectral distribution was one of the most challenging task.This issue was addressed by introducing a novel method named as spectral regularization by optimizing the training objective [65].

A two-branch network structure for deepfake detection focused on amplifying artefacts while suppressing high-level face content. The method has shown promising results on FaceForensics++, Celeb-DF, and Facebook's DFDC preview benchmarks, with low false alarm rates [66]. The research by authors proposed a novel approach to detect fake GAN-generated images using co-occurrence matrices and deep learning, achieving over 99% classification accuracy on two diverse GAN datasets [67]. The authors publicized the analysis on deepfakes of human faces to detect forensic traces in images. It uses the expectation maximization algorithm and ad-hoc validation to distinguish architectures and generation processes [68].The study proposed a new deepvision algorithm for detecting deepfakes in videos, analyzing changes in blinking patterns. This method uses a heuristic approach and machine learning to verify anomalies, achieving an 87.5% accuracy rate in seven out of eight video types [69]. A learning-based method detected real and fake deepfake multimedia content by extracting audio and visual modalities and perceived emotions, utilizing a deep learning network and achieving high accuracy [70]. The authors investigated a new dataset, WildDeepfake, to better support the detection against real-world deepfakes. The dataset contains 7,314 face sequences from 707 internet-generated videos and evaluate baseline detection networks [71]. The authors worked on deepfakes security and privacy risks by considering computer generated image instead of person's face. They proposed OC-FakeDect, a one-class anomaly detection method, overcoming data scarcity limitations and achieving 97.5% accuracy on the FaceForensics++ benchmark dataset [72]. The paper presented the first publicly available dataset of deepfake videos generated from the VidTIMIT database. It shows that face recognition systems are vulnerable to these videos, with 85.62% and 95.00% false acceptance rates, requiring detection methods [73]. The study presented in this research showed that the art world is filled with reproductions, including fakes and forgeries. The authenticity of these artefacts is crucial, but the reality is complex. Forgers like John Myatt and Magritte have painted false works, while digital technologies further complicate the understanding of art [74]. This article analyzed visuals in COVID-19 misinformation, revealing that over half of the pieces serve as evidence for false claims, with most mislabelled. The analysis highlights the importance of examining visual content in misinformation [75].

5.9. Challenges

Deepfake technology comes with many drawbacks, from possible misuse to ethical and legal issues. The

Table 4. Top 20 Globally Cited Documents

Authors	Year	Title	Total Citations
Li Y., et al.[55]	2020	Celeb-DF: A Large-Scale Challenging Dataset for DeepFake Forensics	404
Matern F.,et al.[56]	2019	Exploiting Visual Artifacts to Expose Deepfakes and Face Manipulations	382
Wang S., et al.[57]	2020	CNN-Generated Images Are Surprisingly Easy to Spot... for Now	291
Tolosana R., et al.[59]	2020	Deepfakes and beyond: A Survey of face manipulation and fake detection	256
Verdoliva L.[60]	2020	Media Forensics and DeepFakes: An Overview	242
Westerlund M.[61]	2019	The Emergence of Deepfake Technology: A Review	237
Vaccari C. and Chadwick A.[62]	2020	Deepfakes and Disinformation: Exploring the Impact of Synthetic Political Video on Deception, Uncertainty, and Trust in News	178
Hasan HR. and Salah K.[63]	2019	Combating Deepfake Videos Using Blockchain and Smart Contracts	161
Kietzmann J., et al.[64]	2020	Deepfakes: Trick or treat?	124
Durall R., et al.[65]	2020	Watch Your Up-Convolution: CNN Based Generative Deep Neural Networks Are Failing to Reproduce Spectral Distributions	122
Masi I., et al.[66]	2020	Two-Branch Recurrent Network for Isolating Deepfakes in Videos	104
Nataraj L., et al.[67]	2019	Detecting GAN generated Fake Images using Co-occurrence Matrices	102
Guarnera L., et al.[68]	2020	DeepFake Detection by Analyzing Convolutional Traces	101
Jung T., et al.[69]		DeepVision: Deepfakes Detection Using Human Eye Blinking Pattern	88
Mittal T., et al.[70]	2020	Emotions Don't Lie: An Audio-Visual Deepfake Detection Method using Affective Cues	82
Zi B., et al.[71]	2020	WildDeepfake: A Challenging Real-World Dataset for Deepfake Detection	79
Khalid H. and Woo SS.[72]	2020	OC-FakeDect: Classifying Deepfakes Using One-Class Variational Autoencoder	70
Korshu P. and Marcel S.[73]	2019	Vulnerability assessment and detection of Deepfake videos	63
Floridi L.[74]	2018	Artificial Intelligence, Deepfakes and a Future of Ectypes	61
Brennen JS., et al.[75]	2021	Beyond (Mis)Representation: Visuals in COVID-19 Misinformation	60

following are some significant challenges posed by deepfakes.

Forged Broadcast. It is likely for the journalistic industry that the public will confront the loss of trust in the media due to forged news. Deepfakes pose more of a threat in comparison to "traditional" fake news because they are difficult to be identifed and consumers are more inclined to believe that fake news is genuine. The technology permits the production of false news clips that put the credibility of journalists at stake. So deepfake places stress on journalists who are struggling to separate real news from fake [76].

National Security. Deepfake poses a threat to national security through disseminating propaganda and interfering with elections. In the escalating situation on the border between India and Pakistan in the year 2019, Reuters found fake videos related to the issue, where most of them were older videos from different events. In search of eyewitness videos on the mass shooting that took place in Christchurch, New Zealand, Reuters

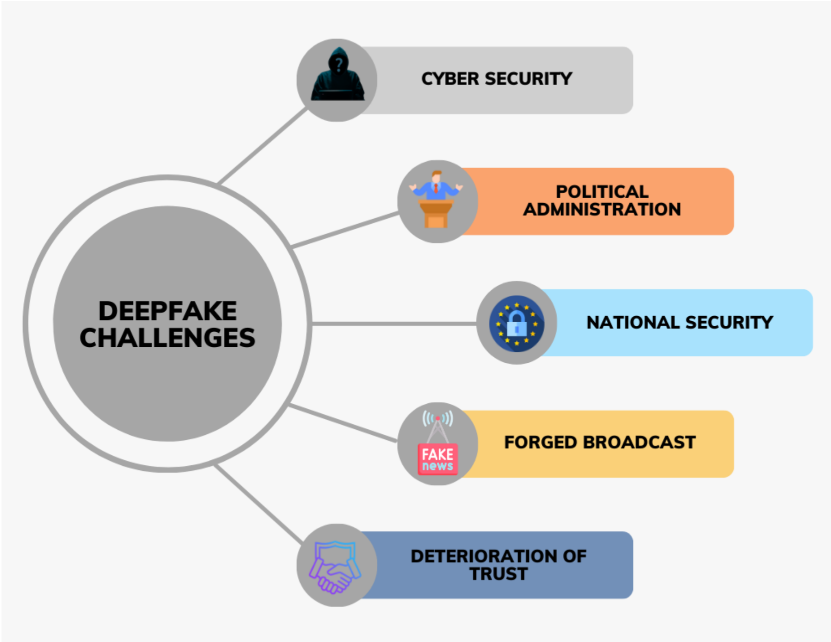


Figure 11. Deepfake Challenges

was able to find a video that claimed that it showed the scene when a suspect was killed by police. They quickly realized it was related to a different event in the U.S.A. The suspect in the Christchurch shooting wasn't killed. So fake news could be used to undermine national security by spreading political propaganda and disrupting elections[77, 78]. Legal considerations are crucial to ensuring responsible and ethical use of deepfake technology to prevent potential legal consequences.

Deterioration of Trust. People may loose trust on media and information sources in general as a result of the proliferation of deepfakes, since they may start to doubt the veracity of audio and visual content available on web and data uploaded and circulated on internet. This would decline the trust and may have wider societal repercussions[79].

Political Administration. Deepfake technology received substantial attention in politics recently as a result of a prominent occurrence. In March 2022, a deepfake appeared on social media featuring Volodymyr Zelenskyy, the president of Ukraine, convincing his warriors to capitulate to Russian forces. Shortly after, the genuine Zelenskyy shared a Facebook video where he denied the prior remark as a modified fake. Experts pointed out that this specific instance was a relatively unrealistic deepfake. Managing political deepfakes poses considerable difficulty in terms of regulation [80].

Cyber Security. Cybersecurity concerns are another risk that deepfakes pose. The world of business has expressed an interest in securing themselves from frauds that are viral, since fakes can be used for manipulating stock prices and markets for instance, by showing the chief executive making vulgar or racist remarks or announcing a fake merger and making false claims of the financial loss or bankruptcy, even portraying the fakes as doing something wrong [81]. To address these problems, legislators, law enforcement, technology developers, and the general public must work together. Promising approaches include developing advanced techniques for detecting them, developing clear moral guidelines, and enacting laws designed to mitigate the negative consequences of deepfakes. Establishing suitable limits for the ethical utilization of this technology remains a persistent challenge.

6. Top 20 Publication sources on deepfakes

RQ3: What are the most relevant sources that work on the creation and detection of deepfakes?

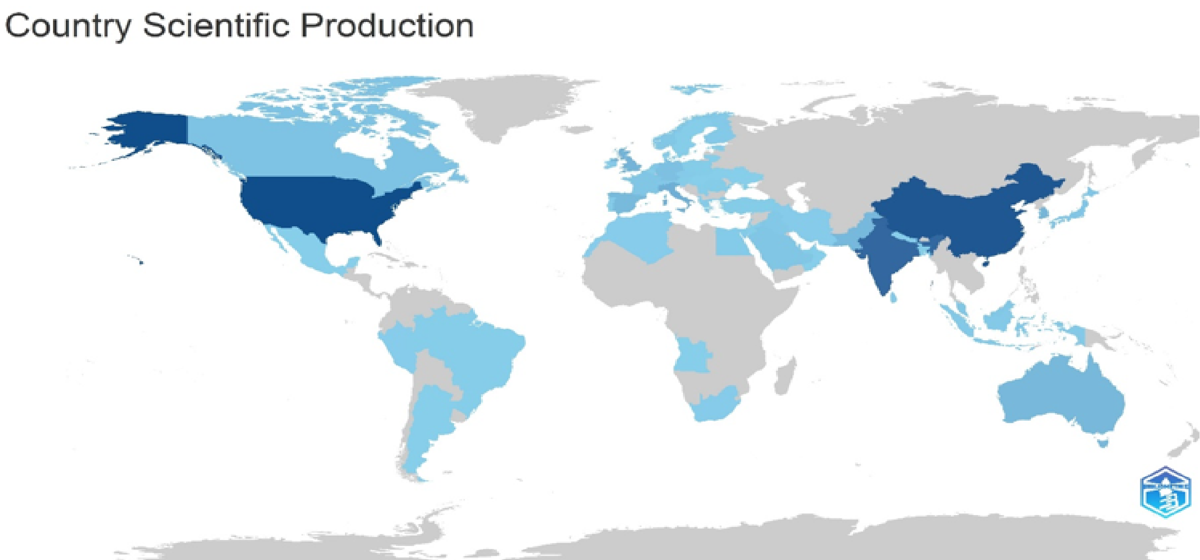
The table 5 illustrates the top 20 publication sources in the field of deepfakes detection and generation over the last 4.5 years.

Table 5. Top 20 Publication sources on Deepfakes

Sources	Articles	Impact Factor	Cite Score	H-Index	Quartile	Publisher	Country
Lecture Notes In Computer Science	25	1.27	2.2	446	Q3	Springer Nature	Germany
International Symposium On Electronic Imaging Science And Technology	19	NIL	NIL	26	NIL	NIL	United States
Lecture Notes In Networks And Systems	13	0.54	0.7	27	Q4	Springer	Switzerland
Advances In Computer Vision And Pattern Recognition	12	0.82	2.4	25	Q1	Springer Science and Business Media	United States
Ceur Workshop Proceedings	11	0.39	1.1	62	NIL	NIL	United States
Synthese	11	1.5	2.6	77	Q1	Springer	Netherlands
Convergence	10	3.56	4.8	49	Q1	SAGE Publications Inc.	United States
IEEE Access	10	4.82	9	204	NIL	Institute of Electrical and Electronics Engineers Inc.	United States
IEEE Computer Society Conference On Computer Vision And Pattern Recognition	9	23.46	40.7	470	NIL	IEEE Computer Society	United States
ACM International Conference Proceeding Series	8	0.5	1.1	137	NIL	Association for Computing Machinery	United States
Communications In Computer And Information Science	8	0.53	1	62	Q4	Springer Science and Business Media	Germany
Multimedia Tools And Applications	8	4.2	6.1	93	Q1	Springer	Netherlands
Conference On Human Factors In Computing Systems	7	0	8.3	216	NIL	NIL	United States
Cyberpsychology, Behavior, And Social Networking	7	6.41	8.7	169	Q1	Mary Ann Liebert Inc.	United States
Journal Of Imaging	7	3.75	4.4	34	Q2	Multidisciplinary Digital Publishing Institute (MDPI)	Switzerland

Table 5 continued from previous page

Sources	Articles	Impact Factor	Cite Score	H-Index	Quartile	Publisher	Country
Porn Studies	7	1.68	2	16	Q1	Taylor and Francis Ltd.	United Kingdom
Expert Systems With Applications	6	10.35	12.6	1.873	Q1	Elsevier Ltd.	United Kingdom
IEEE Transactions On Circuits And Systems For Video Technology	6	8.43	11.2	1.491	Q1	Institute of Electrical and Electronics Engineers Inc.	United States
Lecture Notes In Electrical Engineering	6	0.37	0.6	0.147	Q4	Springer Verlag	Germany
Applied Sciences (Switzerland)	5	3.1	4.5	0.492	Q2	Multidisciplinary Digital Publishing Institute (MDPI)	Switzerland
ICASSP, IEEE International Conference On Acoustics, Speech And Signal Processing	5	3.59	6.3	1	NIL	Institute of Electrical and Electronics Engineers Inc.	United States
IEEE Transactions On Information Forensics And Security	5	8.03	14.7	2.65	Q1	Institute of Electrical and Electronics Engineers Inc.	United States



Rank	Country	Frequency	Rank	Country	Frequency
1st	USA	524	6th	SOUTH KOREA	94
2nd	CHINA	483	7th	AUSTRALIA	84
3rd	INDIA	412	8th	PAKISTAN	83
4th	ITALY	120	9th	SPAIN	78
5th	UK	101	10th	GERMANY	53

Figure 12. Countries Scientific production over time on deepfakes

This table contains the details of sources with the maximum number of articles published in it, the impact factor of the source, cite score, SJR (SCImago Journal Ranking), H-Index, Quartile, Publisher, and the country of the publications [82].

This bibliometric analysis states that the maximum articles for deepfakes have been published in the Springer Nature journal named " Lecture Notes in Computer Science" with a total of 25 publications. The " International Symposium On Electronic Imaging Science And Technology " follows on the list, boasting a total of 19 publications.

The remaining sources have fewer than 15 publications in this specific field. Out of these top 20 sources, 8 sources have the highest Quartile which is Q1. "IEEE Computer Society Conference On Computer Vision And Pattern Recognition" has the highest impact factor which is 23.46. Through this analysis, one can easily find out the best publication source, that can be used to publish one article. The analysis also reveals that half of the published documents originate from journals, while a quarter come from conferences, and another quarter are derived from book chapters.

7. Top Countries contributing documents on deepfakes

RQ4: What are the most relevant countries working on deepfakes?
Deepfake technology is of excessive significance worldwide because it carries broad and implications across several sectors. The involvement of top five countries (China, India, Italy, USA, UK) in advancing the field of deepfakes has been noteworthy as shown in figure 12.
The table comprehensively outlines the rankings of the top 10 country's scientific production in the field of deepfakes. The map is produced by biblioshiny. Various tones of blue represent varying levels of productivity: dark blue signifies high productivity, while grey indicates the absence of articles [83]. At the forefront is the United States holding the 1st rank and boasting an impressive frequency of 524 publications highlighting its substantial contributions to the advancements in this domain. In a near position, China secured the 2nd rank with a frequency of 483. Holding the 3rd position, India exhibits a significant presence with a frequency of 412 publications. The ranking system offers valuable insights into the research prominence of each country within the specified area. The ranking system of the remaining countries(Italy, UK, South Korea, Australia, Pakistan, Spain, and Germany) offers insights into the research prominence with the frequency ranging from 120 to 53.

8. Top 25 authors contributing to research on deepfakes

RQ5: Who is the most relevant author with affiliations between 2019 and 2023 july?
In the era of digitization, digital content serves as the primary source of information and communication, ensuring its concern for authenticity. Deepfake technology, while having legitimate uses in sectors such as the film industry or digital forensics, has been associated with significant threats. This includes identity theft, misinformation, political manipulation, and other forms of social harm. These malicious applications of deepfake technology have spurred global alarm, demanding reliable, and effective countermeasures to safeguard society's critical infrastructures [84]. Despite the existence of these facts, there has been limited research attention directed towards this area over the past 5 years. In bibliometrics, the impact and importance of scientific publications and authors are assessed using quantitative aspects of published literature [85]. In this analysis, as shown in the table 6, the top 25 authors are identified based on citation counts, h-indexes, g-indexes, m-indexes, TC (Total citation), and NP (Number of published Documents). Among these 20 authors, two authors Liu Y and Woo SS possess the highest h-index i.e. 6. But based on the number of publications Woo SS has the highest score. From this analysis, we can easily see that from 2019 to July 2023, the author Li Y had a maximum number of citations.

9. Conclusion and Future Scope

Over the last four and half years, numerous reviews have been explored in the context of deepfakes generation and identification, yet there is a scarcity of comprehensive scientometric analyses. This paper presents a bibliometric study in the field of deepfakes by objectively examining the current landscape and research trends. With the use of Scopus database, 794 relevant publications have been identified in the deepfakes domain. In order to derive more meaningful insights, the bibliometric analysis has been conducted which encompasses keyword analysis, identification of leading research-contributing institutes, co-country analysis, and co-keyword occurrence analysis.
The key findings from this analysis can be summarized as follows:

1. Publications in the field of deepfakes significantly surged from 2019 to July 2023, attributed to the rapid dissemination of information on the internet. Subsequently, the emergence of fake videos involving celebrities and politics has driven the increase in publications.

Table 6. Top 25 authors contributing research on Deepfakes

Author Name	Affliations	h_index	g_index	m_index	TC	NP	PY_start
Li Y	South China Agricultural University, Guangzhou, China	6	10	1.5	131	10	2020
Woo SS	Sungkyunkwan University, South Korea	6	13	1.2	171	15	2019
Fierrez J	Universidad Autonoma de Madrid, Spain	5	8	1.25	364	8	2020
Juefei-Xu F	Alibaba Group, San Mateo, CA, United States	5	5	1.25	92	5	2020
Liu Y	Duke University, Durham, NC, United States	5	13	1.25	462	13	2020
Tariq S	Sungkyunkwan University, South Korea	5	9	1.667	120	9	2021
Tolosana R	Universidad Autonoma de Madrid, Spain	5	8	1.25	364	8	2020
Wang R	School of Cyber Science and Engineering, Wuhan University, China	5	9	1.25	88	9	2020
Ahmed S	Nanyang Technological University, Singapore	4	6	1.333	78	6	2021
Guo Q	Nanjing University of Aeronautics and Astronautics, Nanjing, China	4	4	1	83	4	2020
Javed A	University of Engineering and Technology, Taxila, Pakistan	4	5	1.333	32	14	2021
Kietzmann J	University of Victoria, Canada	4	7	1	179	7	2020
Kim M	Sungkyunkwan University, Suwon	4	4	1.333	77	4	2021
Liu J	Northwest University, Xi'an, China	4	7	1	56	8	2020
Ma L	Shanghai Jiao Tong University, Shanghai, China	4	5	1	85	5	2020
Morales A	Universidad Autonoma de Madrid, Madrid, Spain	4	5	1	275	5	2020
Qi H	Kyushu University, Fukuoka, Japan	4	6	1	442	6	2020
Singh R	Indian Institute of Technology Jodhpur, India	4	7	1	53	7	2020
Rodriguez R	Universidad Autonoma de Madrid, Spain	4	6	1	351	6	2020
Agarwal A	Indraprastha Institute of Information Technology, New Delhi, India	3	4	1	17	4	2021
Akhtar Z	State University of New York Polytechnic Institute, Utica, USA	3	6	0.6	43	6	2019
Battiato S	University of Catania, Italy	3	5	0.75	156	5	2020
Chen J	Fudan University, Shanghai, China	3	5	0.75	108	5	2020
Chen P	Hangzhou Dianzi University, Hangzhou, China	3	5	0.75	38	5	2020

TC : Total citation, NP : Number of published Documents, PY_Start : Starting Publication Year of Author

2. Eight different document types pertain to deepfakes research, with approximately 38% of documents published as articles.

3. The journal "Advances in Computer Vision and Pattern Recognition" holds prominence among researchers and scholars in the deepfakes domain, achieving quartile Q1 status.

4. Visualization results indicate a widening and more international collaboration among countries in the field of deepfakes, with the USA emerging as the most prolific country, displaying the highest frequency in scientific production over time.

5. The most influential institutions in the field of deepfakes include Sungkyunkwan University (South Korea), Universidad Autonoma De Madrid (Spain), and Nanyang Technological University (Singapore), boasting the highest number of articles. Furthermore, it was observed that most organizations with high cooperation frequencies belong to the same country.

Further, this study provides valuable insights for scholars interested in deepfakes, offering a foundational understanding and insight into the research characteristics for their future endeavors.

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