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Assessing the Role of AI in Digital Image Manipulation and Facial Recognition: A Scientometric Analysis

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Abstract

The swift progression of artificial intelligence (AI), especially in the realm of computer vision, has notably enhanced the abilities of digital image editing and facial recognition technologies in various fields, including healthcare, security, and the preservation of cultural heritage. This research provides a scientometric evaluation of AI-fuelled advancements in facial recognition, image improvement, deepfake identification, and heritage categorization by reviewing literature published between 2016 and 2025 from Scopus, Web of Science, and PubMed. Utilizing VOSviewer and RStudio (Biblioshiny), we examined 418 documents to pinpoint significant research trends, prominent contributors, thematic groups, and international partnerships. The findings indicate that China, India, and the USA are at the forefront of scientific productivity, displaying a rise in global collaboration. Principal areas of interest encompass the use of Convolutional Neural Networks (CNNs) in medical diagnostics and cultural heritage classification, the creation of effective deepfake detection systems employing data augmentation and transfer learning, and the role of AI in forensic examination and digital restoration tasks. Co-occurrence and factorial analyses illustrate a significant alignment between technological advancements and practical uses while underscoring persistent issues related to algorithmic bias and ethical implementation. This study provides a thorough summary of the research landscape, highlights new areas of emphasis, and suggests pathways for future interdisciplinary inquiry and responsible advancement in AI-driven image technologies.

Keywords: facial recognition, image manipulation, machine learning, deepfake, CNNs

1. Introduction:

The rapid advancement of artificial intelligence (AI) and computer vision technologies has opened transformative possibilities across a wide range of disciplines, notably in medicine and cultural heritage preservation [1]. In the medical field, facial features are critical diagnostic indicators; however, subtle morphological changes in the early stages of disease often go undetected by the human eye, leading to delayed diagnoses and treatment [2]. AI-driven facial recognition technologies have emerged as powerful tools for enhancing clinical screening, diagnosis, and psychological assessment by enabling the precise extraction and analysis of facial features [3]. Simultaneously, image recognition—particularly through deep learning techniques such as Convolutional Neural Networks (CNNs)—has gained prominence in the documentation, analysis, and conservation of cultural heritage [4]. These technologies facilitate the automated identification, classification, and restoration of artifacts and historical sites, supporting digital preservation efforts and protecting valuable cultural assets from natural and anthropogenic threats [5]. This report employs a bibliometric approach to analyze the developmental trajectory, research trends, and interdisciplinary applications of AI-based recognition technologies in both medicine and cultural heritage, aiming to highlight emerging focal areas and inform future research directions within these rapidly evolving domains [6].

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Facial Recognition Technology:

Facial recognition technology (FRT) is increasingly being applied in healthcare settings to enhance patient safety, streamline identification, and improve diagnostic accuracy [7]. In long-term care homes, FRT is used to monitor residents' movements and secure access to sensitive areas. Institutions like Martin Luther King Jr. Community Hospitals have adopted FRT to bolster data security [8]. Additionally, FRT shows promise in medical diagnostics, such as detecting genetic conditions through facial analysis. Tools like the Face2Gene app, with an 85.7% accuracy rate in identifying congenital syndromes, exemplify its diagnostic potential [9]. The technology also aids in recognizing behavioral patterns linked to conditions like autism and in emotion-based assessments such as pain detection. For instance, the PainChek app uses facial muscle tracking to assess pain in dementia patients, leading to improved care and medication decisions in facilities like St. Michael's Health Group [10]. However, FRT is not without controversy. Studies reveal a 34% drop in accuracy when identifying darker-skinned female faces compared to lighter-skinned males, raising serious concerns about racial and gender bias [11]. This bias has already resulted in real-world consequences, including mistaken identity and wrongful arrests, underscoring the urgent need for inclusive algorithm design and ethical oversight in the deployment of FRT [12].

Facial Manipulation Detection and DeepFake:

Deepfakes are artificially generated or altered media, such as images or videos, created using advanced artificial intelligence, particularly deep learning techniques, to convincingly mimic real content [13]. In response to the growing threat posed by DeepFake,s realistic, AI-generated manipulations of facial imagery, this study explores an advanced data augmentation technique known as *Face-Cutout*, aimed at enhancing DeepFake detection models [14].

Traditional methods like random erasure help mitigate overfitting by introducing variability in training data, but they risk removing key facial features essential for accurate detection [15]. To address this, the proposed method selectively occludes facial regions based on landmark data, allowing models to learn from specific components of the face without compromising critical information. The study evaluates the contribution of different facial areas, such as the eyes, nose, and mouth, by systematically removing them during training and measuring detection performance [16]. Results show that facial features like the eyes are highly informative, while the nose has a lesser impact, indicating which areas are most relevant for model learning. Validated on benchmark datasets such as FF++ and Celeb-DFv2 [17]. The approach not only improves detection accuracy but also offers new insights into feature relevance, ultimately guiding the development of more robust and generalizable DeepFake detection frameworks [18].

The Transformative Role of AI in Image Enhancement and Restoration:

AI plays a significant role in image enhancement and restoration through various advanced techniques. One major application is super-resolution, where AI increases image resolution by generating finer details from low-quality inputs [19]. Denoising helps clean up images by removing grainy textures or unwanted noise, especially in low-light conditions. Through contrast enhancement, AI adjusts brightness and contrast to make images clearer and more visually appealing [20]. Color correction ensures that images display accurate and natural colors by fixing color casts and tone issues. AI also excels at artefact removal, getting rid of unwanted elements like scratches, logos, or stains from images. In cases of motion or focus issues, deblurring techniques can restore sharpness by reconstructing details from blurred photos [21]. When parts of an image are missing or damaged, AI performs hole filling (or inpainting), skillfully predicting and recreating

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the missing content to blend seamlessly. Finally, dimensionality reduction allows AI to simplify image data, preserving important features while reducing file size and processing load, which is especially useful in large-scale image analysis [22].

Advancements and Applications of AI in Face Recognition and Image Processing

Face recognition is a powerful computer vision technology used to identify or verify individuals based on facial images or video streams. With the rise of deep learning, models such as VGGFace and VGGFace2—developed by Oxford's Visual Geometry Group—have significantly enhanced the accuracy and reliability of face recognition systems [23]. These models are now accessible to developers through libraries like Keras, using pre-trained networks and open-source tools. A practical application of this technology is seen in Home Service Robots (HSRs), which use real-time face detection and tracking systems based on adaptive skin detectors, Haar-like classifiers, and motion prediction [24].

Face recognition operates within the broader domain of image processing, which involves converting images into digital form and performing tasks like enhancement, compression, and pattern recognition to extract useful insights. This process generally includes three main stages: image acquisition, processing (such as compression and enhancement), and analysis [25].

Face recognition has become a key area in biometrics, pattern recognition, and computer vision, finding widespread use in security systems, surveillance, and identity verification. Despite challenges such as lighting variation, facial expressions, pose differences, and image quality, the field continues to advance rapidly [26]. Thanks to the progress in digital imaging and machine learning technologies, and the availability of affordable recording devices, face recognition is now integral to applications like e-passports, law enforcement, automated access systems, and human-computer interactions [27].

Cultural Heritage Classification Using Machine Learning and Deep Learning

Cultural heritage, encompassing unique traditions, artifacts, monuments, and artistic expressions, is essential to global history and identity. UNESCO classifies it into tangible (movable and immovable) and intangible forms [28]. The rise of digital technologies has significantly improved the accessibility, preservation, and reconstruction of cultural heritage through digitization, digital access, and long-term preservation. Central to these efforts is classification, a supervised machine learning technique that categorizes heritage data (e.g., images, text, audio, and video) into distinct groups [29]. This method aids in effective management, conservation, and global dissemination, contributing to the preservation of cultural diversity. Research has explored a range of classification techniques, from traditional machine learning algorithms like k-Nearest Neighbors (kNN) and Support Vector Machines (SVM), to advanced deep learning models such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) [30].

CNNs, including AlexNet, ResNet, and Inception, excel at image classification, while RNNs are effective for text classification. Hybrid methods combining image feature extraction (e.g., SIFT, SURF) and spectral data have improved accuracy. Tools like WEKA have further enhanced these methods [31]. This research builds on earlier work by comparing a range of classification algorithms in a thorough analysis, both before and after attribute selection. The work not only reviews current methods but also presents several state-of-the-art models aimed at improving classification accuracy and performance [32].

Some of the recent models are Averaged One Dependence Estimators (AODE), which enhance probabilistic classification; Forest by Penalizing Attributes (Forest PA), which emphasizes enhancing feature importance; Rough Set-based kNN (RSeslibKnn), which combines rough set theory and k-nearest neighbors for improved

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decision-making; and Multilayer Perceptron (MLP), a form of neural network that is renowned for complex pattern modeling. Combined, the methods seek to present a deeper insight into classification methods and more mature solutions. These models are applied to cultural heritage image classification to advance the field by establishing new benchmarks in classification accuracy and cultural heritage preservation [33].

The Impact of CNNs on Medical Imaging and Surgical Practices

Convolutional Neural Networks (CNNs) are revolutionizing medical image analysis, significantly enhancing the accuracy and efficiency of computer vision applications in healthcare [34]. These AI models are essential in enabling machines to see and interpret visual data, improving diagnostic processes, and making image interpretation more accessible [35].

As AI technology evolves, clinicians need to have a basic understanding of CNNs, similar to how knowledge of Hounsfield units enhances the interpretation of CT scans [36]. A foundational knowledge of CNNs helps clinicians engage with AI models, enabling them to effectively incorporate these tools into their practice [37]. This understanding is crucial for leveraging the full potential of AI as it becomes increasingly integrated into healthcare systems [38]. This review aims to simplify CNNs for clinicians, particularly those unfamiliar with AI, and to demonstrate their growing significance in medical image analysis [39]. CNNs are making significant strides in various areas of medicine is depicted in Table 1.

Bibliometric Analysis:

Bibliometric analysis is a statistical method used to analyze data from various scholarly sources such as book chapters, articles, reviews, and editorials. The primary goal of this approach is to understand the trends, characteristics, and research status within a specific field. It provides insights into the structure and evolution of research, assesses citations as a measure of impact, and highlights emerging topics within a given area of study. In this study, a comprehensive literature search was conducted using the keywords "image manipulation AND facial recognition" to gather relevant research articles. The search was performed across three major databases: Scopus and Web of

Table 1: Application of CNN in medical sectors

Medical Field	Application of CNNs	Benefits	Ref..
Opthamology	Assess retinal diseases like retinopathy and glaucoma	Improves diagnostic accuracy	[40]
Dermatology	Classy skin lesions	Archives expert-level precision	[41]
Endoscopy	Detects gastric and colorectal polyps	Enhances accuracy in distinguishing malignant Vs benign polyps	[42]
Gynecology	Cervical screening	Differentiates low and high risk lesions with high accuracy	[43]
Surgery	Analyse laparoscopic surgery videos	Identifies surgical phases, improves training, and enhances intraoperative decision making	[44]

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Science, covering publications from 2016 to 2025. The search results were exported in different formats for each database: CSV for Scopus, PubMed format for PubMed, and plain text (.txt) for Web of Science. In total, 270 documents were retrieved from Scopus and 148 from Web of Science.

The collected data were analyzed using VOSviewer (version 1.6.20) and RStudio with R version 4.4.3. All required packages for bibliometric analysis were installed and implemented based on the methodology proposed by Aria and Cuccurullo (2017) [45]. Through the Biblioshiny interface of the Bibliometrix package, a wide range of analytical outputs was generated, including keyword co-occurrence networks, author collaboration maps, bibliographic coupling, annual scientific production, document type distribution, thematic evolution maps, country-level publication trends, and factorial analyses. This comprehensive workflow enabled a detailed mapping of the intellectual, conceptual, and social structure of the research field. The study offers valuable insights into the scientific landscape of gut microbiota and dairy allergy, highlighting influential contributors, dominant research themes, collaborative patterns, and emerging trends within this multidisciplinary domain.

Result

Publication type- The donut chart shows how different types of documents are split up in AI research on digital image manipulation and facial recognition tech from 2020 to 2025 (Fig. 1). This data comes from Web of Science, Scopus, and PubMed databases.

Most of the publications, 94%, are original research articles. This points to a big focus on hands-on studies creating new algorithms, and putting AI tech to use in visual computing. Review articles make up 5% of the total. This shows more people want to bring together existing ideas, look at new tech advances, and talk about the ethics involved. Book chapters are just 1%, which

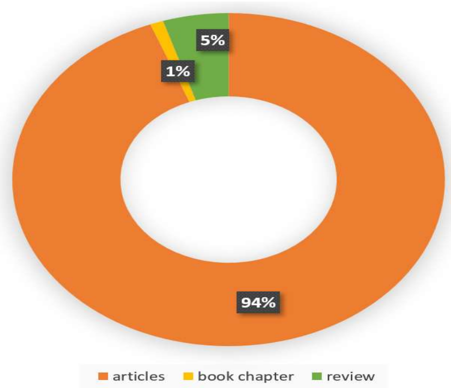

Fig 1: Document Type

means there's not much academic textbook content or big-picture looks at this fast-changing topic. The fact that original articles are so common shows that this field is always changing and loves new ideas. The research world is all about testing things out and making them work in real life.

Annual Scientific Production

The graph titled Annual Scientific Output, AI in Image Manipulation and Face Recognition illustrates research trends from 2020 to 2025, based on data from Scopus and Web of Science.

Both databases indicate a consistent upward trajectory, with Scopus reaching a peak of approximately 82 publications in 2024 and Web of Science recording around 42 publications in the same year. This growth reflects the increasing significance of AI in digital imaging, particularly in face recognition and image modification. The steady rise from 2020 to 2024 underscores heightened attention to security, ethical considerations, and technological advancements. The notable decline in 2025 is attributed to incomplete data for the current year, rather than an actual reduction in research activity. Overall, these figures underscore the rapid evolution and expanding scope of this dynamic field (Fig. 2).

Corresponding Authors Countries

The Table 2 shows the top 10 countries that contribute to AI research in

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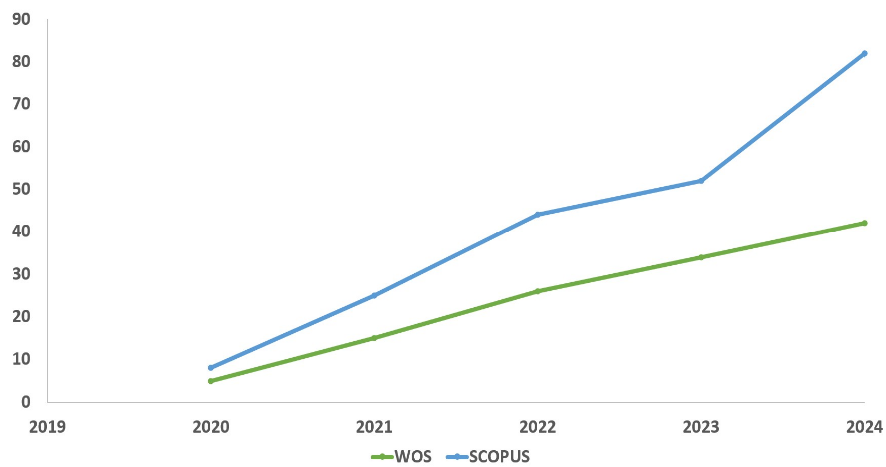

Fig 2: Annual Scientific Production

Table 2: Number of Articles Published by Different Countries

Rank	Scopus		WoS	
	Countries	NOP	Countries	NOP
1	China	79	China	67
2	India	36	India	17
3	Usa	8	Usa	11
4	Korea	7	Korea	9
5	Italy	4	Italy	4
6	Malaysia	3	Japan	3
7	Spain	3	Malaysia	3
8	Australia	2	Australia	2
9	Japan	2	Singapore	2
10	Pakistan	2	Algeria	1

*NOP- Number of publications

digital image manipulation and facial recognition, according to Scopus and Web of Science (WoS) data. China takes the lead in both databases, with 79 publications in Scopus and 67 in WoS, demonstrating its clear dominance in this area

India comes in second, with the USA and Korea following. Countries like Japan, Malaysia, and Australia appear on both lists, which indicates their increasing involvement in AI research. The inclusion of nations such as Pakistan, Algeria, and Singapore, despite having fewer publications, points to a broadening global interest. The distribution suggests that Asia and North America are leading the way in AI innovation for visual technologies, while other regions are starting to make more contributions

Country's Scientific Production

The field of AI-based image manipulation and facial recognition displays distinct regional scientific productivity patterns between the Web of Science (WoS) and Scopus databases. The analysis shows that China and India play major roles in AI research through their significant investments in Scopus (Fig 3). The analysis further indicates that the United States leads AI research in WoS databases because of its specific focus on technology advancement and ethical considerations. The analysis

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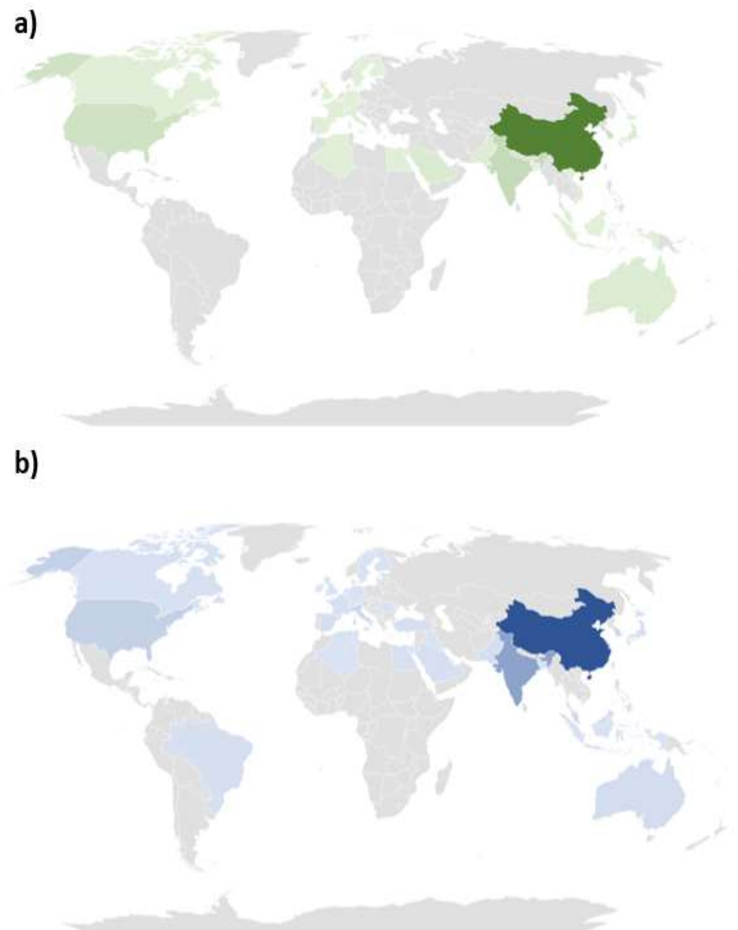

Fig 3: Countries Scientific Production (a) Scopus (b) WoS

demonstrates that South Korea, Australia, and some European countries take part in AI research but show different levels of involvement. The data demonstrates that AI research on visual technology holds significant international value, while Asia leads the world in both research quantity and technological progress.

Countries Collaboration

Figure 3A illustrates the international collaboration network among countries contributing to research in the field under study, constructed using co-authorship data extracted and visualized via VOSviewer. Each node represents a country, with the size of the node corresponding to the total number of publications, while the links denote co-authorship strength and collaborative frequency. China and India emerge as dominant contributors with the largest node sizes, indicating their leading publication volumes in this domain. These countries also exhibit extensive collaboration links, particularly with the United States, Australia, and Egypt, highlighting their central role in

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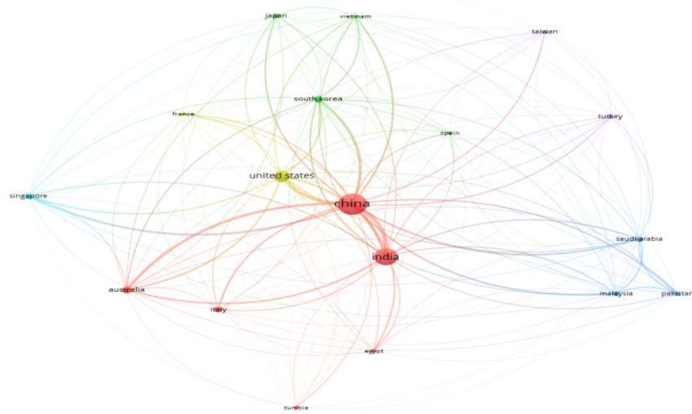

Fig 4: Network visualization of country relationship

global research connectivity. The United States, while slightly smaller in node size, serves as a key intermediary across several clusters, indicating its strategic position in linking Asian, European, and Middle Eastern research entities. South Korea, France, Japan, and Vietnam form part of a densely connected cluster, suggesting strong regional collaborations in East and Southeast Asia. Meanwhile, Singapore, Malaysia, Pakistan, and Saudi Arabia align within another tightly knit group, possibly reflecting regional research alliances and thematic focus areas. The visualization demonstrates in Figure 4, a growing global interdependence in scientific exploration, with a notable shift toward collaborative efforts among emerging economies. This network map not only reflects the current structure of global research productivity but also pinpoints strategic partnerships that are shaping the trajectory of future scientific development.

Co-occurrence

Figure 5 presents a keyword co-occurrence network that visualizes the conceptual structure of research on deepfake detection and face recognition technologies. Using VOSviewer, keywords were clustered based on their co-occurrence in scientific literature, reflecting the thematic interconnectivity within the field. The red cluster represents the core theme of face recognition and deepfake detection, linked with terms such as forgery detection, detection methods, facial images, and frequency domain analysis. The green cluster emphasizes deep learning architectures, including convolutional neural networks (CNN), long short-term memory (LSTM), and face swapping, which serve as foundational tools for both the generation and detection of manipulated media. The yellow cluster is dominated by broader AI and forensic tools, including machine learning, digital forensics, learning systems, and image forensics, showcasing the methodological expansion of the field. The purple cluster includes terms like feature extraction, face, and video forensics, focusing on the technical aspects of feature-level analysis for identity and forgery validation. Meanwhile, the blue cluster centers on fake detection, attention mechanisms, and computer vision, suggesting a bridging domain that connects algorithmic models with visual interpretation strategies. This interconnected map reveals the growing convergence of deep learning, forensic analysis, and real-time media authentication.

Tree Map

Scopus and WoS tree-maps show major trends in facial manipulation detection research, both of which take a focus on deepfake detection as the most prevailing

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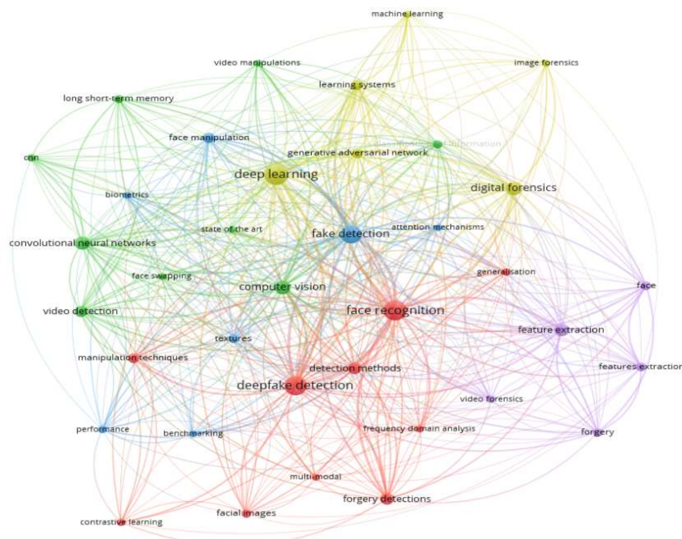

Fig 5: Co-Occurrence Network Visualization

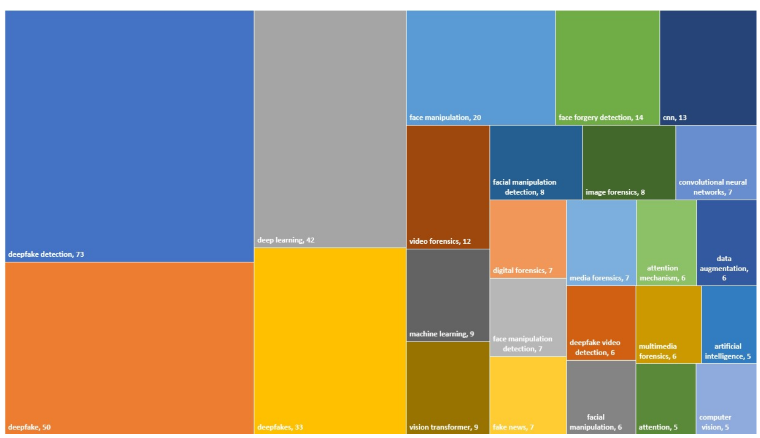

Fig 6: Tree Map of Major Keywords

and ongoing theme (73 in Scopus, 42 in WoS). The usual keywords like deepfake(s), deep learning, and face manipulation reflect a prevalent interest in AI-driven detection methods. Scopus is more focused on technical and model-specific vocabulary, such as CNN, vision transformer, data augmentation, and attention mechanism, as indicative of a study orientation toward enhancing detection performance, model structure, and training effectiveness. Alternatively, WoS displays a wider range by including keywords like face recognition, faces, feature extraction, and forgery, which indicates a further interest in facial identity, image authenticity, and the inclusion of manipulation detection with biometric systems (Fig 6). Both databases also exhibit high overlaps in forensic-related keywords like video forensics, image forensics, and

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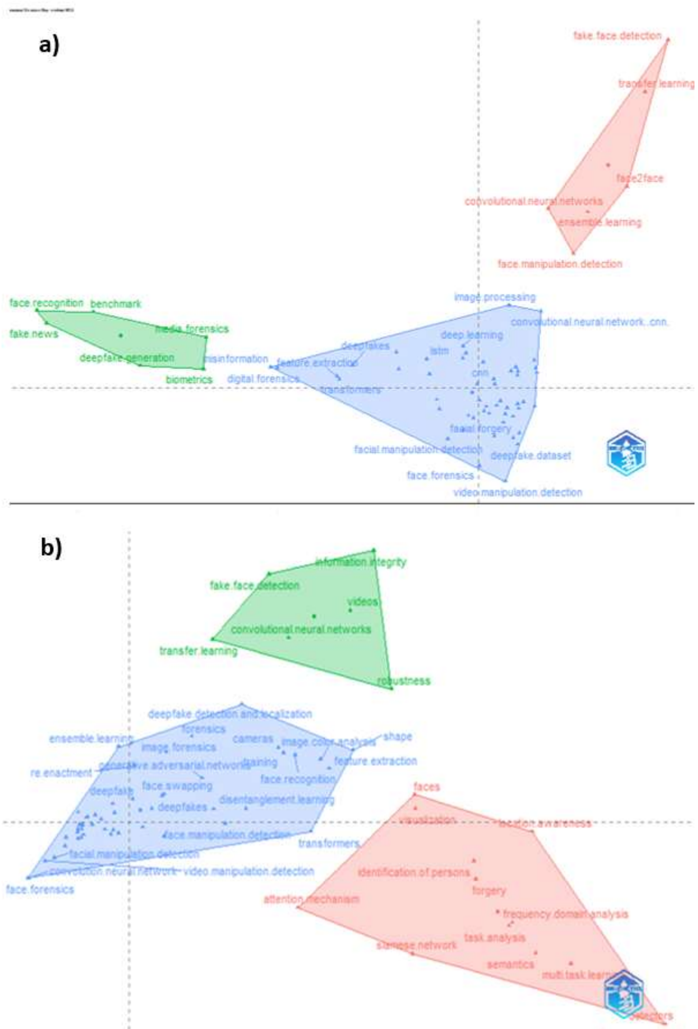

Fig 7: Factorial Analysis

multimedia forensics, which highlights the practical use of detection techniques across different media platforms. On the whole, though both tree map disclose a common nexus based on deepfake detection and AI-based methods, Scopus is more inclined toward technical optimization and system development of detection, as compared to WoS, which has a little broader thematic scope involving identity verification and forensic investigation.

Factorial Analysis

When looking at the Scopus and WoS databases, you can see clear differences between the research clusters (Fig 7 and Table 3). The Blue cluster mainly focuses on the technical side—things like AI methods for detecting deepfakes and facial manipulation, including model training techniques. On the other hand, the red cluster shifts attention toward learning strategies and practical applications, emphasizing ways to improve robustness and handle face-related tasks.

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Table 3: Comparison of factorial analysis

Database	Blue Cluster	Red Cluster	Green Cluster
Scopus	Core AI methods: deep learning, CNN, transformers, facial manipulation detection, and video manipulation detection.	Focus on face manipulation detection, transfer learning, face2face, and ensemble learning.	Broader context: face recognition, fake news, deepfake generation, biometrics, media forensics.
WoS	Wide technical range: deepfake detection, face swapping, GANs, feature extraction, and facial manipulation detection.	Application focus: faces, visualization, task analysis, multi-task learning, forgery.	System robustness: fake face detection, transfer learning, and information integrity.

Lastly, the green cluster takes a wider perspective, dealing with broader topics such as misinformation, verifying identities, improving system robustness, and generalization challenges. Together, these clusters highlight how research in this area is divided between advancing core technologies, applying them in real-world scenarios, and addressing big-picture system issues.

Discussion

The scientometric analysis reveals that AI's role in digital image manipulation and facial recognition has experienced rapid and substantial growth over the past decade, driven primarily by major contributions from China, India, and the USA. The widespread adoption of advanced deep learning architectures, especially Convolutional Neural Networks (CNNs), has been pivotal in propelling advancements across diverse fields, including medical diagnostics, security systems, and the preservation of cultural heritage [46]. These AI-powered tools have enhanced capabilities such as early disease detection through facial analysis, reliable identity verification, and sophisticated digital restoration techniques. At the same time, the proliferation of deepfake technology has sparked intensive research efforts focused on developing robust detection frameworks that employ novel data augmentation, attention mechanisms, and transfer learning to keep pace with increasingly sophisticated manipulations [47]. Alongside these technological strides, the research community is actively grappling with persistent challenges such as mitigating algorithmic bias—particularly issues arising from underperformance in recognizing diverse demographic groups—and resolving ethical concerns related to privacy, consent, and social implications [48]. This dual emphasis on innovation and responsibility has fostered a growing interdisciplinary collaboration among computer scientists, clinicians, ethicists, and legal experts. The literature underscores the urgent need for standardized evaluation protocols, transparent AI model development, and policy frameworks that ensure equitable and trustworthy AI deployment [49]. Overall, the evolving landscape of AI-driven image manipulation and facial recognition is marked by impressive progress merged with conscientious efforts to address societal risks, shaping a future where these transformative technologies can be harnessed safely and effectively for broad public benefit [50].

Future scope

- The future of AI in digital image manipulation and facial recognition is huge and really important since these technologies are becoming part of everyday life and critical industries.
- As deep learning keeps improving, AI will help make diagnoses in healthcare more accurate, make security processes smoother, help protect cultural heritage, and guard against threats like deepfakes[51].

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- With the proliferation of fake and manipulated media and growing privacy concerns, it's crucial to develop AI systems that are transparent, reliable, and fair for tasks such as identification, authentication, and forensic work.

Conclusion

This scientometric analysis delivers a thorough assessment of the changing landscape of artificial intelligence (AI) in the areas of digital image manipulation and facial recognition, emphasizing its considerable influence across sectors such as healthcare, digital forensics, security, and the preservation of cultural heritage [52]. By examining 418 publications from Scopus, Web of Science, and PubMed (2016–2025), key trends, technologies, and global contributions have been identified. The results highlight the crucial role of deep learning models, especially Convolutional Neural Networks (CNNs), in improving facial recognition precision, identifying deepfakes, assisting in medical diagnostics, and conserving cultural artifacts [53]. The research indicates that China, India, and the United States are the foremost contributors to this domain, with a notable increase in global collaboration revealed through co-authorship and co-occurrence networks. Thematic clusters illustrate an interdisciplinary convergence between AI techniques and practical applications, emphasizing the growing incorporation of AI into systems focused on security, authenticity, healthcare, and heritage documentation [54]. Despite the rapid progress, obstacles such as algorithmic bias, ethical dilemmas, and the generalizability of detection models remain. These issues highlight the necessity for responsible AI development, including inclusive training datasets, transparent methodologies, and international collaboration [55]. This study adds to the ongoing discussion by providing insights into technological advancements, research deficiencies, and future opportunities [56]. It urges stakeholders, including researchers, developers, and policymakers, to prioritize ethical implementation, fairness, and cross-disciplinary collaboration as AI continues to reshape the limits of digital imaging and recognition technology (57, 58). Future research will focus on establishing clear ethical guidelines and developing more intelligent AI models that can resist bias and manipulation. It's also essential that experts from different fields work closely together to ensure AI advancements contribute positively to society, improving safety, fairness, and overall well-being.

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