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ARTIFICIAL INTELLIGENCE IN DERMATOLOGY: CURRENT APPLICATIONS AND FUTURE INNOVATIONS

Muhammad Amish Ghafoor [1], Ans Ali [2], Usama Aziz [3], Rashid Mahmood, [4], Muqaddas Salahuddin [5], Hamza Asif [6]

[1]Department of Clinical Medicine, Wuhan University of Science and Technology China, Hubei Province, Wuhan City, 430000, China
amishghafoor22@gmail.com
[2] Department of Clinical Medicine, Wuhan University of Science and Technology China, Hubei Province, Wuhan City, 430000, China
lazypanda299@gmail.com
[3] Department of Clinical Medicine, Wuhan University of Science and Technology China, Hubei Province, Wuhan City, 430000, China
azizusama044@gmail.com
[4]Faculty of Computer Science and Information Technology, Superior University, Lahore, 54000, Pakistan rmbhatti88@gmail.com
[5]Faculty of Computer Science and Information Technology, Superior University, Lahore, 54000, Pakistan muqaddassalahuddin60@gmail.com
[6]Faculty of Computer Science and Information Technology, Superior University, Lahore, 54000, Pakistan hamzaasif008@gmail.com6

Abstract:
Artificial intelligence's (AI) role in dermatology is given in this study. Our conversation centers on technique, AI applications for different skin conditions, constraints, and potential future developments. We examine the present image-based models' implementation across disease subgroups in dermatology and draw attention to the obstacles to their broad use. In order to highlight the significance of creating responsible, just, and equal models in dermatology, we also go over how AI in dermatology may develop in the future as well as the new concept of multi-modal models and large language.

Keywords: Artificial Intelligence (AI), Dermatology, Machine Learning (ML), Federated Learning, Large Language Models (LLM), Melanoma.

What We Already Know:

- The use of artificial intelligence (AI) in dermatology has grown, especially in image-based diagnosis tools for melanoma, skin lesions, and other dermatological disorders.
- In dermatology, machine learning, deep learning, and natural language processing are often employed artificial intelligence techniques for tasks like text analysis and categorization.
- AI models have shown promise in increasing the efficiency and accuracy of diagnosis, especially in areas with limited resources and restricted access to professionals.

What This Article Adds:

- This manuscript highlights recent developments in AI models and methodologies while giving a summary of the present uses of AI in dermatology, with an emphasis on dermatopathology, inflammatory diseases, and skin malignancies.
- The essay addresses the difficulties of applying AI in dermatology, including issues with interpretability, bias, and data quality, and suggests ways to deal with these problems in the future.

- It highlights how large-scale models like Federated Learning and multimodal AI, as well as hybrid human-AI models, have the potential to enhance dermatology's diagnostic precision and individualized treatment.

1. Introduction

The potential of AI models in medicine has garnered attention due to recent advancements [1]. These models include large language models (LLMs) for text analysis [2], computer vision algorithms for medical image interpretation [3], and multi-modal algorithms that handle both text and images [4]. AI algorithms can generate synthetic image data to improve model training [5, 6], discover new patterns in large datasets [7], and analyze unstructured data like clinical notes [8].

Dermatology benefits significantly from AI tools due to its visual diagnostic nature and the growing availability of dermoscopy images, clinical photos, and electronic health records (EHRs) [9, 10, 11, 12]. AI can help bridge access gaps in dermatology care, especially in regions with limited specialists [13, 14] and a shortage of dermatologists in the US [15]. However, integrating AI into dermatology workflows remains challenging, and new medical applications highlight unresolved issues.

This work analyzes AI methods in dermatology, focusing on classifications, training strategies, and the use of AI in predicting and diagnosing skin disorders. It also addresses the challenges of explainability, bias, and generalizability in dermatology AI algorithms. Finally, potential research directions are discussed to improve AI applications in dermatology. Our goal is to provide readers with a comprehensive understanding of AI's role and developments in dermatology.

The paper is structured as follows: Section 2 provides an overview of AI, Section 3 details the methodology, Section 4 discusses applications in dermatopathology, ulcers, inflammatory diseases, skin cancers, and text-based analysis, Section 5 explores hybrid human-AI models, Section 6 covers ethical and legal considerations, and Section 7 concludes with future prospects and key findings.

2. Overview of Artificial intelligence (AI)

AI is divided into two categories: "artificial," meaning human-made, and "intelligence," which remains debated in terms of its exact definition [16]. Below, we provide a brief summary of three key factors.

2.1 What is Artificial intelligence (AI)?

Artificial intelligence (AI) refers to machines that simulate human cognitive processes such as learning and problem-solving [17]. Intelligent agents are systems that perceive their environment, take actions to achieve goals, learn from experiences, and apply knowledge flexibly [18, 19].

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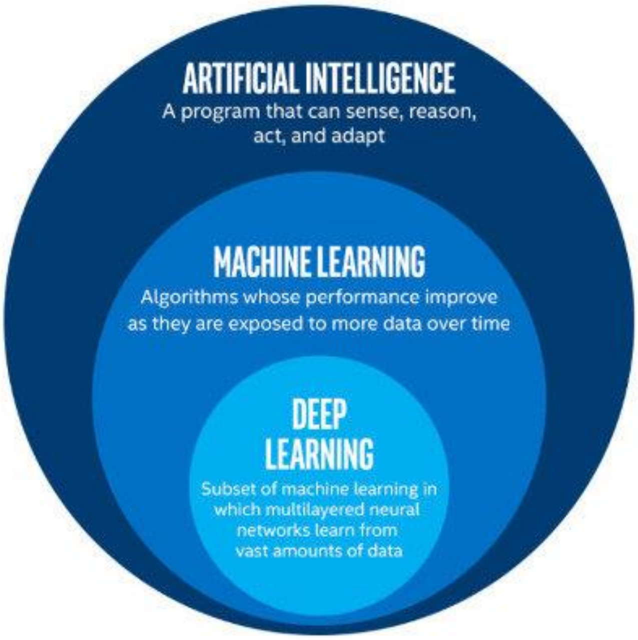

Figure 1: Overview of Artificial Intelligence

2.2 The Evolution of AI in Medicine and Its History:

In 1936, Alan Turing introduced the "Entscheidungsproblem" and "effective calculability," laying the groundwork for algorithms [20]. In 1943, the first electrical circuit-based artificial neural network (ANN) was created [21], and in 1956, Dartmouth College coined the term "artificial intelligence" [22]. The first ANN-based computer study was completed in 1959 with "ADALINE" and "MADALINE" models [23]. AI's first medical use in computer-aided diagnosis came in 1963 for analyzing pulmonary nodules [24]. By 1998, the U.S. FDA approved the first mammography CAD system [25], followed by AI's use in dermatology with MelaFindTM for melanoma detection [26]. Deep learning (DL), a subfield of machine learning, emerged after the 2010s, enabling automatic property extraction from large datasets [27]. AI in dermatology and medicine has since grown rapidly, with breakthroughs like DeepMind's protein structure prediction [28] and advancements in generative adversarial networks (Style GAN3) and computer vision (SEER) to improve AI CAD systems [29]. A detailed timeline is shown in Figure 1.

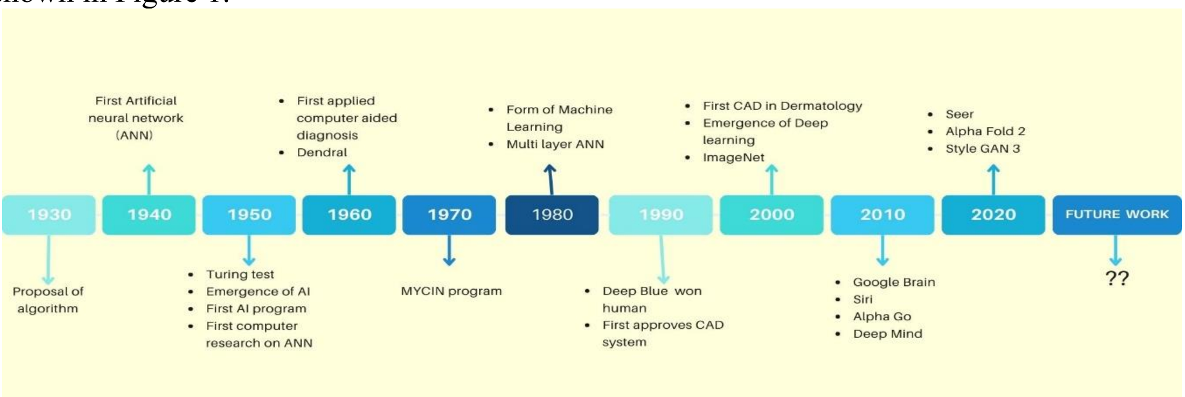

Figure 2: Flowchart showing the selection of studies and the literature search

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2.3 Artificial Intelligence Principles:

AI simulates human cognition, with key subfields like machine learning (ML) and natural language processing (NLP). In dermatology, ML is used for tasks like melanoma diagnosis. Deep learning (DL), a subset of ML, identifies complex patterns from raw data.

ML includes supervised learning (for image models), unsupervised learning (for pattern detection), and reinforcement learning (where agents improve through feedback). NLP combines linguistics and AI to interpret and generate human language. Emerging multimodal AI models, like Med-PaLM, enhance medical data handling in healthcare.

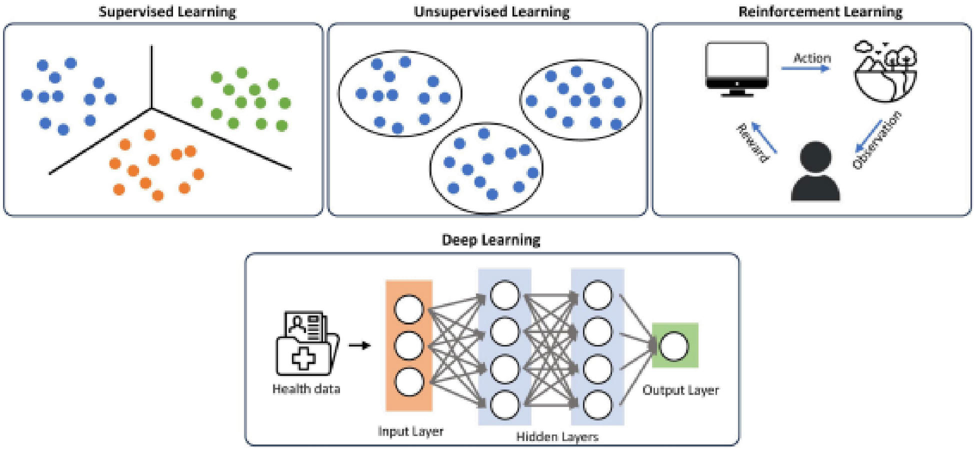

Figure 3: Machine learning classifications: supervised, unsupervised, and reinforcement learning. Deep learning combines all three using neural networks.

2.4 Relevant AI Concept in Dermatology:

Classical AI research focuses on knowledge engineering and representation [30], with its structure built on machine learning (ML) and deep learning (DL). Machine learning enables AI models to improve automatically through experience and historical data [31], while deep learning uses artificial neural networks (ANNs) to mimic biological neural networks. ANN performance is influenced by the configuration of its layers and training data [32]. Deep learning is commonly used for detecting and classifying skin tumors and lesions [33], with popular models including recurrent neural networks (RNNs), generative adversarial networks (GANs), and convolutional neural networks (CNNs) [34].

CNNs, often used in medical image processing, are widely applied in dermatology [35], with popular architectures like GoogleNet, Inception-V3, and ResNet [36]. The accuracy of AI models depends on high-quality image datasets, which are crucial for training CNNs [37]. Common dermatology image sets for AI training include ISIC archives, BCN20,000, HAM10000, and PH2 [38]. Table 1 summarizes AI concepts and elements in dermatology.

Table 1: Key terms related to artificial intelligence (AI) in dermatology

Terms	Meaning
Artificial Intelligence (AI)	The ability of human-made machines to mimic natural intelligence, or the intelligence they display.
Knowledge Representation	It is the area of artificial intelligence devoted to expressing world knowledge in a way that machines can use to resolve challenging problems like making a medical diagnosis or having a natural language conversation.

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Feature Learning	A group of methods that enable an algorithm to automatically extract from raw data the shows required for feature identification or categorization.
Machine Learning (ML)	The study of algorithms for computers that automatically get better with practice.
Deep Learning (DL)	A subset of machine learning techniques that combine representation learning and artificial neural networks.
Supervised Learning	It describes the machine learning project of using sample input-output pairs to learn a function that translates an input to an output. It uses labeled training data, which consists of a collection of training samples, to infer a function.
Transfer Learning	A model for machine learning known as transfer learning enables a model created for one task to be used for another after being adjusted and enhanced.
Artificial Neural Networks (ANNs)	Artificial Neural Networks (ANNs), sometimes commonly referred to as neural networks (NNs), are computer systems that are loosely modeled after the biological neural networks found in animal brains.
Convolutional Neural Networks (CNNs)	CNNs belong to the feedforward neural network class of neural networks. Their artificial neurons, which are most frequently used to analyze visual imagery, can react to a portion of the nearby units in the surface region.
Generative Adversarial Networks (GANs)	GANs are an unsupervised learning technique that uses competition between two neural networks to learn.

3. Applications of AI in Dermatology

Numerous AI has been applied across various dermatological fields, including text-based analytics, dermatopathology, inflammatory skin disorders, and skin cancers [38]. Recent developments explore multimodal approaches integrating clinical texts and patient data alongside imaging, offering new diagnostic insights.

3.1 Malignancies of the skin

AI has been extensively used for detecting and differentiating between benign and malignant skin lesions, such as melanomas and keratinocyte carcinomas. Esteva et al. used a dataset of over 100,000 clinical images to train CNNs for classifying melanoma and benign nevi. Other studies have focused on detecting metastases in lymph nodes using CNN models with histological tissue samples [39].

3.2 Skin conditions that cause inflammation, such as dermatitis and psoriasis:

AI has also been applied to conditions like psoriasis, dermatitis, and acne. CNNs and deep learning models have been used to classify skin lesions and predict the effectiveness of biologic therapies [40]. Additionally, AI models have been developed to forecast treatment outcomes based on patient demographics and clinical history, enhancing personalized medicine [41].

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3.3 Assessment of ulcers

AI techniques have been used to classify skin lesions and assess ulcer severity. Recent studies have explored the use of pixel-level image analysis to evaluate wound edges and anticipate pressure ulcers, helping clinicians manage wound care more effectively [42].

3.4 Pathology of Dermatology

In dermatopathology, AI is used to support the diagnosis of skin cancers, such as basal cell carcinoma, and other dermatological diseases. CNNs have been used to categorize histology slides and assist with melanoma diagnoses [43].

3.5 Text-based analysis and various multiclass categorization

Text-based analysis using natural language processing (NLP) has been employed to analyze unstructured medical records and social media for insights into disease impact on patients. These approaches are being applied in areas like patient education, physician support, and triaging of cutaneous neoplasms.

3.6 Hybrid Human-AI Models

Hybrid human-AI models, combining clinician expertise and AI capabilities, have shown promising results in diagnostics. For example, a CNN outperformed 58 dermatologists in diagnosing melanoma, highlighting AI's potential in clinical settings. Studies like those by Marchetti et al. and Han et al. demonstrate AI's role in enhancing diagnostic accuracy, suggesting a growing integration of AI in dermatology [44].

4. AI Drawbacks and Ethical Issues for Dermatology

AI in dermatology faces several challenges, including biases in training datasets, interpretability issues, and regulatory barriers. Datasets often contain confounders, like surgical markers, that can affect model validity. Biases in datasets, such as underrepresentation of darker Fitzpatrick skin tones, can lead to inaccurate results [45]. Image quality variability, caused by differences in devices and capturing methods, also impacts AI performance. The "black box" nature of AI hinders transparency, making interpretability methods essential [46]. Ethical concerns, such as patient consent, data security, and responsibility for errors, further complicate AI deployment in clinical settings. Lack of prospective, multi-site validation limits the generalizability of FDA-approved AI models, which are often trained on historical data. Maintaining the doctor-patient relationship and ongoing model testing is crucial for integrating AI effectively in clinical practice [47].

5. Opportunities and future directions:

5.1 The development of generalist medical AI and LLMs:

Dermatology is exploring large-scale language models (LLMs) and Vision-Language Models (VLMs), which combine textual and visual data. Models like Skin-GPT4 show potential in diagnosing skin lesions, while VLMs demonstrate competence in medical visual question-answering. These technologies could lead to a generalist medical AI, improving diagnoses and personalized treatments by integrating clinical images, genetic data, and demographics.

5.2 Local Models and Federated Learning in Dermatology:

Federated learning (FL) allows deep learning algorithms to be trained on decentralized datasets, preserving privacy while improving model performance. This method can enhance the generalizability of dermatology models by including diverse demographics and underrepresented skin types. Localized models tailored to specific institutional needs could improve accessibility in resource-limited environments.

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5.3 Improvements to Model Architecture and Assessment Criteria

Recent advances in AI model architectures require a broader evaluation framework that includes clinical relevance, fairness, and subpopulation performance. Dermatologists, scientists, and patients should collaborate to establish guidelines that balance equity and performance.

5.4 Utility and Regulation in Environments with Limited Resources

As AI models evolve, strong regulations are needed to ensure safety and trust. Models must be standardized and validated through rigorous studies to ensure their generalizability and reliability in diverse settings. Explainability remains a key issue for widespread adoption, particularly for "black box" models, and addressing this will enhance AI integration in dermatology.

6. Conclusion

The application of artificial intelligence (AI) in dermatology holds significant potential to revolutionize patient management, disease diagnosis, and treatment optimization. While still in its early stages, AI has already shown transformative promise in improving workflow within dermatology. However, challenges such as ethical concerns, regulatory hurdles, and the need for diverse, high-quality datasets to ensure fairness and accuracy remain. The future success of AI in dermatology depends on collaboration between dermatologists, AI researchers, and policymakers to establish standardized regulations that prioritize safety, equity, and transparency. With continued development and responsible integration, AI has the potential to become a cornerstone of dermatological practice, enhancing the precision and personalization of treatments. The active involvement of the dermatology community will be crucial in guiding the responsible growth and application of AI in clinical practice.

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