University of Asia Pacific

Department of Computer Science and Engineering

An Explainable and Intelligent AI Framework for Vitiligo Diagnosis and Severity Assessment

A proposal for a study on AI-powered vitiligo detection, segmentation, and severity assessment using explainable deep learning approaches for diverse skin types.

Undergraduate Research Proposal

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Abstract

White patches on the body are one of the manifestations of vitiligo, a chronic skin condition that is caused by death of melanocytes, the pigment-producing cells. Although it is not harmful in the physical context, it usually causes colossal psychological and social distress, especially when it is wrongly or delayed diagnosed. The usual method of diagnosis relies very much on clinical inspection by dermatologists and strongly depends on both their experience as professionals and the diversity of the colors of their patients' skins.

A deep learning model that is intelligent and understandable for computerized vitiligo diagnosis, lesion segmentation, and severity estimation is proposed in this work. The model employs squeeze and excitation blocks to highlight lesion-important features, a transformer module to learn global dependencies, and a Convolutional Neural Network (CNN) backbone to learn features. The model is trained on a diverse set of datasets representing all Fitzpatrick skin types (I–VI) to provide equity and generalizability.

Explainable AI (XAI) techniques like Grad-CAM and LIME are used to visualizable rationale for decisions in a bid to construct clinical trust. For improved accuracy and customization, the system also takes multimodal inputs like patient metadata (e.g., skin color and age).

Mobile phones or web platforms may be used to roll out the end-to-end system in urban hospitals and rural health clinics. To make dermatological care more accessible, this proposal will fill gaps in diagnostic equity, interpretability, and accessibility.

Chapter 1

Introduction

Vitiligo is a chronic autoimmune skin disease that leads to the destruction of melano -cytes, pigment cells, leading to white spots on the skin. Although not physically dangerous or infectious, vitiligo is likely to lead to severe psychological, emotional, and social distress, especially in individuals with higher exposed skin contrast. Early and accurate diagnosis is essential in facilitating timely treatment and emotional well-being.

Although diagnosis of vitiligo is important, it remains difficult in clinical practice. It is largely based on experience within a dermatologist and on the presence of special equipment such as Wood's lamps or dermoscopy. Furthermore, accuracy of diagnosis can significantly vary from one patient to another with respect to complexion, typically being disadvantageous to very fair- or very dark-skinned patients. These issues illustrate the need for readily available, automatic, and objective diagnostic support systems capable of functioning reasonably well across a diverse population.

Figure 1.1: Vitiligo affects individuals across all skin tones, highlighting the importance of inclusive and fair AI diagnostic tools.

Recent advances in artificial intelligence (AI), i.e., deep learning, have facilitated the attainment of high-performance image classification and segmentation models in the medical field. Convolutional Neural Networks (CNNs) have been utilized heavily in dermatology for application to disease identification tasks. For example, Makena Low *et al.* [1] introduced a CNN-based U-Net model for vitiligo lesion segmentation that had good performance on benchmark datasets. Guo *et al.* [2] have introduced a YOLOv3 and UNet++-based hybrid model for lesion localization and vitiligo severity scoring. Sharma *et al.* [3] have reported high skin condition prediction diagnostic accuracy using InceptionV3.

However, several challenges remain unaddressed in current AI-based vitiligo research. Most existing models:

- are acquired from small or non-diverse training data which limit generalizability,
- are not transparent and interpretable in their predictions,
- are not end-to-end integrated for diagnosis and severity scoring.

To address these gaps, this research proposes an end-to-end AI model that can diagnose vitiligo, outline lesion areas, quantify severity, and justify its predictions. The model is to employ CNN and Transformer blocks, with Squeeze-and-Excitation (SE) blocks, to learn the local and global features of the lesion. Grad-CAM and LIME will also be employed as Explainable AI (XAI) techniques to justify the model's decision-making. Furthermore, the model will be trained and tested on Fitzpatrick skin types I-VI to ensure fairness and diversity.

By synergistic combination of state-of-the-art deep learning and interpretability and fairness, this proposal has a long-term vision of building a scalable diagnostic aid tool to be deployable in hospitals, telemedicine platforms, and mobile health apps.

Chapter 2

Motivation and Methodology

2.1 Motivation

Vitiligo is a seeming but overlooked dermatologic disorder affecting almost 1 percent of the global population. Although universal, diagnosis largely remains contingent upon clinical examination by dermatologists and may differ based on the type of skin. Delayed or incorrect diagnosis may lead to less than optimal treatment as well as profound psychological impact in patients. With the growing use of artificial intelligence (AI) in medical imaging, there is a clear potential to use these technologies to increase the accuracy, accessibility, and equity of vitiligo diagnosis and evaluation.

2.2 Social and Ethical Issues

One of the key real-world problems this study resolves is diagnostic bias. Current AI dermatology models are suboptimal in darker-skinned patients because they have limited representations in training data sets. This is a simple ethical problem in terms of health care equity. Our model avoids this with training data for Fitzpatrick skin types I-VI, thereby ensuring balanced performance across populations. In addition, explainability also plays a critical role in guaranteeing ethical uses of AI in medicine. Our system leverages visual interpretation techniques such as Grad-CAM and LIME to provide clinicians with some insight into how the model made the decision.

2.3 Environmental and Sustainability Issues

All but the most advanced traditional techniques, such as dermoscopy and Wood lamps, are too expensive and non-portable to be used in low-resource or rural settings. Our proposed model is made to be mobile-device or web-platform friendly and lightweight. By reducing the reliance on expensive diagnostic equipment and unavoidable clinic visits, the model makes the health infrastructure more accessible and sustainable.

2.4 Related Works

A few works have focused on AI usage in dermatological diagnosis. Makena Low *et al.* [1] trained CNN-based U-Net for vitiligo lesion segmentation. Guo *et al.* [2] presented a hybrid model that utilized YOLOv3 and UNet++ for detection and estimation of severity respectively. Sharma *et al.* [3] utilized InceptionV3 to distinguish between skin lesions with high diagnostic performance. Nevertheless, most current literature does not put together explainability, fairness of skin tones, and end-to-end diagnosis within a single pipeline.

2.5 Limitation of Previous Work

- Failure to generalize to diverse skin tones
- Low interpretability (black-box models)
- Two models for prediction and severity scores
- Biased or small datasets
- Dissonance with low-resource or mobile settings

2.6 Problem Statement

Current vitiligo diagnosis frameworks are susceptible to bias, lack explainability, and exhibit disjointed functionality. Current systems are trained on homogeneous data and lack the ability to offer lesion localization and severity analysis in an integrated pipeline. Clinical adoption is thus limited, and patients with underrepresented skin colors experience reduced diagnostic accuracy. This paper presents an integrated, comprehensible, and fair AI model for vitiligo diagnosis automation, lesion segmentation, and grading to achieve transparency along with deployability feasibility in different clinical contexts.

2.7 Our Proposed Method

We suggest an end-to-end deep learning framework with several components for effective vitiligo analysis:

- **CNN Backbone (e.g., ResNet34):** to extract spatial features from the skin images.
- **Transformer Module (e.g., Swin Transformer):** to model long-range dependencies and enhance global context understanding.
- **Squeeze-and-Excitation (SE) Blocks:** to emphasize the regions related to the injury and inhibit background noise.
- **Multimodal Input:** includes both image data and patient metadata (e.g. age, sex, skin tone).
- **Explainable AI (XAI):** uses Grad-CAM and LIME to visualize important regions that influence model predictions.
- **Cross-Skin-Type Training:** ensures generalization across all Fitzpatrick types (I–VI).
- **Severity Scoring Module:** calculates lesion coverage and contrast to assign a severity grade.

oindent The overall system architecture is illustrated in Figure 2.1.

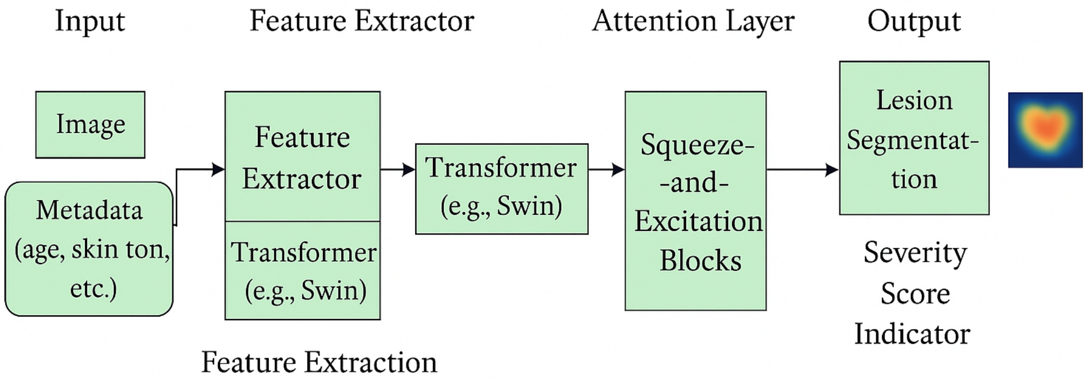

Figure 2.1: Proposed AI-based framework for vitiligo diagnosis, segmentation, and severity scoring

Contribution of This Research

- Proposes a common framework for vitiligo diagnosis, segmentation, and severity estimation.
- Ensures fairness on various skin tones with inclusive training datasets. ¡/itemize¿.
- Includes explainability to enable clinical transparency and trust.
- Optimized for use on mobile and telemedicine platforms.

Chapter 3

Conclusion

Conclusion

This paper suggests a uniform, interpretable, and unbiased AI model for segmentation, grading, and diagnosis of vitiligo. This architecture-based hybrid model with the use of Convolutional Neural Networks (CNNs), Transformer blocks, and Squeeze-and-Excitation (SE) blocks gives an end-to-end solution to automate and improve the assessment of vitiligo.

Use of explanation AI models such as Grad-CAM and LIME improves model transparency, confidence in dermatalogist, and simpler clinical interpretation. Using patient metadata and training on all Fitzpatrick skin types enables the model to generalize across a broad variety of skin pigments, and this is a beneficial advantage of AI models used in dermatology.

The system is web- and mobile-enabled and therefore low-resource adequate to be utilized in telemedicine and healthcare settings. The paper offers a milestone towards the development of smart, inclusive, and accessible dermatology devices.

Current Limitations

- Scale up the data set to include other hypopigmented diseases (e.g., pityriasis alba, tinea versicolor) to be used in differential diagnosis.

- Create and roll out a light-weight mobile application with models for offline diagnosis.

- Design and release a mobile app with model integration for differential diagnosis assistance in offline mode.

Future Work

- Augment the data base with additional hypopigmented disorders (e.g., pityriasis alba, tinea versicolor) for supporting differential diagnosis.
- Create and release a light application with models for offline differential diagnosis support.
- Explain further by means such as SHAP or explanation-based on concepts.
- Collaborate with hospitals and dermatology clinics for in-real-life clinical trials and model calibration.

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