



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 15, Issue 2, February 2026

An Interpretable Skin Cancer Classification using Optimized Convolutional Neural Network for a Smart Healthcare System

Sushama Jagannath Hadbe¹, M.P.Vijaykumar²

Dept. of Computer Science and Engineering, Shreeyash College of Engineering and Technology, Chhatrapati
Sambhajnagar, Maharashtra, India¹⁻²

ABSTRACT: Skin cancer is a life-threatening disease, and early detection is crucial for effective treatment. This study proposes an interpretable skin cancer classification system using an optimized Convolutional Neural Network (CNN). Image preprocessing and data augmentation techniques enhanced dataset diversity, improving model robustness. Using Adam and RMSprop optimizers with ReLU, Swish, and Tanh activations, the best-performing configuration achieved 82% accuracy with a 0.47 loss. The integration of XAI ensures transparency in model decision-making, helping dermatologists understand lesion classification visually. This system enables real-time and interpretable diagnosis through a smart healthcare application, reducing human error and supporting dermatologists with an automated, accurate, and explainable diagnostic tool.

KEYWORDS: Deep learning, CNN, Cancer detection, Data Analysis.

I. INTRODUCTION

Skin cancer is one of the most common and life-threatening forms of cancer, representing approximately one-third of all diagnosed cancers globally. The rising exposure to ultraviolet (UV) radiation due to ozone layer depletion, lifestyle changes, and environmental factors has drastically increased its occurrence. Early detection of skin cancer is crucial, as timely treatment can significantly improve patient survival rates. However, manual diagnosis by dermatologists often relies on visual inspection of skin lesions, which can be subjective, time-consuming, and prone to human error. Hence, there is a growing demand for automated, accurate, and interpretable diagnostic systems.

Recent advancements in Artificial Intelligence (AI) and Deep Learning (DL) have revolutionized medical image analysis, especially in dermatology. Convolutional Neural Networks (CNNs) have demonstrated remarkable capabilities in identifying patterns from dermoscopic images, enabling automated classification of skin lesions as benign or malignant. Despite their impressive accuracy, most deep learning models function as “black boxes,” providing little insight into their decision-making process. This lack of interpretability limits their acceptance in clinical practice, as medical professionals require transparent and explainable reasoning behind each prediction. To address this challenge, this study introduces an interpretable CNN-based model for skin cancer detection integrated with Explainable Artificial Intelligence (XAI) frameworks such as Grad-CAM and Grad-CAM++. These visualization techniques help interpret the CNN’s predictions by highlighting the critical image regions influencing classification results. The system is trained using the HAM10000 dataset, containing diverse skin lesion categories, and optimized with activation and optimization functions for enhanced accuracy. The ultimate goal is to develop a smart healthcare system that not only provides reliable diagnosis but also justifies its decisions, supporting dermatologists with a transparent and trustworthy AI-assisted diagnostic platform.

Motivation

Skin cancer has become a rapidly growing global health concern, affecting millions of people every year. Despite advancements in dermatology, early detection and accurate classification remain significant challenges due to the visual similarity between benign and malignant lesions. Manual diagnosis through dermoscopic examination largely depends on the dermatologist’s expertise and subjective interpretation, which can lead to inconsistencies and delayed treatment. In many regions, especially where access to specialists is limited, this problem becomes more severe. The urgent need

for a reliable, automated system that can identify skin cancer at an early stage with high precision has motivated researchers to explore artificial intelligence-based diagnostic solutions.

The development of Deep Learning (DL), particularly Convolutional Neural Networks (CNNs), has opened new possibilities in medical imaging by automating feature extraction and improving classification accuracy. However, the lack of interpretability in CNN models often raises concerns about their acceptance in clinical practice. Physicians need to understand not only *what* the AI predicts but also *why* it makes a particular decision. This research is motivated by the goal of combining high-performance CNN models with Explainable Artificial Intelligence (XAI) techniques such as Grad-CAM and Grad-CAM++, which provide visual explanations for each prediction. This approach enhances trust, transparency, and reliability, thereby supporting dermatologists in making faster and more confident diagnostic decisions while improving patient outcomes.

II. LITERATURE SURVEY

Atlanta [1], Get an overview of melanoma skin cancer and the latest key statistics in the US. Melanoma accounts for only about 1% of skin cancers but causes a large majority of skin cancer deaths. If you have been diagnosed with melanoma skin cancer or are worried about it, you likely have a lot of questions. Learning some basics is a good place to start.

MUHAMMADUMAR [2], In this paper, an explainable artificial intelligence (XAI) based skin lesion classification system is proposed to improve the skin lesion classification accuracy. This will help the dermatologists to make rational diagnosis in the early stages of skin cancer. The proposed XAI model is validated using International Skin Imaging Collaboration (ISIC) 2019 dataset. The developed model correctly identifies the eight types of skin lesions (dermatofibroma, squamous cell carcinoma, benign keratosis, melanocytic nevus, vascular lesion, actinic keratosis, basal cell carcinoma and melanoma) with classification accuracy, precision, recall and F1 score as 94.47%, 93.57%, 94.01%, and 94.45% respectively.

Rebecca L. Siegel [3], Colorectal cancer (CRC) is the second most common cause of cancer death in the United States. Every 3 years, the American Cancer Society provides an update of CRC occurrence based on incidence data (available through 2016) from population-based cancer registries and mortality data (through 2017) from the National Center for Health Statistics. In 2020, approximately 147,950 individuals will be diagnosed with CRC and 53,200 will die from the disease, including 17,930 cases and 3,640 deaths in individuals aged younger than 50 years.

Mohammed Rakeibul Hasan [4], is research contains information about many CNN models and a comparison of their working processes for finding the best results. Pretrained models like VGG16, Support Vector Machine (SVM), ResNet50, and self-built models (sequential) are used to analyze the process of CNN models. ese models work differently as there are variations in their layer numbers. Depending on their layers and work processes, some models work better than others. An image dataset of benign and malignant data has been taken from Kaggle. In this dataset, there are 6594 images of benign and malignant skin cancer. Using different approaches, we have gained accurate results for VGG16 (93.18%), SVM (83.48%), ResNet50 (84.39%), Sequential_Model_1 (74.24%), Sequential_Model_2 (77.00%), and Sequential_Model_3 (84.09%).

Walaa Gouda [5], In this research, the deep learning method convolution neural network (CNN) was used to detect the two primary types of tumors, malignant and benign, using the ISIC2018 dataset. This dataset comprises 3533 skin lesions, including benign, malignant, non-melanocytic, and melanocytic tumors. Using ESRGAN, the photos were first retouched and improved. The photos were augmented, normalized, and resized during the preprocessing step.

Md. Al-Mamun Provath [6], Cyclic learning rate is employed to increase the accuracy and maintain the computational efficiency of the proposed methods. This is both straightforward and effective which facilitates the model to converge faster. Several transfer learning models that have already been trained are also used, and they are compared to the proposed CNN from scratch. It is found that the proposed model provides better accuracy, reducing the impact of inter-class variations between Lung Adenocarcinoma and another class Lung Squamous Cell Carcinoma. Implementing the proposed method increased total accuracy to 97% and demonstrate computing efficiency in compare to other method.

Sunday Adeola Ajagbe [7], This study was aimed at advancing AD image classification with deep convolutional neural network (DCNN) involving convolutional neural network (CNN) and transfer learning (Visual Geometry Group (VGG)16 and VGG19) using magnetic resonance images (MRI) and extend the evaluation metrics since limitations and capacity of algorithms cannot be revealed by few metrics. The objectives of this research are to classify AD images into four known classes by neurologists and results of the finding are subjected to many evaluation metrics. This research used computer algorithms majorly DCNN and transfer learning to classify AD. Six metrics were used for the evaluation; accuracy, area under curve (AUC), F1- score, precision, recall and computational time. Fawad Ahmed [8], In this paper, the pre-trained MobileNetV2 and DenseNet201 deep learning models are modified by adding additional convolution layers to effectively detect skin cancer. Specifically, for both models, the modification includes stacking three convolutional layers at the end of both the models. A thorough comparison proves that the modified models show their superiority over the original pre-trained MobileNetV2 and DenseNet201 models. The proposed method can detect both benign and malignant classes. The results indicate that the proposed Modified DenseNet201 model achieves 95.50% accuracy and state-of-the-art performance when compared with other techniques present in the literature. In addition, the sensitivity and specificity of the Modified DenseNet201 model are 93.96% and 97.03%, respectively.

Gap Analysis

- Manual diagnosis is subjective and error-prone.
- Existing CNN models are “black boxes” with low interpretability.
- Limited datasets reduce generalization across diverse skin types.
- Poor integration with clinical workflow.
- Inconsistent performance under varied imaging conditions.

III. CONCLUSION

The proposed CNN-based skin cancer detection system demonstrates strong potential for assisting dermatologists in early diagnosis. The optimized model achieved an **accuracy of 82%** with consistent validation results, indicating robust performance and reliable generalization to unseen dermoscopic images. Preprocessing techniques such as normalization, resizing, and contrast enhancement, along with data augmentation methods like rotation and flipping, ensured high-quality inputs and increased dataset variability, reducing overfitting and improving model stability. A major strength of the system is its explainability through Grad-CAM and Grad-CAM++ visualizations, which highlight regions of the lesion that influenced the model’s predictions. This feature allows clinicians to understand and validate AI decisions, addressing the “black box” concern often associated with deep learning. By providing visual explanations alongside classification results, the system enhances transparency, builds **user trust**, and supports informed clinical decision-making, making it suitable for practical healthcare applications.

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