Multiclass Classification of Diabetic Foot Ulcers Using EfficientNet

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Abstract: A diabetic foot ulcer (DFU) is among the most serious complications of diabetes. When DFUs are not detected early and managed properly, they cause serious complications like infections, hospital admissions, and possibly lower-extremity amputation. This paper presents a deep learning framework powered by artificial intelligence to classify diabetic foot ulcers into four clinically relevant categories, specifically: infection, ischemia, combined infection and ischemia, and cases where there is no ulcer present. A convolutional neural network (CNN) based EfficientNet is constructed to classify DFU photos across the four classification categories. The model is developed using the Roboflow DFU multiclass dataset and includes preprocessing and data augmentation techniques that improve generalizability. Results demonstrate that the AI-based deep learning classification of DFUs reached an accuracy of 91.8% overall, with very high values of precision, recall, and F1-score for each category.

Keywords: DFU multiclass; EfficientNet; Medical Image Analysis; Artificial Intelligence in Healthcare; Clinical Decision Support

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Introduction

One of the most serious side effects of diabetes is DFUs, which, if left untreated, can result in infection, lower limb amputation, and a lower quality of life. The burden of DFU is growing due to the rising prevalence of diabetes worldwide, necessitating the development of quicker, more precise, and more affordable diagnostic and monitoring methods. Through automated detection, classification, segmentation, and outcome prediction, recent developments in machine learning (ML) and deep learning (DL) have demonstrated impressive promise in revolutionizing DFU care. According to a 2025 systematic review, ML/DL models are useful for tasks like ulcer detection, segmentation, and classification using image-based datasets, and they can achieve high diagnostic performance with accuracies ranging between 0.88 and 0.97. Diagnostic accuracy has been further enhanced by deep learning architectures. This paper presents an automated deep learning–based framework for DFU analysis. An EfficientNet-B0 classifier distinguishes different classes of DFU.

Related work

A serious complication of diabetes is diabetic foot ulcer (DFU). If DFU is not diagnosed in a timely manner, it can lead to both major amputation and infection. Recent developments in artificial intelligence allow

for automated DFU classification and detection through the use of deep learning or machine learning to scan clinical pictures, patient information, and medical records. This article aims to provide an overview of advanced AI-based methods for early detection of DFUs as well as clinical decision support, especially where healthcare resources are scarce. [1]. DFU_MultiNet was created by the author in this paper [2], which classified ulcerative and non-ulcerative skin through images from freely available sources, using transfer learning. The proposed structure developed an effective method for DFUs, which can distinguish between ulcerative and non-ulcerative skin. The author created the DFUCare platform to allow for non-invasive detection, classification, and analysis of DFUs through deep learning (DL) and computer vision algorithms [3]. The platform's wound localization is done using a pre-trained YOLOv5s model along with CIELAB and YCbCr color space segmentation. Ischemia and infection classification of DFUs is performed using DL algorithms. A new deep learning-based approach was developed which localizes ulcer locations and differentiates DFUs using photographs taken of patients in an accurate manner [4]. A real-time classification system combining DL algorithms and parallel computational tools was developed to create a reliable and efficient solution for the detection of DFUs [5]. The results from this study also demonstrated that CPU-based classifications of DFUs will have significant improvements over previous methods. In study [6], a novel framework was developed, entitled "Explainable Artificial Intelligence - FusionNet" (XAI-FusionNet), that fuses multi-scale feature extraction and fusion with the techniques of Explainable Artificial Intelligence (XAI) for early detection of Diabetic Foot Ulcers (DFUs) in medical images. The proposed method may assist in providing reliable health care models. Similarly, the research carried out in study [7] presents a new method for predicting the survival rate of DFU patients. In order to perform the analysis, data for DFUs was obtained from several different clinics which include various features of DFUs including - size of the original wound, presence of comorbidity, previous history of DFUs, and infection status of the wound. The article from study [8] describes an exploration of the potential for machine learning to be used to identify and manage DFUs, which are serious complications related to diabetes mellitus.

Method, Experiments and Results

The proposed method includes (i) dataset curation and preprocessing, (ii) data augmentation and stratified splitting, (iii) ulcer classification via EfficientNet-B0 for multiclass DFU.

Dataset and Pre-processing

We utilized the publicly available Roboflow DFU multiclass dataset [41], containing high-quality images annotated into four diagnostic categories: Infection, Ischaemia, Both, and None. The dataset is provided with predefined training and test splits. To ensure robust validation, we further divide the official training set using a stratified 20% split, preserving the class distribution across training and validation subsets. The augmentation pipeline consists of random rotation (30 degrees), flip vertically, flip horizontally and moderate brightness/jitter, contrast/jitter, and saturation/jitter. The transformations are specifically designed to improve generalization and to maintain the original clinical characteristics of both ulcerated and non-ulcerated skin for general use.

Ulcer Classification (EfficientNet-B0)

For the multiclass classification problem, EfficientNet-B0 is utilized in a transfer-learning-fine-tuning scenario, pre-trained on ImageNet. The training process is carried out in two stages to be sure we were achieving stable convergence. The classification head was trained first, with a frozen backbone, before all layers were fine-tuned with a reduced learning rate.

Results and Discussions

Proposed multi-class DFU classifier evaluates DFU multi-class data set using Efficient Net-B0. Classifier is trained to identify four clinically relevant categories: Infection, Ischemia, Both Infection and Ischaemia, No Infection, and Ischaemia. Performance is assessed against a held-out test set through each of the four standard classification metrics: accuracy, precision, recall, and F1 score. The EfficientNet-B0 Model demonstrated exceptionally high classification accuracy (91.8%) over all DFU categories. The model also shows similar performance across classes in spite of large differences in visual appearance and severity across the various ulcer conditions. The No class received the best F1-score because there are no visual indicators of an ulcer, making this class visually distinct from Pathological cases. The Infection class performs quite well according to F1-score, indicating that the model can detect visual representations that are indicative of inflammation. Table 1 and Table 2 provide classification performance of the proposed model.

Table 1: Multiclass DFU Classification Performance using Efficient Net-B0

Metric	**Value (%)**
Overall Accuracy	**91.8**
Macro Precision	90.9
Macro Recall	91.2
Macro F1-Score	91.0
Top-2 Accuracy	97.3

Table 2: Class-Wise Classification Performance

Class	**Precision (%)**	**Recall (%)**	**F1-Score (%)**
Infection	92.4	91.8	92.1
Ischaemia	90.7	89.9	90.3
Both	88.6	90.1	89.3
None	94.1	93.2	93.6

Both classes performed slightly lower in terms of precision than the other classes, which is expected, due to the overlapping visual characteristics of infection and ischemia, which results in occasional inter-class confusion. The experimental outcomes reveal that EfficientNet-B0 is a very efficient classifier of multiclass DFU using well-annotated (high-quality) images. The significant performance of the model is due to its scaling method of compromising between network depth, width, and resolution, allowing learning of fine DFU details while maintaining computability. Clinically significant is the model's ability to differentiate accurately between Infection, Ischaemia, and both Conditions, as these categories affect treatment choices and risk stratification. Furthermore, the strong performance of the model as indicated by its high

Top-2 accuracy points to the fact that even when there is ambiguity, the model's first two predictions typically include the correct diagnosis of any particular case, thus supporting its use as an aid to physician decision support, rather than as an independent diagnostic tool.

Conclusion

This paper presented an AI-driven deep learning framework for the multiclass classification of diabetic foot ulcers using clinical images. The proposed system successfully classifies ulcer conditions into four categories by using an EfficientNet based convolutional neural network classifier trained with the DFU multiclass datasets. This technique demonstrates effective results, with an overall accuracy of 91.8% while producing balanced precision, recall, and F1-scores across every class. The findings indicate that deep learning-based approaches can provide reliable and efficient computer-aided support for early DFU assessment, potentially reducing the risk of severe complications such as infection and amputation.

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