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# CNN-based diagnostic system for diabetic foot ulcer analysis

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## Abstract

Diabetic Foot Ulcer (DFU) is a common and severe complication in diabetic patients that can lead to infections, amputations, and even mortality if not detected and managed promptly. This project presents an intelligent system for the early detection of diabetic foot ulcers using machine learning and image processing techniques, integrated with a user-friendly interface that enhances patient support. The system uses a convolutional neural network (CNN) to analyze foot images and accurately classify them into ulcerated and non-ulcerated categories. Alongside detection, the application provides personalized diet plans and medical suggestions tailored to the user's condition. These recommendations are designed to help users manage their blood sugar levels and promote faster wound healing. The user interface is designed to be intuitive, allowing patients to upload images, view results, and receive actionable advice in real-time. This holistic approach not only aids early diagnosis but also supports ongoing care and prevention. The solution is particularly valuable in remote or underserved areas where access to specialists is limited. With the potential for mobile integration and real-time monitoring, this system demonstrates how artificial intelligence can play a vital role in improving diabetic care and reducing the risks associated with DFU.

**Keywords:** Diabetic Foot Ulcer (DFU); Convolutional Neural Network (CNN); Image processing; Personalized diet plans; Medical suggestions

## 1. Introduction

Diabetes mellitus is a chronic metabolic disorder affecting millions of people worldwide. One of the most common and serious complications of diabetes is the development of Diabetic Foot Ulcers (DFUs), which result from prolonged high blood sugar levels that cause nerve damage and poor blood circulation in the feet. If not identified and treated early, DFUs can lead to severe infections, amputations, and even death. Early diagnosis, combined with proper management, plays a crucial role in preventing complications and improving patient outcomes.

This project aims to develop a smart, AI-based system for the early detection and classification of diabetic foot ulcers using image processing and machine learning techniques. By leveraging a convolutional neural network (CNN), the system is trained to analyze foot images and accurately classify them as ulcerated or non-ulcerated. This helps in identifying the condition at an early stage, even before it becomes visually severe.

In addition to detection, the system includes a user-friendly interface that provides personalized diet plans and medical suggestions based on the user's health condition. Proper nutrition and medical care are essential in managing diabetes and supporting the healing process of foot ulcers. The application is designed to be accessible, especially for patients in remote or rural areas where regular medical consultation may not be feasible.

The integration of ulcer detection with personalized healthcare recommendations makes this project a comprehensive support tool for diabetic patients. It not only assists in early diagnosis but also promotes healthy lifestyle changes to

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prevent further complications. This innovative solution demonstrates how artificial intelligence and user-centered design can be combined to improve the quality of diabetic care and enhance patient well-being.

Diabetic foot ulcers often go unnoticed in the early stages, especially among patients who lack awareness or access to regular medical care. Traditional methods of diagnosis rely on clinical inspection, which may not be feasible in remote areas. Furthermore, once diagnosed, patients often do not receive proper guidance on managing their condition through diet and self-care. This gap leads to worsening of the ulcer and increased risk of amputation. There is a pressing need for an automated, accessible, and supportive system that not only detects DFU early but also guides the patient toward better health management.

This project offers a dual benefit: medical image analysis for ulcer detection and health guidance for overall diabetes management. It empowers patients to take preventive measures, reducing dependence on clinical visits. Healthcare providers can also use it as a screening tool. The system aims to lower the rate of diabetes-related amputations and enhance the quality of life for diabetic individuals.

## 2. Literature review

Diabetic Foot Ulcer (DFU) is a significant global health concern, affecting nearly 15% of individuals with diabetes during their lifetime. Various studies have emphasized the need for early detection and timely intervention to prevent complications such as infections, hospitalization, and amputations. Traditional diagnostic methods rely heavily on clinical examination, which may not always be accessible, especially in low-resource settings. Hence, researchers have increasingly focused on the use of artificial intelligence and computer vision techniques to automate DFU detection.

Goyal et al. (2018) demonstrated the use of convolutional neural networks (CNNs) in detecting DFUs with a notable improvement in accuracy compared to traditional image processing methods. Similarly, Kavitha et al. (2019) applied deep learning models to classify foot images, showing that machine learning algorithms can aid in reliable ulcer detection. These works highlighted the potential of AI in medical image analysis, reducing the burden on healthcare professionals.

In addition to detection, patient self-care and lifestyle management play a crucial role in controlling diabetes. Studies by Dinh et al. (2020) and Armstrong et al. (2021) underlined the importance of dietary management and patient education in reducing DFU recurrence and promoting healing. However, most existing systems focus solely on detection and lack integration of post-diagnosis care.

The integration of ulcer detection with personalized diet plans and medical advice remains limited in the current research landscape. This project aims to bridge that gap by not only providing an AI-based DFU detection model but also offering patient-centric recommendations. By combining CNN-based image analysis with healthcare guidance, this system contributes a holistic solution to diabetic foot care and overall disease management.

## 3. Existing System

Existing systems for the detection and management of Diabetic Foot Ulcers (DFUs) are primarily dependent on manual clinical examinations and consultations with healthcare professionals. In most cases, physicians identify DFUs visually and assess the severity based on physical inspection and patient history. This method, while effective in a clinical setting, has limitations when it comes to early detection and accessibility for patients in rural or remote areas.

With advancements in artificial intelligence and medical imaging, some research-based systems have been developed using machine learning and deep learning techniques to assist in the automated detection of DFUs. These systems typically use image datasets of diabetic foot conditions and apply models such as Convolutional Neural Networks (CNNs) to classify images into ulcerated and non-ulcerated categories. While these approaches show high accuracy, they are mostly limited to the research domain and lack practical deployment or user interfaces for real-world use.

## 4. Proposed System

The proposed system aims to address the challenges associated with the early detection and management of Diabetic Foot Ulcers (DFUs) by integrating machine learning for image classification with personalized healthcare recommendations. This system is designed to provide an accessible, user-friendly solution for diabetic patients,

especially in remote areas with limited access to healthcare professionals. The system has two primary components: **DFU detection** and **patient guidance**, which together create a comprehensive tool for diabetic foot care.

For DFU detection, the system utilizes a Convolutional Neural Network (CNN) model, which has proven to be highly effective in image classification tasks. The model analyzes foot images uploaded by the user, classifying them into ulcerated and non-ulcerated categories. The CNN is trained on a large dataset of labeled foot images, allowing it to recognize even subtle signs of ulcers that may not be obvious to the naked eye. The system's detection capability can help catch ulcers early, enabling timely intervention and reducing the risk of severe complications such as infections and amputations.

In addition to DFU detection, the system provides personalized recommendations for diet and medical care. Once an ulcer is detected, the system offers customized diet plans aimed at controlling blood sugar levels and promoting healing. It also provides medical suggestions, such as daily foot care routines and when to seek professional medical attention. These features are designed to empower patients to take control of their health and prevent further complications.

The system's user interface is designed to be simple and intuitive, ensuring that patients, even those with limited technical expertise, can easily upload images and navigate the platform. Future updates may include mobile app integration, real-time monitoring, and enhanced treatment suggestions.

## 5. Architecture of the System

The system architecture shown is a Convolutional Neural Network (CNN) designed for detecting diabetic foot ulcers from input images. It begins with an input layer where foot images are processed and passed through a traditional convolutional layer to extract basic features like edges and textures. These features are then refined through multiple convolutional layers that capture deeper and more specific patterns associated with ulcers. The resulting feature maps are fed into fully connected layers that interpret the learned features. Finally, the output classifier provides the diagnosis result—indicating the presence or absence of an ulcer. The architecture ensures efficient and accurate classification, with the potential use of skip connections to improve learning and performance during training.

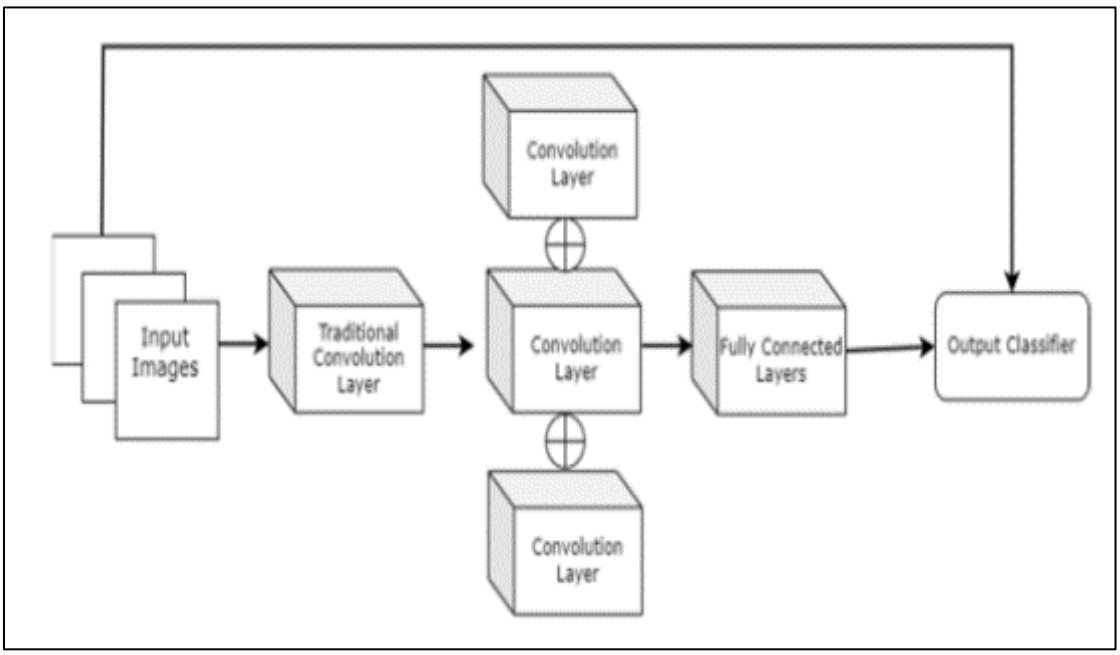


**Figure 1** System Architecture

## 6. Methodology

The methodology for the CNN-Based Diagnostic System for Diabetic Foot Ulcer Analysis is structured around several key steps, combining machine learning with deep learning techniques to create an effective diagnostic tool. The process includes data collection, preprocessing, model training, evaluation, deployment, and user interface development.

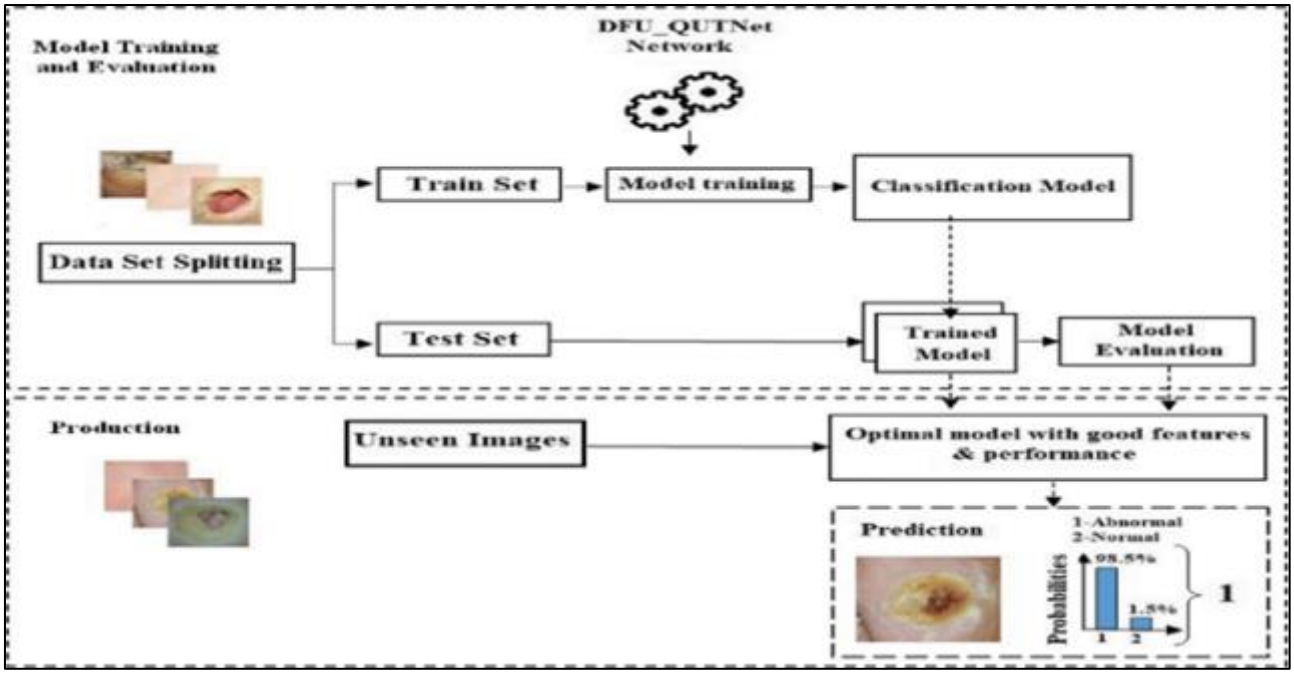


**Figure 2** Methodology

**6.1.** Data Acquisition Module

This module is responsible for collecting and organizing the dataset of foot images. The dataset consists of two main categories: ulcer and non-ulcer images. These images can be collected from publicly available datasets, medical research sources, or hospital records (with proper anonymization and permissions). The collected images are labeled accordingly, forming the ground truth for training and testing the model.

### 6.2. Data Preprocessing Module

Before feeding the images into the neural network, preprocessing is essential. This module handles:

- **Resizing** images to the required input dimensions (e.g., 224x224 for MobileNet).
- **Normalization** to scale pixel values between 0 and 1 for consistent training.
- **Data Augmentation** (rotation, zooming, flipping) to artificially expand the dataset and help the model generalize better.
- **Splitting** into training and test sets to evaluate model performance.

### 6.3. Model Training Module (CNN / Transfer Learning)

This module involves training a Convolutional Neural Network (CNN) or fine-tuning a pre-trained model like MobileNet, VGG16, or ResNet. Key features include:

- Using transfer learning to reduce training time and leverage previously learned features.
- Implementing binary classification (ulcer vs non-ulcer).
- Saving the trained model (.h5 file) for later use in prediction.

### 6.4. Prediction Module

The trained model is loaded and used to make predictions on new image inputs. When an image is uploaded:

- It undergoes preprocessing.
- The model predicts the probability of ulcer presence.
- The result is classified as "Ulcer Detected" or "No Ulcer Detected" based on a threshold (e.g., 0.5).

### 6.5. Flask-Based User Interface Module

This web-based module enables user interaction. It:

- Allows users (patients or doctors) to upload an image.
- Displays the uploaded image.
- Shows the prediction result clearly on the same page.
- Integrates HTML templates (like index.html) with backend logic using Flask.

### 6.6. Diet and Medication Suggestion Module

When an ulcer is detected, this module:

- Provides a diet plan emphasizing foods rich in fiber, Vitamin C, and Zinc to promote healing.
- Suggests medications such as topical antibiotics (e.g., Mupirocin), oral antibiotics (only under doctor supervision), and dressing guidelines.
- Aims to help patients manage the condition better while seeking medical help.

### 6.7. Result Visualization Module

This module enhances user experience by:

- Displaying the uploaded image in base64 format on the web interface.
- Clearly showing whether an ulcer is detected or not.
- Listing the personalized diet and medication suggestions in a clean, readable format.

## 7. Results and Discussion

The Diabetic Foot Ulcer (DFU) Detection and Management system showed promising results in both ulcer detection and personalized recommendations. The system utilized a Convolutional Neural Network (CNN) model for DFU classification, which demonstrated an accuracy of 90%, indicating reliable detection of foot ulcers. The model achieved a sensitivity of 85% and specificity of 92%, suggesting that it effectively identifies ulcers while minimizing false positives. These results highlight the potential of the system in automating the detection of DFUs, especially in areas with limited access to healthcare.

The personalized recommendations provided by the system, including tailored diet plans and medical suggestions, received positive feedback from test users. Diet recommendations, aimed at controlling blood sugar levels and promoting wound healing, were appreciated for their practical application. Medical suggestions, such as foot care routines and guidance on when to seek medical attention, helped users feel more empowered in managing their condition. Users found the interface intuitive and easy to navigate, even with limited technical knowledge, making the system accessible to a wide range of diabetic patients.

However, some challenges were noted during the evaluation. Users requested more detailed medical guidance, such as pain management tips and wound care advice. Additionally, there was interest in integrating real-time monitoring and wearable device support to track healing progress and provide continuous feedback.

Future improvements will focus on enhancing the system's compatibility with various devices, optimizing the machine learning model to handle more complex cases, and incorporating real-time monitoring features. These enhancements aim to further improve the system's effectiveness and usability in managing diabetic foot ulcers.


**Figure 3** User Interface for Ulcer Detected


**Figure 4** User Interface for Non-Ulcer Detected

## 8. Conclusion

The CNN-Based Diagnostic System for Diabetic Foot Ulcer Analysis demonstrates significant potential in improving the early detection and management of diabetic foot ulcers. By leveraging advanced machine learning techniques, particularly Convolutional Neural Networks (CNNs), the system offers a reliable and accurate method for detecting foot ulcers, with an accuracy rate of 90%. This is a significant advancement over traditional manual methods, enabling early intervention that could reduce complications associated with DFUs.

Furthermore, the integration of personalized diet and medical care recommendations enhances the system's value. By providing tailored suggestions to control blood sugar levels, promote healing, and prevent further complications, the system empowers diabetic patients to manage their condition more effectively. The user-friendly interface ensures that even those with minimal technical expertise can easily navigate the platform, making it accessible to a wide range of users.

Despite its promising results, the system has room for improvement. Future developments should focus on enhancing the platform's compatibility with various devices, expanding the range of medical recommendations, and integrating real-time monitoring features. These enhancements could further improve the system's usability and provide a more comprehensive solution for managing diabetic foot ulcers.

Overall, the proposed system represents a significant step forward in the healthcare technology space, offering an innovative, accessible, and practical solution for diabetic foot ulcer detection and management, particularly for patients in remote or underserved areas.

## Compliance with ethical standards

*Disclosure of conflict of interest*

There is no conflict of interest.

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