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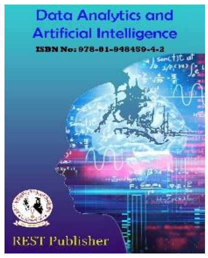

Diabetic Foot Ulcer Detection Using Deep Learning with Image Processing

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Abstract: *As of 2016, the majority of adults have diabetes. One of the major complications of this is diabetic foot ulcers. Diabetic disease can lead to amputation if not treated properly. Current clinical approaches to DFU treatment are based on patient and clinician boundaries that include significant limitations to DFU, such as high diagnostic, therapeutic and long-term treatment costs. We have collected an extensive set of foot images with DFUs from various patients. This article proposed using conventional computer vision capabilities to detect foot ulcers in diabetic patients, a cost-effective, remote and convenient healthcare solution. In this DFU classification task, two grades were evaluated: normal skin (healthy skin) and abnormal skin (DFU). We proposed DenseNet, a novel convolutional neural network architecture with enhanced feature extraction capabilities to detect differences between healthy skin and DFU function. Here we present the development of a novel and highly sensitive DenseNet for objectively detecting the presence of DFU. This new approach could change the paradigm of diabetic foot care. Also, a hospital recommendation system is proposed to help the patients in finding the suitable hospitals.*

Keywords: *Diabetic Foot Ulcer (DFU), Convolutional neural network (CNN), DenseNet*

1. INTRODUCTION

Hyperglycaemia commonly known as Diabetes Mellitus, is a lifelong condition resulting from high blood sugar levels, which can lead to major life-threatening complications such as cardiovascular diseases, kidney failure, blindness and lower limb amputation. There is about a 15%-25% chance that a diabetic patient will eventually develop Diabetic Foot Ulcer and if proper care is not taken, that may result in lower limb amputation. Patients suffering from diabetes lose part of their leg due to the failure to recognize and treat DFU appropriately. A Diabetic patient with a 'high risk' foot needs periodic check-ups of doctors, continuous expensive medication, and hygienic personal care to avoid the further consequences as discussed earlier. The evaluation of DFU in modern clinical practice involves a number of important tasks for early diagnosis, subsequent development, and several long-term measures taken in the treatment and management of DFU in each case. 1) Evaluate the patient's medical history. 2) The DFU is carefully examined by an orthopaedic orthopaedic surgeon or a diabetic orthopaedic surgeon. 3) A treatment plan can be established through additional examinations such as CT, MRI, and X-ray. DFU patients usually have leg swelling, but in some cases it can be itchy and painful. Generally, DFUs have irregular structures and uncertain outer boundaries. The appearance of the DFU and surrounding skin varies with stage. Significant tissue types such as redness, callus formation, blisters, granulations, scales, haemorrhages, and skin peeling. Ulcer evaluation using computer vision algorithms is therefore based on accurate evaluation of visual characteristics such as color descriptors and textural features. We use DenseNet to propose and develop a new fast CNN architecture that outperforms other algorithms in terms of accuracy.

2. OBJECTIVE

The main objective in the DFU classification problem is to classify the images into two classes as normal skin (healthy skin) and abnormal skin (DFU). The novel convolutional neural network architecture, DenseNet, which has a better feature extraction to identify the feature difference between healthy skin and the DFU. The development of a novel and highly sensitive DenseNet is for objectively detecting the presence of DFUs. This novel approach has the potential to deliver a paradigm shift in diabetic foot care.

3. IMPLEMENTATION

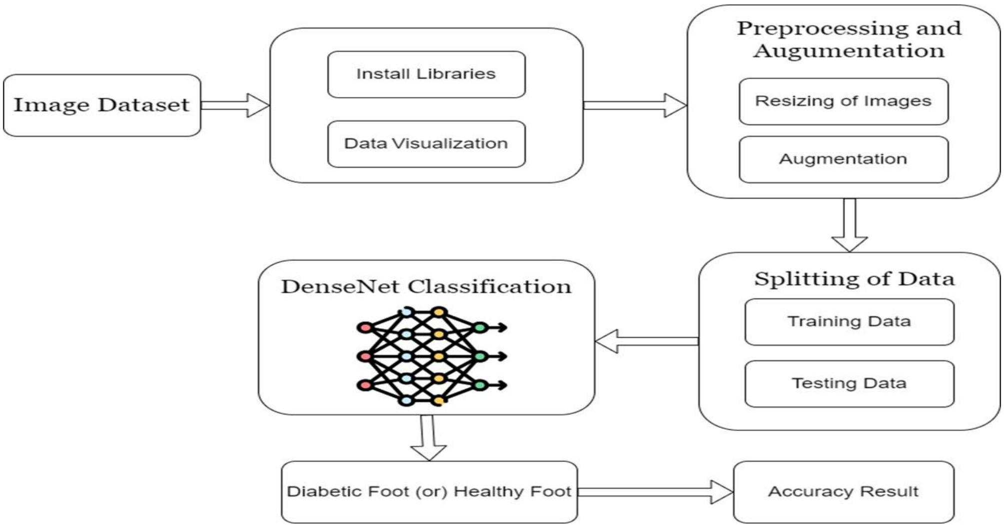

FIGURE 1. System Architecture

4. PROPOSED SYSTEM

In the proposed solution, DenseNet based deep neural technique is used to detect the diabetic foot ulcer from the input images. The proposed method produces instant output which is a solution to existing time-consuming methods. The diabetic foot ulcers can be detected with high accuracy without manual interpretation. DFU classification problem, is to classify images to different classes as healthy skin, high, low and Medium (DFU). A novel convolutional neural network architecture, DenseNet, with better feature extraction to identify the feature differences between healthy skin and the DFU has been implemented.

Dataset collection: Appropriate datasets are required at all stages of foot ulcer recognition research, starting from training phase to evaluating the performance of recognition algorithms. All the images collected for the dataset were downloaded from the Internet. There are three types of datasets which was categorized as normal foot image and low, medium and highly infected diabetic foot ulcer images.

Image Pre-processing: Images downloaded from the Internet were in various formats along with different resolutions and quality. In order to get better feature extraction, final images intended to be used as dataset for deep neural network classifiers were pre-processed in order to gain consistency. Furthermore, procedure of image pre-processing involved cropping all the images manually, in order to highlight the region of interest.

Augmentation Process: The main purpose of applying augmentation is to increase the dataset and introduce slight distortion to the images which helps in reducing overfitting during the training stage. Image data augmentation is a technique that can be used to artificially expand the size of a training dataset by creating modified versions of images in the dataset. Training deep learning neural network models on more data can result in more skill ful models, and the augmentation techniques can create variations of the images that can improve the ability of the fit models to generalize what they have learned to new images.

Neural Network Training: The main goal of training the network is for neural network to learn the features that distinguish one class from the others. Therefore, when using more augmented images, the chance for the network to learn the appropriate features has been increased. For each hidden layer, for each training sample, for each iteration, ignore (zero out) a random fraction, p, of nodes (and corresponding activations). Testing Phase: Use all activations, but reduce them by a factor p (to account for the missing activations during training).

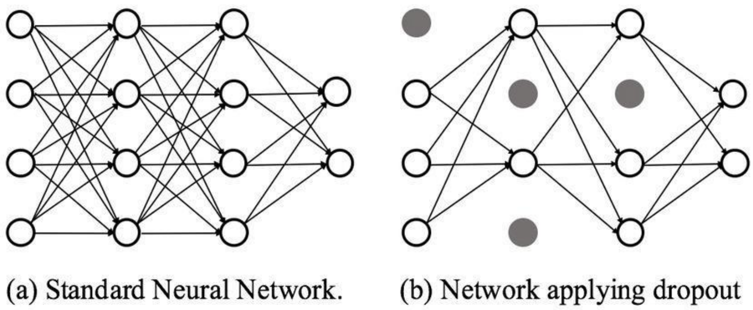

FIGURE 2. Neural Network

Dense Layer: The dense layer is a neural network layer that is connected deeply, which means each neuron in the dense layer receives input from all neurons of its previous layer. The dense layer is found to be the most commonly used layer in the models. In the background, the dense layer performs a matrix vector multiplication.

Dense Net Structure: Dense Net falls in the category of classic networks. This image shows a 5-layer dense block with a growth rate of k =4 and the standard Res Net structure.

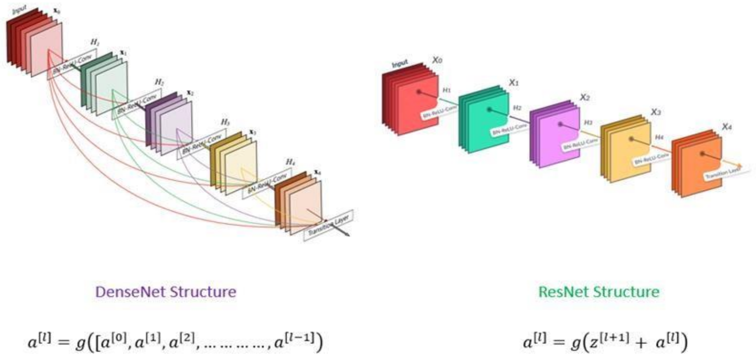

FIGURE 3. Densenet Structure

An output of the previous layer acts as an input of the second layer by using composite function operation. This composite operation consists of the convolution layer, pooling layer, batch normalization, and non-linear activation layer. These connections mean that the network has L(L+1)/2 direct connections. L is the number of layers in the architecture. The DenseNet has different versions, like DenseNet-121, DenseNet-160, DenseNet-201, etc. The numbers denote the number of layers in the neural network. The number 121 is computed as follows:

DenseNet-121:-
5+(6+12+24+16)*2 = 121

5 – Convolution and Pooling Layer
3 – Transition layers (6,12,24)
1 – Classification Layer (16)
2 – DenseBlock (1x1 and 3x3 conv)

Testing Trained Model with Valuation Data: Finally, the trained network is used to detect the disease by processing the input images in the valuation dataset and results are processed.

5. RESULT

On input of images, it is fed to the trained model which in turn checks with which class (i.e, healthy, high, medium, low) the images belong to and displays the output along with recommended hospital if the image is classified as diabetic foot ulcer.

6. CONCLUSION

In this work, a classifier based on DenseNet, a new CNN architecture, was trained for DFU classification that differentiates DFU skin from healthy skin. With highly efficient classification measures, DenseNet enables accurate automatic detection of DFU in foot images and creates an innovative method for evaluating and treating DFU. For DFU detection, understanding the difference between DFU and healthy skin is very important to know the difference between these two grades from a computer vision perspective. This research has the potential to transform the detection and treatment of diabetic foot ulcers and to a technology that could lead to a paradigm shift in the clinical management of diabetic foot.

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