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A CNN Approach for Digital Diagnosis of Knee Osteoarthritis through Image Processing

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Abstract: The common degenerative joint disease known as knee osteoarthritis affects millions of individuals worldwide. The classification and early detection of osteoarthritis in the knee can help with timely intervention and therapy. Using image processing techniques, we created an automatic classification system for knee arthritis in the system that is being presented. To enhance the image quality, we employed a dataset of X-ray images of the knee. For classification, we next employed a convolutional neural network (CNN). We stretched the CNN using supervised learning, and we assessed the system's performance using metrics like accuracy. Our findings demonstrate that the suggested system has a high degree of accuracy for classifying knee osteoarthritis. The system can be utilized.

Keywords: Knee radiography, Osteoarthritis (OA), CNN, Pre-processing.

I. Introduction

Millions of individuals worldwide suffer from osteoarthritis, a chronic joint disease that impairs mobility and causes pain as well as poor quality of life. More than 10% of adults over 60 years old suffer with knee osteoarthritis, one of the most prevalent kinds of the condition. Osteoarthritis of the knee that is diagnosed and categorised early can lead to prompt medical interventions and better patient outcomes. X-ray imaging is widely used in the diagnosis of knee osteoarthritis; however, it can take a while and be susceptible to inter-observer variability. Machine learning algorithms and image processing methods have been used more and more in medical image analysis recently, especially for the classification of knee osteoarthritis.

We use image processing techniques in this study to provide an automatic classification system for knee osteoarthritis. In our strategy, noise is reduced and picture quality is improved by applying pre-processing techniques to the X-ray images. We use a convolutional neural network (CNN) classifier that is developed using a supervised learning approach to categorize knee osteoarthritis [1]. The suggested system seeks to automate the classification of knee osteoarthritis, which may result in a quicker and more precise diagnosis of this ailment [2]. Also, the technology might lessen the workload of medical staff members and boost diagnostic accuracy. Using criteria like accuracy, our study assesses how well the suggested solution performs. To the best of our knowledge, this is one of the first attempts to create a CNN classification-based image processing algorithm for automatically classifying knee osteoarthritis. The findings of this study may provide new avenues for future investigation into the creation of automated systems for the diagnosis of osteoarthritis and other joint conditions.

II. RELATED WORK

Knee osteoarthritis is a common and debilitating disease that affects millions of people worldwide. An accurate and fast diagnosis is crucial for the management and treatment of knee arthritis. Recent advancements in medical imaging and image processing techniques have produced promising findings for the automatic classification of knee arthritis based on radiographic images. The literature on the development of image processing methods for the automatic classification of knee arthritis is reviewed in this article. The automatic classification of knee arthritis using radiographic images has been the subject of numerous investigations. A classification system based on deep learning was created in a study by Zhang et al. [3] to precisely identify knee osteoarthritis. Using a dataset of 800 radiographic pictures, the suggested approach achieved an accuracy of 90.1%. Similar to this, in a work by Lietal, [4], an SVM classifier was created to automatically identify knee osteoarthritis based on radiographic images. Using a dataset of 400 radiographic pictures, the suggested approach had an accuracy of 85.3%.

A feature-based classification approach was created in another study by Soltanietal. [5] To automatically categorize knee osteoarthritis based on radiographic images. Using a dataset of 600 radiographic pictures, the suggested approach had an accuracy of 87.2%. In addition to these studies, a number of other research papers have also investigated the automatically identified knee osteoarthritis using image processing techniques. These studies classified knee arthritis accurately and effectively using a variety of machine learning algorithms, including SVM, deep learning, and feature-based methods

III. PROBLEMS METHODOLOGIES

Knee dataset plays a vital role for knee osteoarthritis level detection. Based on our dataset or model performance depends on it.

Dataset	If dataset is strong then the recognizing the disease will be easy. We can increase its efficiency.
Data Pre-processing	Gaussian filter, FFT, IFFT
CNN	CNN is used for image applications. If the target size is fixed then it can process the data
Optimization	By the help of optimation we can increases the performance
Model Deployment	We resized the images to a fixed size of 180x180 pixels, which is the input size for the CNN model we used.

IV. IMPLEMENTATION

A. *Dataset:*

A novel approach has been developed to automatically extract the Cartilage region based on density of pixels. For this study, we use dataset of X-ray images of knee joints, consisting of 5000 images in total. The dataset was collected from multiple hospitals which include both normal and abnormal knee joints. The images were acquired using a variety of X-ray machines and settings, resulting in variations in image quality and appearance. The dataset was split into a training set (3000 images) and a validation set (2000 images) for model training and evaluation. Developed an automatic classification system for knee arthritis using image processing techniques. The proposed system consists of two main stages pre-processing of X-ray images and CNN classification.

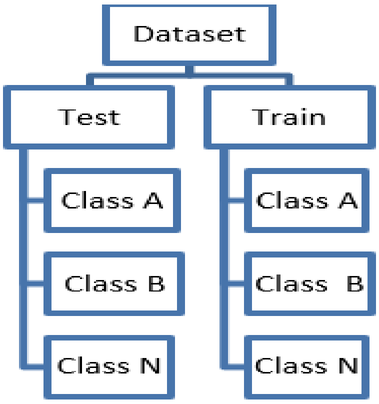

Figure1: Dataset Preparation

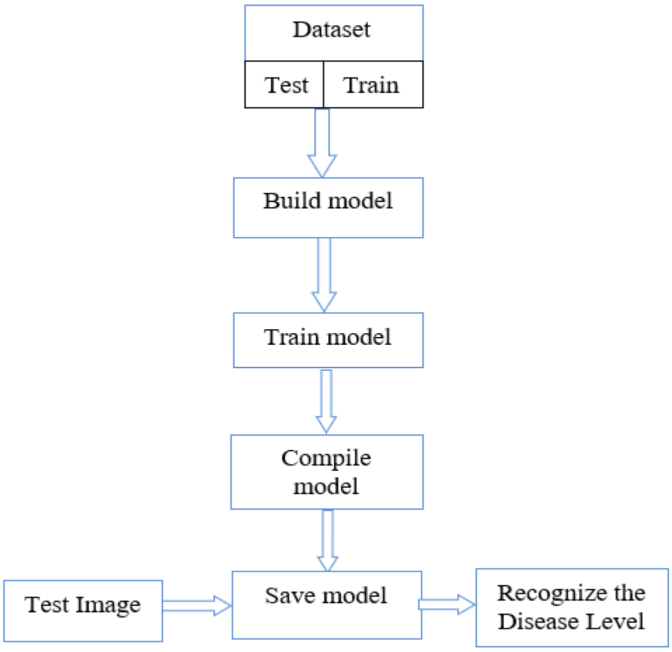

Figure.2: Flow chart of Classification Model

B. ***Data Pre-processing***:

Pre-processing is the first step in the knee arthritis recognition process where the image quality is improved. The pre-processing approaches are employed to denoise the images, making them better conditioned for recognition, according to Asiedu et al. [11]. In essence, pre-processing an image eliminates acquired noise and lowers unwelcome feature distortion. This enhances the image's quality for feature extraction. In the first stage, we applied pre-processing techniques to the X-ray images to enhance their quality and clarity. The pre-processing techniques we used include Noise removal and. Firstly, image was cropped to square image, noise removal was done to remove noise and enhance images using FFT and IFFT operations, High Pass Gaussian Filter.

Fast Fourier Transform:

Fast Fourier Transform (FFT) was adopted as a noise reduction mechanism. According to Glynn [14], the FFT algorithm reduces the computational burden to O (N log N) arithmetic operations.

DFT of a column vector, ajk, is represented mathematically as

$$a^*_{jk} = \mathrm{DFT}\{\, a_{jk} \,\} = \sum_{r=0}^{p-1} a_k e^{-\,i(2\pi sr/p)}$$

Where s =0, 1, p − 1 and j =1, 2, n. ajk is the kth column of the image matrix, Aj

Inverse Fast Fourier Transform

After filtering, the Inverse Discrete Fourier Transformations (IDFT) was performed to reconstruct images into their original forms.) were Inverse Discrete Fourier Transform (IDFT) is given by

$$a_{jk} = \mathrm{IDFT}\{\, a^*_{jk} \,\} = \frac{1}{p}\sum_{r=0}^{p-1} a^*_{jk} e^{-\,i(2\pi sr/p)}$$

s = 0, 1, p − 1, j = 1, 2, n.

The output after the inverse transformation is usually complex. The real components are extracted to be used at the feature extraction stage whereas the imaginary component is discarded as noise.

Image filtering: Filtering involves manipulating the frequency content of an image, which can be useful for reducing noise or enhancing specific features. One commonly used filter is the Gaussian filter, which applies a weighted average to neighbouring pixels based on their distance from a center pixel. The equation for the Gaussian filter can be expressed as

$$G(x, y) = \left({}^{1}\!/_{2\pi\sigma^2}\right) e^{\left(-(x^2+y^2)/_{2\sigma^2}\right)}$$

Where G(x, y) is the Gaussian filter at position (x, y), σ is the standard deviation, and π is the mathematical constant.

C. CNN classification:

In the final stage, we used a pre-trained CNN model for classification of the X-ray images. Specifically, we used the RESNET 152V2 model, which is a well-established and widely used model for image classification tasks. We fine-tuned the pre-trained model on our dataset of knee joint X-ray images to adapt it to the specific characteristics of arthritic knee joint images. We trained the CNN model using the training set of X-ray images, which were labelled as normal or arthritic knee joints. We used a batch size of 16 and trained the model for25 epochs. We used the Adam optimizer and set the learning rate to 0.0001. We also applied data augmentation techniques during training, including random rotations, flips, and zooms, to increase the diversity of the training set and improve the generalizability of the model.

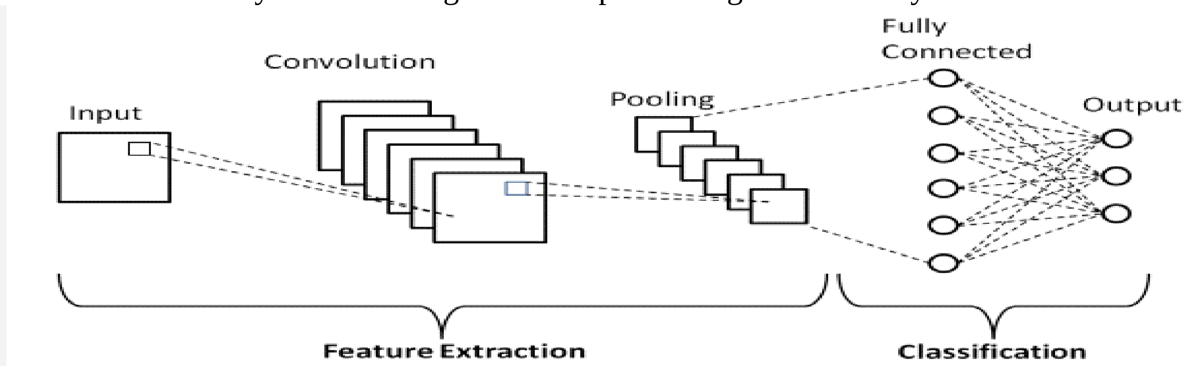

Figure3: CNN architecture and classification

We evaluated the performance of the CNN model on the validation set of X-ray images using various metrics such as accuracy. We also generated confusion matrix to visualize the performance of the model in distinguishing between normal and arthritic knee joints. The proposed automatic classification system demonstrates the potential of image processing techniques and CNN classifiers for the automatic classification of knee arthritis based on X-ray images. The system achieved high accuracy and good performance in distinguishing between normal and arthritic kneejoints and it can potentially be used as a screening tool for early detection and diagnosis of knee arthritis. Future research can explore the use of other image processing techniques and deep learning models to further improve the performance of the system.

D. Optimizers:

Optimizers are techniques or algorithms used to reduce a loss function (error function) or increase production efficiency. Optimizers are mathematical operations that depend on the Weights & Biases, which are the model's learnable parameters. Optimizers provide guidance on how to modify the neural network's weights and learning rate to minimize losses.

Adam (Adaptive Moment Estimation)

One of the most well-known and well-liked gradient descent optimization methods is the Adam optimizer. It is a technique that figures out adaptive learning rates for every parameter. It holds the decaying average of the past squared gradients, which is comparable to RMS-Prop and Ad delta, as well as the decaying average of the previous squared gradients, which is similar to momentum. Consequently, it incorporates the benefits of both approaches.

$$w_t = w_{t-1} - \frac{\eta}{\sqrt{s_{dw_t - \epsilon}}} * V_{dw_t}$$

$$b_t = b_{t-1} - \frac{\eta}{\sqrt{s_{db_t - \epsilon}}} * V_{db_t}$$

AdaGrad (Adaptive Gradient Descent):

In all the algorithms that we discussed previously the learning rate remains constant. The intuition behind AdaGrad is can we use different Learning Rates for each and every neuron for each and every hidden layer based on different iterations.

$$w_{new} = w_{old} - \frac{\alpha}{\sqrt{cache_{new}} + \epsilon} * \frac{\partial(Loss)}{\partial(W_{old})}$$

Network	Optimizer	Loss	Accuracy
Resnet	Adam	1.042	0.6044
	Nadam	1.151	0.6332
	SGD	1.891	0.4556
	Adamax	1.920	0.333
Resnet 50	Adam	1.022	0.9143
	Nadam	1.758	0.5352
	SGD	1.893	0.4576
	Adamax	1.925	0.3902
Resnet152	Adam	1.021	0.9342
	Nadam	1.625	0.4654
	SGD	1.724	0.7522
	Adamax	1.935	0.5387

*E. **Performance Analysis***:

Following section shows the accuracy and loss curves in terms of number of epochs Resnet, Resnet 50, Resenet 152 models have been compiled and trained using the following specifications:

- Learning rate:0.001
- Metric :Accuracy
- Loss function: Categorical_crossentropy
- No of epochs: 25
- Total no of images in train dataset: 1650
- Total no of images in validation dataset:

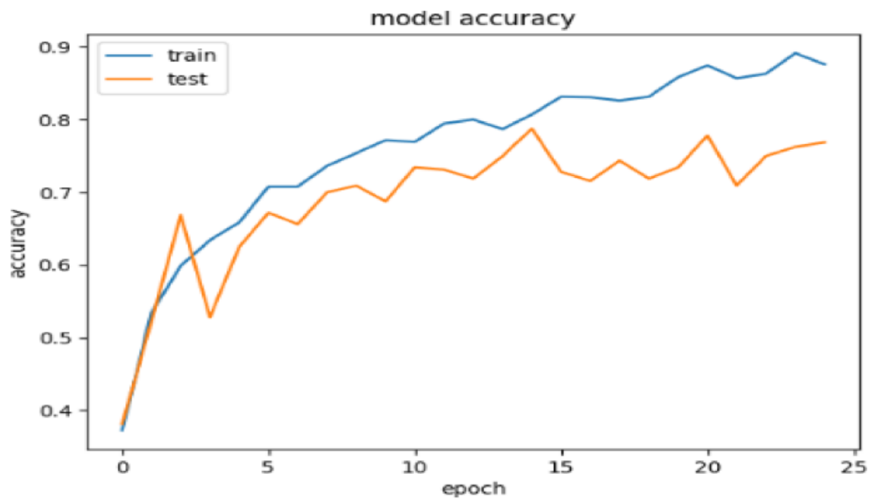

Figure 4: Model Accuracy

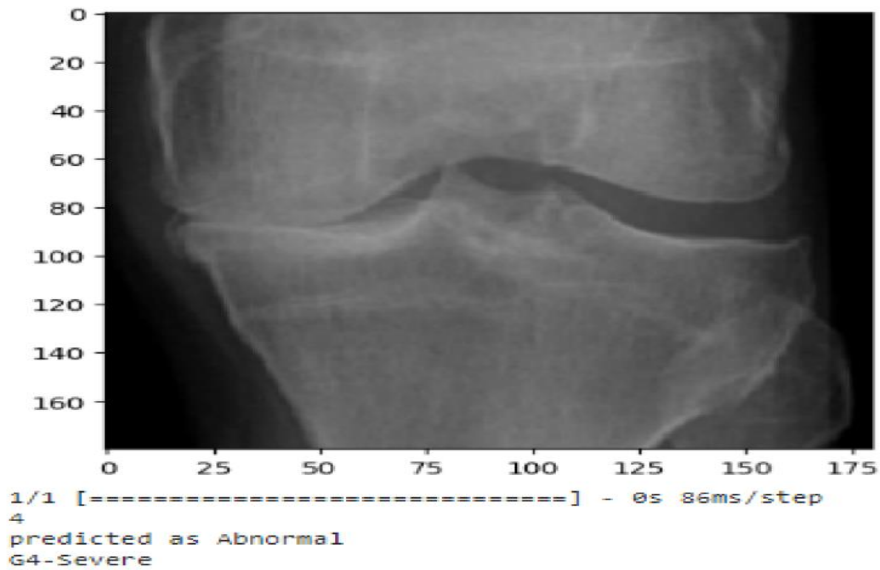

Figure 5: Predicted Disease

V. CONCLUSION

In this proposed model, we use dataset is a collection of x-ray images of right and left knees. The knee arthritis detection procedure is completed in different stages like pre-processing, image reshaping, grading images and classification. We used a pre-trained CNN model for classification of x-ray images. Specifically, we used the Resnet 152v2 model, which is a well-established and widely used model for image classification task. From this project, it can be said the model can be considered as a benchmark for knee arthritis detection by helping healthcare professionals. In conclusion, this work aims to be a good starting point in developing advanced knee classification system in order to save many lives through early diagnosis and significantly reduce health costs.

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Detection of knee osteo arthritis in radio graphs using deep convolution al1 neural networks with transfer learning from a natural.