Classification of Kee Osteoarthritis on X-ray images using image processing

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I. Abstract

Classification of Knee-Osteoarthritis study addresses the significant issue of knee joint osteoarthritis(OA) by proposing an innovative strategy that combines machine learning,deep learning and image processing. The research utilizes a diverse set of methodologies,including Convolutional Neural Network(CNNs), dimensionality reduction through Principal Component Analysis(PCA).It reduces human interaction and provides a Back-to-Back approach to computerized osteoarthritis detection by incorporating the image processing model.The rating is based on X-ray images from the Osteoarthritis Initiative(OAI) dataset.The training on a huge dataset 5778 knee joint images,our method accurately classifies 0.84 of data.

Keywords– Knee osteoarthritis, CNN(Convolutional Neural Network), PCA(Principal Component Analysis)

II. Introduction

Osteoarthritis(OA) is the common form of arthritis, affecting millions of people worldwide. Among its various manifestations, Knee OA stands out as a significant source of pain, disability and reduced quality of life, particularly in the aging population. [1] This degenerative joint disorder primarily affects the knee joint, leading to the gradual breakdown of cartilage. [1]The motivation behind addressing knee OA arises from its substantial impact on people's lifestyles,particularly in older individuals. This degenerative disease of synovial joints is characterized by the focal loss of articular hyaline cartilage. The goal is to enhance the quality of life for affected individuals, considering the disease's profound impact on daily activities. [2] There is a growing recognition of the potential of computer-based tools, machine learning, and deep learning techniques to improve the diagnosis and classification of various medical conditions. By leveraging advanced technologies, we aim to provide more accurate and efficient methods for identifying and categorizing knee osteoarthritis, ultimately leading to better informed treatment decisions and improved outcomes for individuals affected by this condition. The integration of these innovative approaches reflects a commitment to advancing medical diagnostics and addressing the unique challenges posed by degenerative joint diseases like knee OA. [3]

Fig. 1. Difference between a Normal knee and Knee-Osteoarthritis knee.

[4]

Classification of Knee OA using X-ray images aims to detect and classify knee osteoarthritis.An OA dataset of knee joint X-ray images is chosen for this study. The dataset was split into training and testing datasets.We took advantages of ResNet50,VGG-19 and Inception V3 and employed ensemble techniques to enhance the overall performance of the models.

III. LITERATURE SURVEY

Knee OA early detection and treatment are crucial for improving the quality of life, especially in older individuals. Knee OA classification accuracy through deep learning and machine learning also applied transfer learning ResNet-34

and others.An ensemble models to improve performance. The model achieved high accuracy,precision,recall and F-score result. [5]

In recent study concentrating on Knee OA , a condition characterized by the deterioration of cartilage in the knee joint leading to notable joint pain and movement limitation , The methodology involved utilizing deep feature, with a particular emphasis on the application of a Convolutional Neural Network(CNN) to extract these intricate feature from images associated with knee OA. specifically the Support Vector Machine, K-Nearest Neighbour and Naive Bayes. The result of the experiment were noted,demonstrating an accuracy 0.90. [13]

Knee OA is a common form of arthritis. This study aims to automatically detect and classify knee OA according to grading system.Classify the feature by support vector machine with an accuracy 0.95. Restricted boltzmann machine model for feature extraction. [6]

OA is a significant health issue worldwide, causing impaired joint function and decreasing overall quality of life . This common condition primarily affects joint cartilage, and since there's no cure for OA , treatments mainly target symptom management. The main goals include relieving pain,enhancing joint function and maintaing stability. [7]

IV. PROPOSED METHOD

A. Dataset

The dataset is organized from OAI(https://oai.epi-ucsf.org/datarelease/), which is having huge number of X-ray images,which is the primary prevent and manage knee osteoarthritis,which is the primary reason of debility in adults. Dataset contains 5,778 train images and 1,656 test images of different grade of Knee OA. [17]

The dataset contains five different grade based on severity level as follows:

Grade 0-Healthy: Healthy Knee images.

Grade 1-Doubtful: Doubtful joint narrowing with possible osteophytic lipping.

Grade 2-Minimal: Definite presence of osteophytes and possible joint space narrowing.

Grade 3-Moderate: Multiple osteophytes,definite joint space narrowing. [17]

Grade 4-Severe: Large osteophytes,significant joint narrowing.

We divided knee X-ray images into train test and validation sets at random. To sustain grade distribution among training, testing and verification stes,this spilt-up is done grade-by-grade based on the KL grade of the knee joint in an X-ray image.

B. Data enhancement

Data enhancement was done by using histogram equalization.This method is useful in images with backgrounds and foregrounds that are both bright or both dark.In particularly, the method can lead to better views of bone structure in X-ray images, and to better detail in photographs that are either over or under-exposed. [12]A key advantage of the method is that it is a fairly straightforward technique adaptive to the input image and an invertible operator.Enhanced X-ray images may undergo processing to remove unwanted elements that could hinder accurate diagnosis. [8]

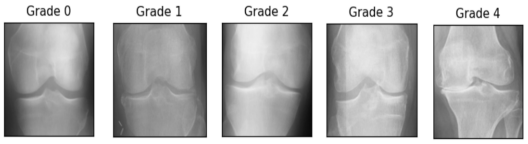

Fig. 2. Different grade based on severity level.

- The probability of an occurrence of a pixel of level i in the image is

$$p_x(i) = p(x = i) = \frac{n_i}{n}, \quad 0 \leq i < L$$

where n_i is the frequency of occurrence of i and n is the total number of observations. [14]

- The cumulative distribution function $\mathrm{cdf}_x(i)$ can be expressed as:

$$\mathrm{cdf}_x(i) = \sum_{j=0}^{i} p_x(x = j)$$

where $p_x(x = j)$ is the probability distribution function for x. [14]

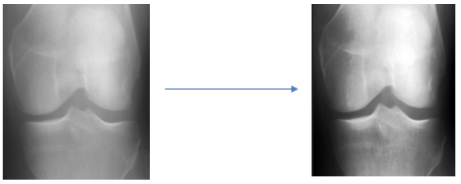

Fig. 3. Difference between a normal image and an enhanced image.

C. Region of Interest(ROI)

To classify the severity of knee OA, the region which helps us to find the severity of the injury is the meniscus region. In region-of-interest(ROI) imaging, a filter with a central aperture is used to substantially reduce patient dose outside of an ROI while maintaining or improving image. [10]

D. Data segmentation

Image segmentation is the process of partitioning an image into multiple segments. [15] The goal of segmenting an image is to change the representation of an image into something that is more meaningful and easier to analyze. It is usually used for locating objects and creating boundaries.K-Mean is best method for segmentation for x-ray images.after k-mean

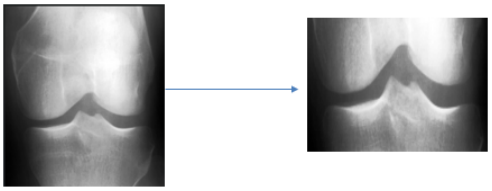

Fig. 4. Region of Interest.

segmentation with k=3 , we see distinct regions corresponding to different color clusters. Each cluster represents a different group of pixel intensities.

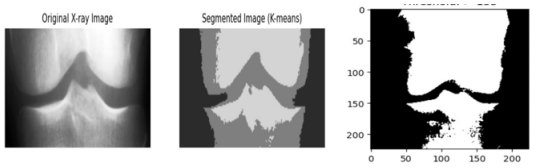

Fig. 5. Segmentation

E. Feature extraction

To classify the grade of knee osteoarthritis(OA) based on severity of the disease, an ensemble model has used . This ensemble combines the strengths of three distinct models:VGG-16 ,InceptionV3 and ResNet50 . The objective is to classify knee images into different grades. [9] Each model in the ensemble brings its unique architectural characteristics and learned feature to the diverse and complementary strength of each model. This approach enhance the overall the robustness and accuracy of the classification system. [16]

1) ResNet50: ResNet50 consists of 50 convolutional layers, making it a deep Convolutional Neural Network designed for various computer vision tasks. Pre-trained on large datasets such as ImageNet, ResNet50 is capable of extracting and leveraging high-level features, making it suitable for transfer learning across various visual recognition tasks. [13]

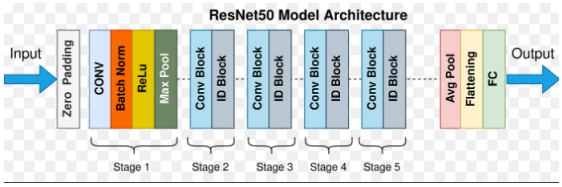

Fig. 6. ResNet50 architecture

2) VGG-16: The input size for the first Convolutional Neural Network in VGG-16 is 224x224 pixels. VGG-16 employs a padding of 1 pixel for its 3x3 convolutional layers. This ensures that the spatial dimensions are preserved after convolution.Max-pooling is a down-sampling operation that helps in capturing the most important features while reducing the spatial dimensions.
The soft function of VGG-16:

$$y_i = \sum_{j=1}^{n} e^{z_j} \cdot e^{z_i}$$

The loss function will be:

$$E = \frac{1}{3}\left(d(c_1, G_1) + d(c_2, G_2) + d(c_3, G_3)\right)$$

[11]

V. RESULT AND DISCUSSION

Modles	ResNet50	VGG-16	Ensembel models
Accuracy	0.62	0.75	0.84
Loss	0.92	0.69	0.49

The decision to chosen a specific model should indeed be guided by the project's objectives and requirements. While ResNet, with an accuracy of 0.62 and a loss of 0.92 and VGG-16 ,with an accuracy of 0.75 and a loss of 0.69,the ensemble model surpasses them with an accuracy of 0.84 and a loss of 0.49. If the primary project objective prioritizes higher accuracy,the ensemble model emerges as a promising choice due to its superior performance. However, its crucial to weigh this decision against other factors such as computational complexity, interpretability and real-time requirements.

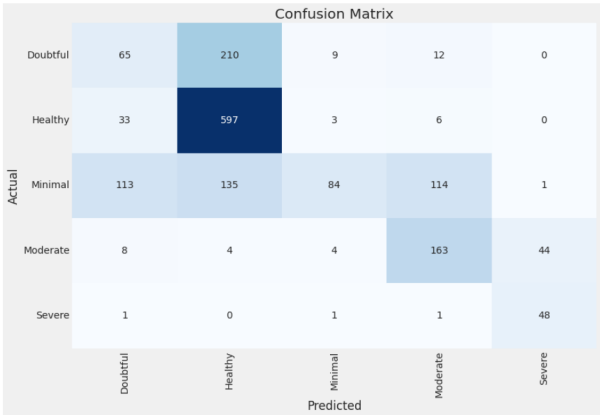

Fig. 7. Confusion matrix on 5 grade system.

An epoch is a unit of measurement for the amount of time it takes to train a neural network utilizing the training data. We utilize all the data just once. One pass consists of a forward and backward pass. Since one epoch is too enormous to send to the computer, we split it into several smaller batches,We employed 20 epochs in this scenario.

VI. CONCLUSION AND FUTURE SCOPE

The knee osteoarthritis (OA) project is dedicated to the development of an ensemble model with the primary objectives of classifying the severity of knee OA based on medical images.This ensemble model, a collaborative effort of VGG-16,InceptionV3 and ResNet50 harnesses the strengths of these advanced architecture to deliver predictions that are not

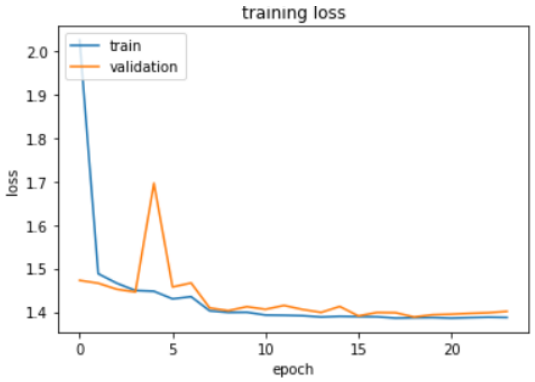

Fig. 8. Training loss

only accurate but also reliable. By leveraging the distinctive features and capabilities of each model, the ensemble ensures a comprehensive approach to severity classification.

The future evolution of the knee osteoarthritis project is poised to advance significantly with a strategic focus on real-time implementation. The integration of real-time capabilities will empower medical professional to obtain immediate results during patient examinations, revolutionizing the diagnostic process for knee osteoarthritis. This aspect of the project holds immense promise in enhancing the efficiency of medical practitioner,enabling swift decision-making and timely interventions based on instant model predictions.

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