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PREDICTION OF KNEE OSTEOARTHRITIS USING DEEP LEARNING

Poojitha S*1

*1Student, Department Of MCA, PESITM, Shimoga, Karnataka, India.

ABSTRACT

Osteoarthritis of the knee is a common degenerative joint disease that causes discomfort and impairs movement. This highlights the significance of early diagnosis and prognosis for the best possible patient care and successful therapies. This research delves into utilizing both clinical records and radiographic data to forecast knee- osteoarthritis through advanced deep learning algorithms, including neural-networks. The dataset includes a wide range of imaging results, medical histories, and demographic information from a heterogeneous group of people. Metrics like AUC-ROC, recall, accuracy, precision, and F1-score are used to evaluate the models; neural networks are shown to be the most reliable and accurate. Results indicates that deep-learning algorithms hold promise in efficiently predicting knee osteoarthritis, thereby assisting healthcare providers in decision-making processes and potentially paving the way for personalized treatment strategies. Future endeavors will concentrate on incorporating larger datasets and developing real-time prediction systems to enhance clinical applicability.

Keywords: Knee Osteoarthritis, Machine Learning, Prediction Models, Clinical Data, Radiographic Data, Early Diagnosis.

I. INTRODUCTION

Osteoarthritis of the knee has affect millions worldwide, causing chronic pains, limited mobility, and a decline in quality of life. As our population ages, prevalence of OA is expected to increase, posing challenges for healthcare systems. Early and accurate prediction of knee OA are critical for effective management and intervention, potentially slowing disease progression and improving patient outcomes. Traditionally, diagnosing and predicting OA of knee relied on clinical assessments, imaging, and patient- reported symptoms. However, methods used are often lack sensitivity, especially in the disease's early stages. Recent advancement in medical imaging and computational techniques have led to precise predictive models. Deep learning, subset of artificial intelligence, has emerged as a powerful tool in this area, capable of automatically learning more complex patterns from the large datasets.

Deep learning a subset of artificial intelligence, by making use of algorithms like CNNs have shown promise in tasks such as medical images analysis. By leveraging extensive datasets and high-performance computing, CNNs can achieve superior accuracy compared to traditional ways. This research aims to explore the applications of deep-learning for predicting osteoarthritis of knee, specifically using CNNs for analyzing knee-joint images and identify early signs of OA. This work focuses on using CNNs—a type of deep-learning technique—to predict knee osteoarthritis from medical photographs. The model attempts to discover patterns and features indicative of OA that might not be readily apparent to human eyes by training a CNN on a sizable dataset of knee X-rays. The ultimate objective is to create a dependable, automated instrument that will help medical professionals diagnose knee OA earlier and with greater accuracy. By using this strategy, it intend to advance the rapidly expanding field of artificial intelligence in the healthcare industry by offering a cutting-edge solution that will improve diagnostic capacities and, in the end, patient outcomes for knee-osteoarthritis patients.

Objectives:

1. Develop a robust deep-learning model to predict OA of knee from radiographic images.
2. Assess the predictive capacity of the model overall as well as its accuracy, sensitivity, efficiency and specificity.
3. Compare the model's predictive capability with traditional diagnostic methods.

The related works reviewing various methodologies and techniques include: The paper [1] authored by Harish H et al., brings a significant stride in field of medical imaging and predictive analytics. It showcases how deep-learning can revolutionize medical-imaging and disease prediction, offering a precise method for predicting knee osteoarthritis (OA). Their research provides a ray of hope for earlier interventions that can greatly improve patient outcomes. By delving into advanced deep-learning techniques, the authors have crafted a powerful tool for the earlier detection of knee-osteoarthritis. This breakthrough has the potentials to uplift clinic outcomes and enhance quality of life for the patients.

The work described in [2] by C. Kokkotis et al., offers a clear overview of the utilization of machine-learning techniques in the realm of knee osteoarthritis (OA). Their paper delves into various machine-learning methods like neural networks, decision trees, and support vector machines, discussing their strengths and weaknesses in analyzing medical data pertaining to knee OA. Through an in-depth analysis, the authors illuminate how technologies enhance patient outcomes, tailor treatment strategies, and facilitate early diagnosis. By synthesizing findings from existing studies and addressing current challenges, research provides valuable insights for into future trajectory of machine-learning integration into clinical practice for knee OA.

This paper [3] by R. Almajalid, J. Shan et al., present an innovative method for forecasting knee osteoarthritis (OA) progression through use of machine-learning algorithms and MRI data. Their research introduces a cutting-edge approach that involves analyzing MRI scans to pinpoint patterns and characteristics indicative of disease progression. What sets their method apart is its remarkable predictive accuracy, surpassing that of conventional techniques. This suggests that machine-learning holds great potential in improving our comprehension and management of knee OA. By concentrating on MRI data, the study strives to enhance patient-care and outcomes by enabling clinicians to implement timely and targeted interventions. Ultimately, their work offers clinicians a precise and non-invasive tool for monitoring OA progression, thereby aiming to improve patient outcomes.

This paper [4] by Ningrum D N et al., delve into the realm of deep learning for predicting knee- osteoarthritis (OA) progression using non-image- based longitudinal medical records. Through they use of clinical measurements, treatment histories, and demographic data for their study pioneers use of deep-learning techniques on patient data over- time to discover suggestive of OA developments and progressions. Their method demonstrated exceptionally high predictive accuracy, highlighting the values of using non-image clinical data for OA prediction. This strategy demonstrates the enormous potential of deep-learning to improve predictive analytics in the medical field, providing a viable path for knee-OA early identification and individualized therapy.

II. METHODOLOGY

The working is divided into two primary phases: the Training Phase and the Detection Phase. Each phase includes distinct steps that are essentials for effective prediction of knee-osteoarthritis using deep-learning models.

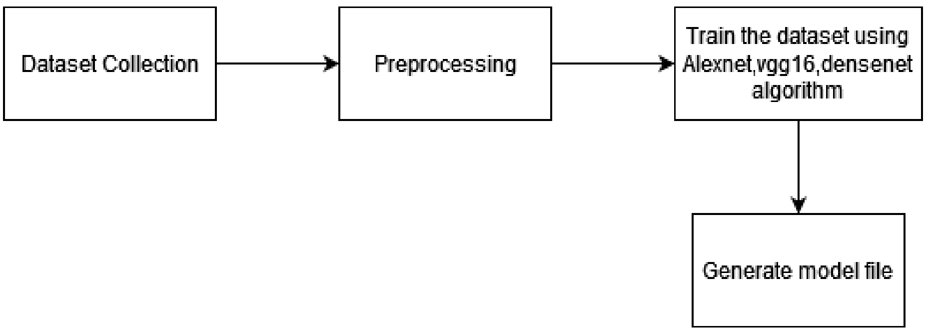

Fig 1: Training Phase

1. Dataset Collection

- Dataset Collection: Gather a dataset of knee-X- ray-images with annotated osteoarthritis grades. Ensure the dataset is large and diverse to train robust models.

2. Preprocessing

- Image Normalization: Scale pixel values to a standard range to ensure consistency.

- Augmentation: Apply transformations such as rotation and scaling to the increase data variability and improve model robustness.
- Resizing: Resize images to the input size required by the models.

3. Model Training

1. AlexNet: Train the deep-convolutional-neural- network with 5 convolutional layers followed by 3 fully connected layers.
2. VGG16: Train the deeper network with 16 layers, comprising 13 convolutional layers and 3 fully connected layers.
3. DenseNet: Train the densely-connected- convolutional-network that connects each layer to every other layer in a feed-forward manner. Use training data to adjust model weights, optimizing for accuracy in osteoarthritis detection.

4. **Model Generation**

- Save Trained Models: Save the trained models to files for use in the detection phase. Each model (AlexNet, VGG16, DenseNet) will generate a separate model file.

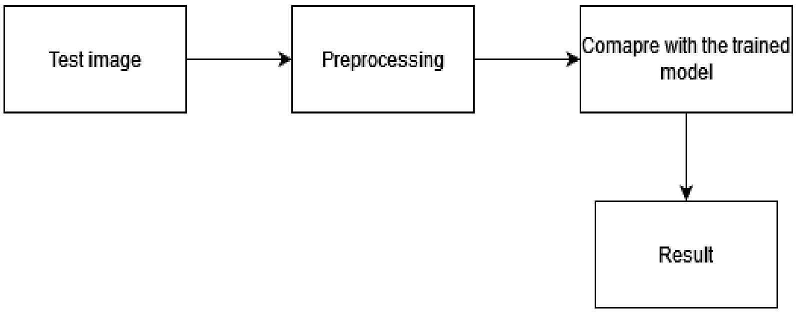

Fig 2: Testing Phase

1. Test Image Acquisition: Obtain a new knee X- ray-image for osteoarthritis detection.
2. Preprocessing: Normalize the test image. Resize the image to match the input dimensions required by the models.
3. Comparison with Model: Load the trained model file (AlexNet, VGG16, or DenseNet). Feed the preprocessed test image into the model. Perform inference to obtain the prediction result.
4. Result Generation: Interpret the model's output to determine for presence and grade of knee osteoarthritis. Present the result, indicating whether osteoarthritis is detected and its severity level.

Table 1: K-L grading scheme

Grade	Description
0	Normal
1	Doubtful narrowing of joint space and possible osteophytic lipping
2	Possible narrowing of joint space and definite osteophytes
3	Definite narrowing of the joint space, moderate multiple osteophytes, some sclerosis and possible deformity of bone ends
4	Marked narrowing of joint space, large osteophytes, severe sclerosis and definite deformity of bone ends

III. ALGORITHMS USED

Convolutional Neural Network (CNN):

A CNN is a deep-learning system which excels at picture identification and processing, similar to how our brains interpret what we see. A CNN consists of multiple layers, each responsible for a certain task. The convolutional-layers are the most significant ones; they employ filters to scan the image and identify critical details like edges, textures, and forms. Subsequently, the data is transferred to the pooling-layers, which streamline the process by minimizing the volume of data, analogous to condensing an extensive essay into its essential elements. This keeps CNN from becoming bogged down by extraneous details and allows them to concentrate on the image's most crucial elements. Finally, the fully-connected-layers function as the brain's decision-making hub, utilizing all the data acquired to categorize or anticipate the image.

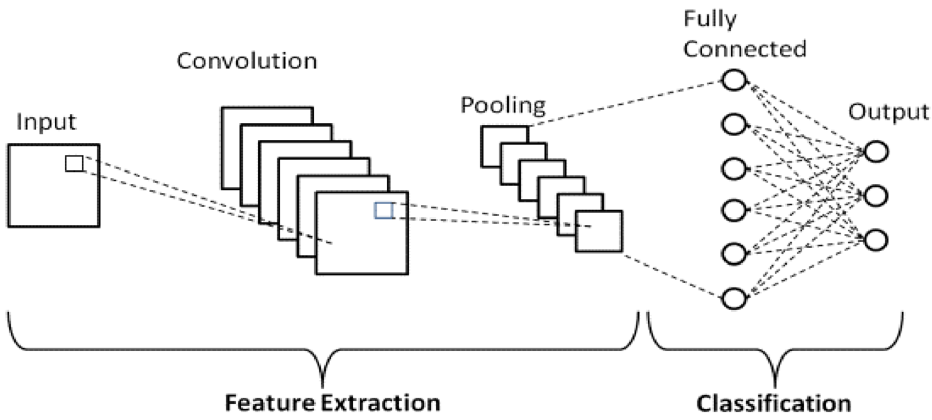

Fig 3: CNN Architecture

1) AlexNet: Train the deep-convolutional-neural- network with 5 convolutional layers followed by 3 fully connected layers. AlexNet consists of 5 convolution layers, 3 max-pooling layers, 2 Normalized layers, 2 fully connected layers and 1 SoftMax layer. Each convolution layer consists of a convolution filter and a non-linear activation function called "ReLU". The pooling layers are used to perform the max-pooling function and the input size is fixed due to the presence of fully connected layers. The input size is mentioned at most of the places as 224x224x3 but due to some padding which happens it works out to be 227x227x3.
2) VGG16: VGG16 is a convolutional-neural-network (CNN) architecture that gained fame by winning the ILSVR (ImageNet) competition in 2014. It remains one of the top vision model architectures. What sets VGG16 apart is its simplicity and effectiveness. Instead of using a large number of hyper-parameters, VGG16 focuses on using convolution layers with 3x3 filters and a stride of 1, along with consistent padding and max-pooling layers with 2x2 filters and a stride of 2. This straightforward yet powerful arrangement of convolution and max-pooling layers is applied consistently throughout the entire architecture. At the end of the network, there are two fully connected (FC) layers, followed by a softmax layer that produces the final output. Train the deeper network with 16 layers, comprising 13 convolutional layers and 3 fully connected layers.
3) DenseNet: DenseNet, a densely connected CNN architecture, has been investigated for its ability to detect and classify knee-osteoarthritis severity from medical images. In the context of knee OA prediction, DenseNet's architecture allows it to effectively capture and learn from complex patterns in both radiographic images and clinical data. By integrating diverse data sources, DenseNet can identify subtle biomarkers and patterns indicative of OA progression. This capability enhances algorithm's predictive accuracy, making it a valuable tool for early OA detection and personalized treatment planning. Train the densely-connected- convolutional-network that connects each layer to every other layer in a feed-forward manner. Use training data to adjust model weights, optimizing for accuracy in osteoarthritis detection.

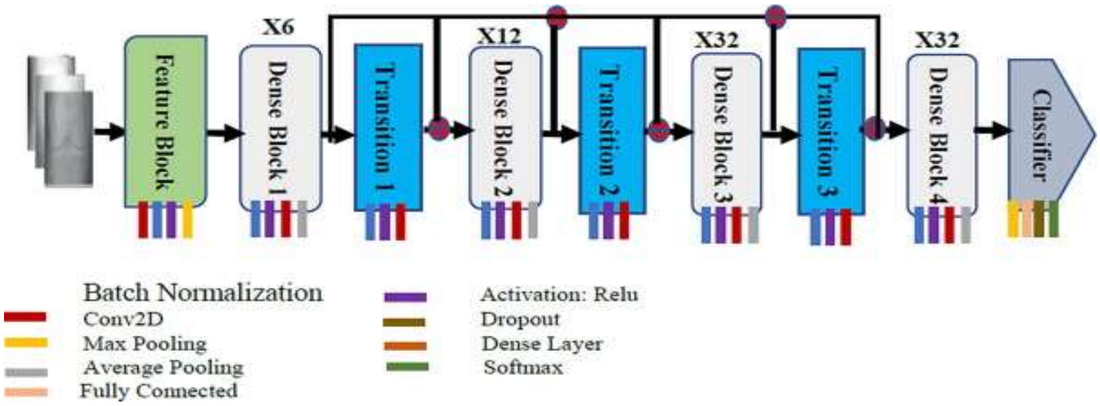

Fig 4: DenseNet Architecture

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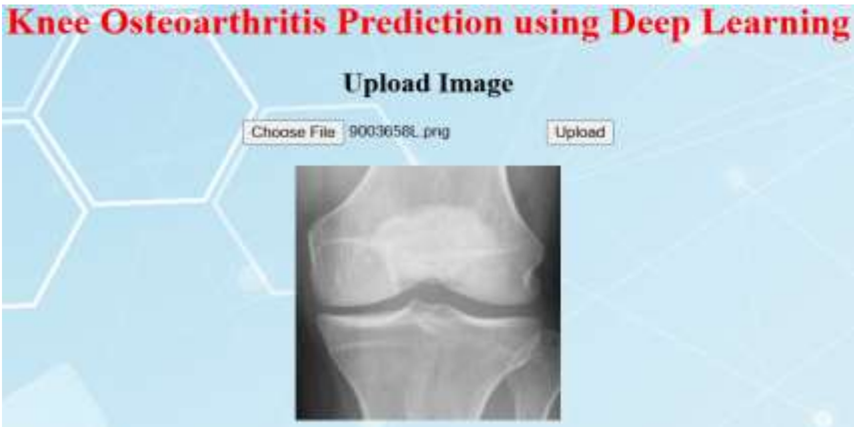
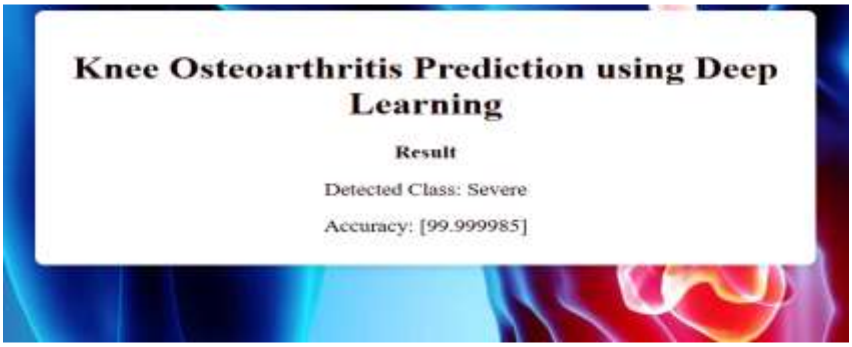
IV. RESULTS AND DISCUSSION

Module 1: Welcome Page

Module 2: Login Page



Module 3: Image Uploading Page



Module 4: Result Page

Generated Model Files:

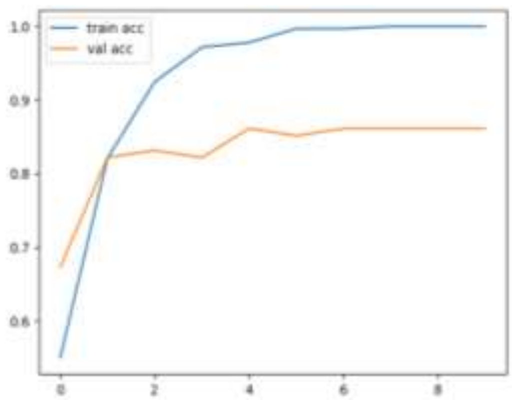


Fig 5: Accuracy Graph

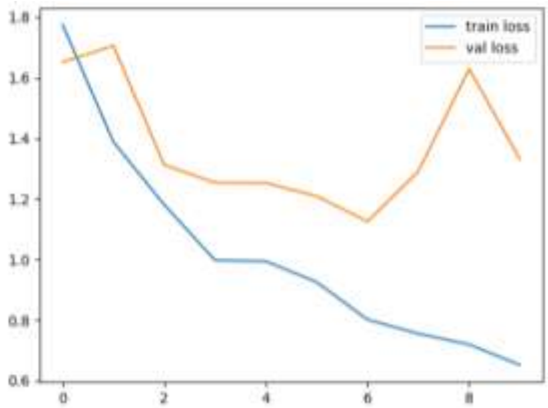


Fig 6: Loss Graph

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V. CONCLUSION

In this study, we utilized deep-learning with an ordinal classification approach to grade knee- osteoarthritis (KOA) X-rays, achieving innovative and accurate automated classification across all KL grades. By developing an ensemble of optimized models, we significantly enhanced performance, offering a quick, reliable, and early evaluation method for medical professionals. The improved accuracy and evaluation metrics, coupled with the model's ability to understand visual cues and predict KOA severity, suggest potential for personalized treatment plans. Future work will involve incorporating more diverse datasets to further refine the model and revolutionize intervention and care coordination for Knee OA.

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