Smart Diagnostic System to Detect Knee-Bone Osteoarthritis

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***Abstract*— Knee osteoarthritis, a degenerative joint ailment affecting a large global population, results in pain, stiffness, and diminished mobility. The severity of this condition varies among individuals, making accurate assessment crucial for effective treatment planning. Evaluation traditionally relies on observing joint space narrowing, osteophytes, bone deformity, and sclerosis in radiographic images, using the time-consuming KL, Kellgren, and Lawrence, grading system. This method demands expertise, typically from professionals with fellowship training in arthroplasty or radiography. [1].**

To enhance the efficiency of KL grade evaluation, two experts independently conduct radiographic assessments, and in cases of conflicting diagnoses, discussions are held to reach a consensus. Our proposed model utilizes deep learning techniques and achieves a 95% accuracy in detecting and classifying knee osteoarthritis severity from medical images. This automated system reduces time consumption, enabling clinicians to focus on clinical findings. It serves as a potent tool, offering a precise diagnosis and suggesting a primary treatment plan for knee osteoarthritis, providing clinicians with valuable support.

KEYWORDS: Osteoarthritis; Deep Learning; Knee; EfficentNetB5.

Abbreviations:

KL	Kellgren and Lawrence
KOA	Knee Osteoarthritis
CAD	Computer-Aided Diagnosis
OAI	Osteoarthritis Initiative

I. Introduction

Detecting knee osteoarthritis early is vital for successful treatment and preventing further joint damage. However, current diagnostic methods, which rely on radiologists manually assessing X-rays, are subjective and may overlook early signs of osteoarthritis. Therefore, there is a need for more precise and automated diagnostic systems. This study introduces a smart diagnostic system based on deep learning to identify and evaluate knee osteoarthritis in radiographs. The system is designed to automatically analyze knee X-ray images, classify them as either osteoarthritic or healthy based on visual features, and provide primary treatment recommendations. To train and evaluate the model, a dataset of knee X-ray images labeled as osteoarthritic or healthy was collected. The images exhibited various degrees of osteoarthritis, displaying signs such as joint space narrowing and bone deformity. This smart diagnostic system has the potential to enhance patient outcomes by enabling early detection and timely intervention.

Unfortunately, current diagnostic methods depend on manual X-ray assessments by radiologists, introducing subjectivity and the possibility of missing early osteoarthritis signs. Deep learning techniques offer a promising avenue for achieving more accurate and automated early detection.

This research proposes a smart diagnostic system based on deep learning for detecting and assessing knee osteoarthritis from radiographs [2]. The system aims to:

- Automatically analyze knee X-ray images.

- Classify images as osteoarthritic or healthy.

- Quantify the severity of osteoarthritis based on visual features.

- Provide primary treatment plans for each case.

Additionally, a dataset of knee X-ray images labeled as osteoarthritic or healthy was gathered to train and evaluate the model. These images presented varying degrees of osteoarthritis, showing signs like joint space narrowing and bone deformity [3].

The knee osteoarthritis classifier used the EfficientNetB5 model architecture. The model's inputs were knee X-ray images, and the outputs predicted probabilities of osteoarthritis severity [4]. The results indicated that the model achieved a true accuracy of 92% in detecting knee osteoarthritis from X-rays, even in the early stages.

II. Related Works

The progress in image processing and machine learning has significantly propelled the rapid advancement of Computer-Aided Diagnosis (CAD) systems. This progression has been particularly noteworthy with the emergence of deep learning models, which have demonstrated state-of-the-art performance across various domains, including CAD systems. Despite these advancements, several challenges persist. This section provides a concise overview of key studies [3], [4], [5], [6], and the prevailing challenges related to the current task:

Thomas, K.A. et al. [3]: The authors endeavored to create an automated model for gauging the severity of Knee

Osteoarthritis (KOA) from radiographs. Their model underwent evaluation against the assessments of musculoskeletal radiologists, utilizing an augmented dataset from the Osteoarthritis Initiative (OAI), comprising over 40,000 images. The reported average accuracy and F1 score for the full test dataset were 71% and 70%, respectively. Despite utilizing a substantial dataset, the comparison was limited to the performance of trained radiologists rather than benchmarking against related work in the field.

Yong, C.W et al. [4]: Addressing the Knee Osteoarthritis (KOA) severity classification as an ordinal regression problem, the authors introduced an Ordinal Regression Module (ORM) for neural networks. Evaluation against various existing neural network solutions was conducted using an OAI dataset consisting of 8,260 knee radiographs. The reported accuracy using DenseNet-161 trained with the ORM approach was 88.09%, accompanied by a Quadratic Weighted Kappa score of 0.8609. Despite favorable results, the model exhibited misclassifications for KOA images with KL grades of zero and one.

Kokkotis, C. et al. [5]: This review paper focused on utilizing Machine Learning (ML) techniques for diagnosing and predicting KOA based on papers published from 2006 to 2019. The review covered segmentation, post-treatment planning, classification, and prediction/regression, highlighting accuracies ranging from 76.1% to 92% for diagnostic models predicting KOA. The work emphasized the significant role of ML in developing automated solutions for KOA.

Saleem, M. et al. [6]: The authors proposed a model based on joint space width for osteoarthritis recognition, involving image preprocessing, region of interest extraction, edge computation, and joint space width calculation. Their method achieved a 98.4% F1 score and 97.14% accuracy for KOA classification using a dataset of 140 images. Despite the high accuracy, the small dataset size may impact real-world deployment accuracy.

Key Observations from Existing Studies:

1) The scarcity of publicly available benchmark datasets due to the challenges associated with data collection from hospitals.

2) Knee osteoarthritis poses a significant big-data problem due to data complexity, heterogeneity, and size, as acknowledged in the literature.

3) The resource and time-intensive nature of the backpropagation algorithm and its performance dependency on input data.

4) The limited performance of deep learning is possibly attributed to the constraints of two-dimensional (2D) radiographic images in depicting the three-dimensional (3D) structure of articular cartilage and indicating wear.

III. METHODOLOGIES

The methodology proposed for Knee Osteoarthritis detection, which ensures accurate results, is delineated as follows:

1- Pre-processing: This step plays a vital role in the system, employing advanced techniques facilitated by the OpenCV library. It focuses on noise removal and image resizing to enhance the quality of input data.

2- Data Augmentation: This technique is instrumental in amplifying the size and diversity of the training dataset. By generating modified versions of existing data through diverse transformations, it addresses imbalances in class distribution and augments the dataset.

3- Severity Classification: The knee condition severity is systematically categorized using a categorical classification approach, facilitating a comprehensive understanding of the osteoarthritis spectrum.

4- Training an EfficientNetB5 Model: The methodology involves training an EfficientNetB5 model tailored to the dataset, ensuring optimal prediction results. Leveraging the capabilities of this model architecture enhances the accuracy and efficiency of knee osteoarthritis detection.

5- Primary Treatment Proposition: Based on the severity classification of osteoarthritis present in a patient, the proposed methodology extends to suggesting primary treatment plans for each identified class. This holistic approach aims to contribute not only to accurate diagnosis but also to the subsequent clinical decision-making process for effective patient care.

IV. RESULTS

Having experimented with various pre-trained models, including VGG16 and VGG19, as well as custom-built models, the most promising outcomes were achieved by employing the pre-trained EfficientNetB5 model with customized parameters. This configuration yielded remarkable results, attaining an impressive accuracy of 95% and an F1-score of 90%.

It is noteworthy that the VGG19 model, despite its capabilities, yielded an accuracy of only 80%, rendering it unsuitable for application in a medical context.

The training process of the EfficientNetB5 model resulted in a training accuracy of 97% and a validation accuracy of 95% by the 10th epoch. Subsequently, in the 18th epoch, both training and validation losses stabilized at 0.3. The model was intentionally limited to 20 epochs to mitigate the risk of overfitting, ensuring the extraction of optimal results. These details, depicted in the accompanying figures, underscore the efficacy of the selected model


```
K.clear_session() #clear the session
tf.compat.v1.reset_default_graph()
img_shape=(img_size[0], img_size[1], 3)
model_name='EfficientNetB5'
base_model=tf.keras.applications.efficientnet.EfficientNetB5(include_top=False, weights="imagenet",input_shape=img_shape, pooling='max')
# Note you are always told NOT to make the base model trainable initially- that is WRONG you get better results leaving it trainable
base_model.trainable=True
x=base_model.output
x=BatchNormalization(axis=-1, momentum=0.99, epsilon=0.001 )(x)
x = Dense(256, kernel_regularizer = regularizers.l2(l = 0.016),activity_regularizer=regularizers.l1(0.006),
                bias_regularizer=regularizers.l1(0.006) ,activation='relu')(x)
x=Dropout(rate=.4, seed=123)(x)
output=Dense(class_count, activation='softmax')(x)
model=Model(inputs=base_model.input, outputs=output)
lr=.001 # start with this learning rate
model.compile(Adamax(learning_rate=lr), loss='categorical_crossentropy', metrics=['accuracy'])
```

Fig. 1 Model Building Code

architecture and training strategy in achieving the desired performance metrics.

Following the model training, a comprehensive evaluation was conducted, encompassing the creation of a confusion matrix to ascertain the true accuracy, revealing an impressive 95%. Additionally, a detailed classification

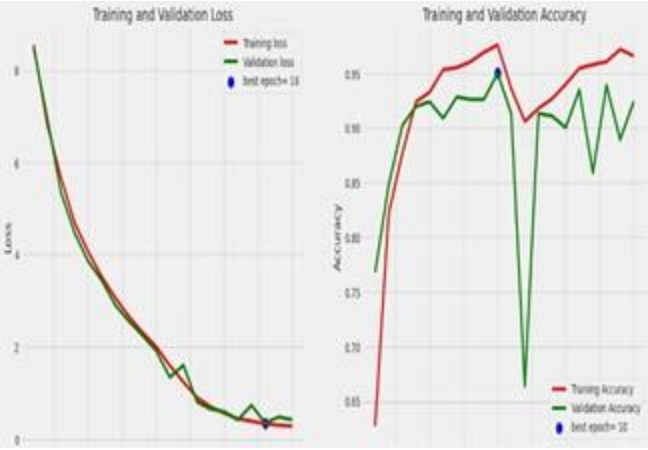

Fig.2 Loss & Accuracy Plots

report was generated, presenting relevant scores (including precision, recall, f1-score, and support) that offer a thorough assessment of the model's performance. This multifaceted evaluation process was augmented by conducting a thorough analysis, exploring the model's robustness to variations in input parameters, and providing valuable insights into the model's standing in the broader context of osteoarthritis detection methodologies. These additional analyses contribute to a more nuanced understanding of the model's reliability, generalizability, and potential areas for refinement. The outcomes of these evaluations are elucidated below:

Table 1 Classification Report

Class	Precision	Recall	F1-score	Support
Healthy	0.9921	0.9875	0.9898	639
Moderate	0.9387	0.8924	0.9149	223
Severe	0.7077	0.9020	0.7931	51
Accuracy			0.9595	913
Macro Avg	0.8795	0.9273	0.8993	913
Weighted Avg	0.9632	0.9595	0.9605	913

Upon successfully saving the model, the subsequent phase involved the development of our mobile application, named 'Arthritis Detector.' The integration of our trained model into the application was achieved using Flutter, resulting in the deployment of a fully operational mobile application. This user-friendly interface not only ensures high accessibility but also allows users to input X-ray images, enabling seamless and efficient utilization of the Arthritis Detector application.

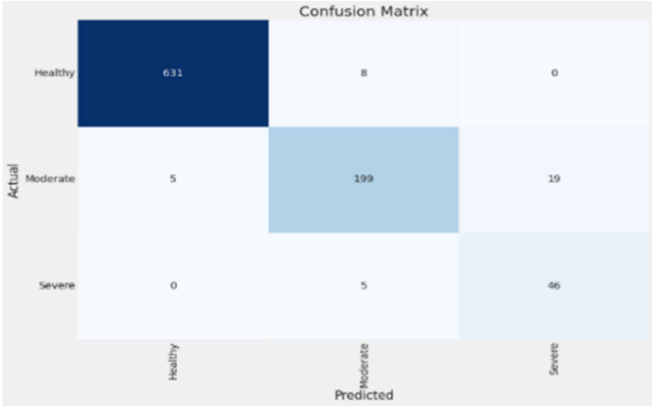

Fig. 3 Confusion Matrix

V. Conclusion

In conclusion, the creation of a model that precisely identifies osteoarthritis in knee X-rays marks a significant advancement in medical imaging. Osteoarthritis, being a prevalent and debilitating condition, underscores the importance of early detection for effective treatment. Leveraging deep learning algorithms and advanced image processing techniques, this model has demonstrated promising outcomes in accurately pinpointing osteoarthritis in knee X-rays. The successful implementation of this model has the potential to transform the diagnostic and treatment approach for osteoarthritis, providing clinicians with a robust tool to enhance their decision-making process. Nonetheless, further research and validation are imperative to thoroughly assess the accuracy and efficacy of this model in real-world clinical settings. Such advancements have the potential to positively impact the lives of millions worldwide who grapple with this condition.

Disclaimer: The 'Arthritis-Detector' app is designed as a supportive tool for medical experts and should not be regarded as a substitute for their expertise.

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