Osteoarthritis Prediction with Machine Learning

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Abstract**—**Osteoarthritis (OA) is a long-term, degenerative joint condition that impacts millions of individuals globally, causing discomfort, stiffness, and decreases mobility overtime. Early identification and diagnosis play a vital role in slowing disease progression and enhancing the patient's overall quality of life. Conventional diagnostic methods, such as X-ray imaging and clinical assessments, provide reliable results but can be time-consuming.

Therefore, using Machine Learning(ML), OA can be predicted before time ans irreversible changes can be avoided. .The model presents Deep Learning-based approach that leverages convolutional neural networks(CNNs) for classifying OA using X-ray images. The feature extractor that model uses is EfficientNetB0 and custom dense layers for classification.

The proposed model demonstrates optimistic results in distinguishing between different OA severity levels that is (Grade 0-4), which offers a scalable and efficient model for clinical usage.

By integrating deep learning with medical imaging(X-rays) and other patient's metadata, this model aims to automate OA, enhance treatments outcomes, support clinical decisions and enable timely interventions.

Future work will be focusing on training model with larger dataset and real time clinical applications.

Keywords**—***Osteoarthritis, Machine Learning, Deep Learning, Early Detection, EfficientNetB0*

Introduction

A. Overview

Osteoarthritis(OA) is the most common type of arthritis, characterized as a chronic and progressive joint disorder that affects millions of people globally. It leads to stiffness, pain, and reduced mobility, hence impacting daily routine and life. The onset and progression of OA result from a combination of biological, genetic, and mechanical factors, with major risk factors including aging, previous joint injuries, hereditary influences, and obesity.

This condition is mainly defined by the deterioration of cartilage and inflammation in the joints, primarily affecting weight-bearing areas like the knees, spine, and hips, leading to a significant decline in a patient's quality of life. Although there is no permanent cure for OA, several treatment strategies can help relieve pain, control symptoms, and slow its progression.

Thus, early detection and accurate severity assessment play a crucial role in delaying OA advancement, optimizing treatment strategies, and improving overall patient outcomes. Timely diagnosis enables better disease management, ultimately enhancing the quality of life for individuals affected by OA.

B. Literature survey

The incorporation of machine learning and deep learning in medical field has yielded remarkable advancements in recent years, positively impacting treatment methodologies. Previous studies have investigated the application of machine learning for osteoarthritis (OA) detection, utilizing techniques for instance support vector machines (SVM), random forests, and convolutional neural network (CNN) to enhance diagnostic accuracy and efficiency.

Among these, deep learning models—especially CNN-based architectures—have shown remarkable effectiveness in medical image classification. Several studies have leveraged pretrained models like ResNet, VGG, and DenseNet to enhance OA prediction accuracy.

Various studies have confirmed that this integration results in automated methods for OA classification and prediction.

In this study[7], multiple pre-trained deep learning models, including ResNet101 and DenseNet121, were utilized for the classification of osteoarthritis (OA) severity. These models, known for their advanced feature extraction capabilities, were fine-tuned to analyze X-ray images and differentiate between varying OA severity levels.The outcomes demonstrated improved accuracy with residual neural networks, achieving approximately 89% accuracy in multi-class classification. This improvement highlights the effectiveness of deep learning in detecting intricate patterns in medical imaging, leading to more precise OA severity grading. Additionally, the use of residual connections in ResNet101 helped overcome vanishing gradient issues, enabling deeper networks to learn more efficiently.By leveraging these advanced architectures, the study reinforces the potential of AI-driven diagnostic tools in reducing human errors, enhancing early detection, and supporting clinical decision-making. Future enhancements, such as integrating patient metadata and Explainable AI (XAI), could further refine predictions and ensure wider clinical applicability.[7].This study[12] incorporates Explainable AI (XAI) techniques, such as Grad-CAM, alongside deep learning models like EfficientNetB7, to enhance the interpretability and reliability of OA severity classification. By utilizing Grad-CAM, the model provides visual explanations of its predictions, helping clinicians understand which regions of the X-ray contribute most to the diagnosis.

The study demonstrated that the model could effectively distinguish between severe and normal OA cases, achieving an impressive accuracy of up to 99.13%. This high accuracy underscores the potential of deep learning in automated OA detection, reducing subjectivity in traditional assessments.

Moreover, integrating XAI techniques ensures greater transparency in AI-driven medical diagnoses, increasing trust among healthcare professionals. Future advancements could focus on incorporating patient metadata and expanding datasets to further enhance model generalization and real-world applicability..[12].This study[14] explores various machine learning approaches and their applications in knee osteoarthritis (OA) research, focusing on key areas such as prediction, segmentation, classification, and disease progression. By leveraging advanced ML techniques, researchers aim to develop more accurate and automated diagnostic tools for OA assessment.The study focuses on the critical role of Explainable AI (XAI) in enhancing the accuracy, reliability, and trustworthiness of these models. XAI ensures that AI-driven decisions are transparent and interpretable, making them more suitable for clinical deployment.Furthermore, the research highlights the potential of integrating multi-modal data, including patient history, imaging, and biomarkers, to improve OA diagnosis and progression tracking. Future advancements may focus on refining model generalization and ensuring seamless integration into healthcare systems for widespread clinical adoption.[14]This study[13] provides an overview of ml methadologies, techniques and algorithms applicable to osteoarthritis (OA) prediction, analysis, and treatment planning. It explores how ML-based models can enhance early detection, severity classification, and personalized treatment strategies, offering a more data-driven approach to OA management.

The review emphasizes the importance of diverse and extensive datasets to improve the robustness and generalizability of AI models. It emphasis on the need for continued research and collaboration to develop more effective predictive tools.

Additionally, the study suggests that incorporating multi-source data—including medical history, lifestyle factors, and imaging data—can significantly enhance model performance, ultimately leading to better patient outcomes and improved clinical decision-making.[13].This paper[11] gives a detailed review of research papers published inbetween the years 2006 to 2020, focusing on the applications of Machine learning (ML) in osteoarthritis (OA) diagnosis and management. It categorizes ML applications into four key areas:Classification, Segmentation, Predictions or Regression and Optimum Post-Treatment Planning.The study highlights the core characteristics of ML algorithms, comparing their performance, advantages, and limitations in automated OA detection and analysis. It shows the importance of deep learning, feature engineering, and hybrid AI models to improve diagnostic accuracy and enhance clinical decision-making. Future research directions include integrating Explainable AI (XAI), federated learning for data privacy, and multi-modal data fusion to refine ML-driven OA assessments.[11]

All these studies are inclined towards making OA diagnosis easy and to provide AI-driven solutions to improve the existing traditional methods of OA prediction.

C. Challenges Faced by the Traditional Method

There are more than 180 million cases of arthritis in India alone. Out of this, a study done in 2024 reported that the number of OA patients rose from approximately 23.46 million in 1990 to about 62.35 million in 2019.

Osteoarthritis (OA) has traditionally been diagnosed through clinical symptoms, physician assessments, physical examinations, and X-ray imaging. Since 1961, the World Health Organization (WHO) has recognized the Kellgren-Lawrence (KL) grading system, the standard system for evaluating OA severity using X-rays. This system classifies the disease into five grades (0-4): 0 - perfect condition, 1 - doubt condition, 2 - minimum condition, 3 - average condition, and 4 - critical condition.

The classification is determined based on key factors for instance joint osteophyte formation, space narrowing, and structural abnormalities in the affected joints.

However, the manual interpretation of X-rays is inherently subjective, often resulting in inconsistencies among radiologists and a higher risk of misdiagnosis due to human error.

This challenge highlights the need for more accurate and reliable diagnostic methods in medical imaging. artificial intelligence (AI), particularly machine learning (ML) and deep learning (DL), offers a promising solution by enhancing the precision and efficiency of OA prediction, reducing variability, and improving diagnostic outcomes.

D. Machine learning(ML) in brief

Machine Learning (ML), a sub branch of Artificial intelligence (AI), allows the machines to learn from the data, identify patterns, and generate data-driven predictions using advanced algorithms.

In the medical field, ML has revolutionized disease diagnosis and prognosis by enhancing accuracy and efficiency. For osteoarthritis (OA), ML plays a crucial role in automating prediction and severity classification, minimizing reliance on manual evaluations, reducing human error, and improving overall diagnostic precision.

In ML-based medical analysis, a sample(patient data) is presented by the set of features which may include X-ray images, medical history, and patient metadata such as age, weight, and genetic predisposition. These features serve as inputs for the ML model to train and make predictions.

ML Model Phases:

Training Phase – The model is trained on labeled datasets, where it learns the relationships and pattern between features and their corresponding OA severity levels.

Testing Phase – The trained model is tested on previously unfamiliar data, where it must classify or predict OA severity based on learned patterns.

Pre-Processing & Feature Engineering:

Before training, data undergoes pre-processing, which includes:

Data Cleaning – Handling missing or inconsistent values.

Data Integration – Merging multiple sources of patient data.

Data Transformation – Converting data from one format to another into a format suitable for ML models.

Feature extraction (feature engineering) is applied to select the most relevant features that influence OA detection and classification. This ensures the model captures the key characteristics of OA progression, leading to more accurate predictions.

During the testing phase, the trained model processes unfamiliar patient data and predicts the OA severity based on learned patterns. The decision making process of the model is based on the extracted features and relationships it has established during training.

By continuously refining its predictions through optimization techniques and larger datasets, the model improves its accuracy, reliability, and clinical applicability over time.

Future advancements may integrate multi-modal data sources, deep learning techniques, and real-time analytics, further enhancing the model's diagnostic precision and decision - making capabilities in OA detection and classification.

E. Deep Learning(DL) in OA Prediction

Deep learning, a subset of machine learning, has shown remarkable success in medical image analysis, outperforming traditional computer vision methodologies. Convolutional Neural Networks (CNNs), in particular, has been extensively utilized for the feature extraction and classification of medical images, including X-rays.

By identifying intricate patterns within these images, CNNs can achieve high accuracy in detecting osteoarthritis (OA) and assessing its severity.

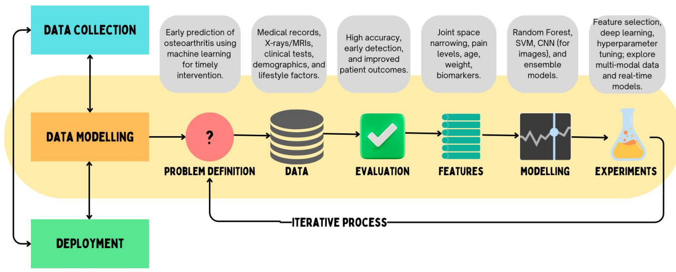
While this approach significantly enhances OA prediction, integrating patient metadata—such as medical history, age, and weight—alongside X-ray analysis could further refine diagnostic accuracy. Incorporating such additional data points can lead to more precise and personalized predictions, ultimately improving the model's effectiveness in real-world clinical applications.

Moreover, leveraging advanced DL techniques for instance multi - modal learning and attention mechanisms could enhance feature representation. Future studies may also explore federated learning to utilize diverse datasets while maintaining patient privacy. These advancements will contribute to more robust and efficient OA diagnosis systems.

OBJECTIVE

This study includes a deep learning-based approach for automated OA classification using X-rays. Our model uses EfficientNetB0(a state-of-the-art CNN architecture) to extract features and fully connected layers for the OA severity classification.
To improve model generalization, advance training techniques have been incorporated for instance categorical cross-entropy loss, data augmentation, learning rate scheduling and AdamW optimizer. Moreover to address class imbalance, weighted loss functions are used to ensure robust predictions for all severity levels.
The study aims build an effective model that predicts OA accurately and to compare it with the assessment of clinical experts and their methods. OA predictions can be made efficient with the integration of the model and the medical field thus reducing human efforts.
The trained model will be deployed using streamlit to create a user friendly interface for the patients and healthcare experts to interact with the model. The model's outcomes will be evaluated against the existing methodologies and approaches. Further improvements and enhancements will be made.

SYSTEM ARCHITECTURE



MATERIALS AND METHODS

A. MODEL ARCHITECTURE

1)Pretrained Backbone:

a pretrained DL model is for extracting relevant features from the input images that is xrays.

- used for feature extraction

-include_top=False : to remove original classifier

-weights='imagenet': to leverage pretrained weights.

-trainable=False : freezes weights to prevent overfitting.

2) Feature Extraction (Global Average Pooling)

- it converts extracted features into a fixed-size vector.

-also helps to reduce the parameters and enhance efficiency of the model

3)Fully Connected Layers (Dense Layers)

-Multiple Dense layers with decreasing neurons.

-L2 Regularization (l2(0.01)) to prevent overfitting.

-Dropout (0.3) for better generalization.

4) Final Output Layer

- For multi-class classification, softmax activation is used (Grades 0-4).

- The output is the probability scores for every class which leads to accurate OA severity classification.

B. TRAINING DETAILS

1. Loss function:
Categorical Crossentropy: Measures the divergence between predicted and actual class probabilities, making it ideal for multi-class classification tasks.

2. Optimer:
AdamW: A variant of the Adam optimizer that integrates weight decay (weight_decay=0.01) to enhance model regularization and minimize overfitting.

3. Learning Rate Adjustment:
ReduceLROnPlateau: Automatically lowers the learning rate by a factor of 0.5 and patience=3 when the validation loss (val_loss) stagnates for three consecutive epochs, facilitating better convergence.

4. Data Augmentation:
ImageDataGenerator - Enhances dataset variability by applying transformations such as rotations, flipping, and scaling, improving model generalization.

5.Handling Class Imbalance:
compute_class_weight: Determines appropriate class weights to ensure balanced learning, preventing underrepresented classes from being overshadowed during training.

RESULTS

The trained model was evaluated on a test set and its performance metrics were recorded.
The following are the results:

Performance metrics	***Values***
Classification Reshape Accuracy	58.50%
Classification Reshape Loss	1.1729

-Overall Loss: 1.8535
Currently, the model achieves an accuracy of 58.50%, which is expected to improve as it is trained on a larger and more diverse dataset. Expanding the dataset will enhance the model's ability to recognize patterns, reduce overfitting, and improve generalization.
Additionally, fine-tuning hyperparameters, optimizing data augmentation techniques, and incorporating patient metadata could further boost performance, making the model more reliable for real-world clinical applications.

CONCLUSIONS

This study highlights the effectiveness of deep learning in predicting osteoarthritis (OA). By utilizing a CNN-based model, it achieves reliable classification results, demonstrating that AI and deep learning can complement clinical assessments for more accurate diagnoses.

Future research will focus on improving model generalization by incorporating larger, more diverse datasets and integrating patient metadata, such as age, medical history, and genetic factors, to enhance prediction accuracy.

Additionally, exploring hybrid models that are combined with deep learning with traditional machine learning techniques may further refine diagnostic capabilities. Ultimately, these advancements aim to support personalized, timely intervention, treatment early, detection and strategies for OA, leading to better patient outcomes.

DEPLOYMENT

The model will be deployed using Streamlit, enabling a user-friendly interface for both medical professionals and patients to interact with.
Streamlit, a Python-based library, is specifically designed for building data-driven web applications, interactive dashboards, and machine learning interfaces, making it an ideal choice for this deployment.
In the final implementation, the trained model will be integrated into a Streamlit-based web application, allowing users to upload X-ray images for inference. The interface will be intuitive and accessible, enabling doctors and patients to seamlessly upload medical images.
Once an X-ray is uploaded, the model will analyze the image, classify OA severity, and display the results in an easy-to-understand format. This real-time assessment can assist healthcare professionals in making quicker and more accurate diagnoses, facilitating early intervention and better patient management.
Future enhancements may include multi-modal inputs (such as patient history) and integration with hospital systems for a more comprehensive diagnostic tool.

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