Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, April : 2023

PREDICTION OF KNEE OSTEOARTHRITIS USINGDEEP LEARNING ALGORITHMS

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Abstract

Knee Osteoarthritis (KOA) is a degenerative disease that affects the knee joint and causes pain, limited mobility, and reduced quality of life for millions of people. It is the prevalent type of arthritis and a major contributor to disability globally. Manual diagnosis, segmentation, and annotation of knee joints are the primary methods used in clinical practice to diagnose OA, but they are time-consuming and subject to user variation. To address the limitations of current methods, numerous deep-learning approaches have been developed to improve clinical workflow efficiency. Medical imaging techniques like MRI can produce 3D images that reveal hidden structures in a volumetric view. This study aims to investigate the use of deep learning (DL) algorithms for the classification of knee osteoarthritis diagnosis, which is a complex problem involving many medical factors. The ultimate goal is to develop an efficient machine-learning approach that can effectively classify knee osteoarthritis while considering multiple medical factors.

Keywords: *Knee Osteoarthritis, Degenerative disease, Knee joint, Deep-Learning, Medical Imaging Techniques, Segmentation, Machine-Learning.*

INTRODUCTION

Knee osteoarthritis (KOA) is a widespread type of arthritis that affects millions of individuals globally. Current clinical practices rely on manual diagnosis and segmentation of knee joints, which can be time-consuming and subject to variation among clinicians. To address these limitations, researchers are turning to deep learning approaches to improve the efficiency of clinical workflows. Medical imaging techniques like MRI can produce high- quality 3D images that provide detailed insights into the knee joint. Deep Learning algorithms can be trained to automatically analyze these images and classify them according to the presence or severity of KOA. This approach has the potential to revolutionize how KOA is diagnosed and treated, as it can account for the complex and multifactorial nature of the disease.
By analysing large datasets of patient information, including medical images, electronic health records, and genetic data, deep learning models can identify patterns and relationships that traditional methods may miss. This can lead to the discovery of new biomarkers and uncover new insights into the underlying biological mechanisms of KOA, ultimately leading to more effective treatments. One significant advantage of using deep learning for KOA detection is that it can produce explainable and interpretable results. This can help clinicians and researchers better understand the disease mechanisms involved in KOA and develop more personalized treatments.

LITERATURE SURVEY

"Recognition of Knee Osteoarthritis (KOA) Using YOLOv2 and Classification Based on Convolutional Neural Network" by Usman Yunus et al. (2022): This research paper that proposes a deep learning model to detect and classify knee osteoarthritis (KOA) using YOLOv2 and a convolutional neural network. The authors used MRI images of the knee joint to train their model and achieved high accuracy in detecting and classifying KOA. The proposed model has the potential to assist medical professionals in the diagnosis and treatment of KOA, as it can accurately detect and classify the disease at an early stage [1].

"Automatic Detection and Classification of Human Knee Osteoarthritis Using Convolutional Neural Networks" by Mohamed Yacin Sikkandar et al (2021): This paper describes a study that uses convolutional neural networks (CNNs) for automatic detection and classification of human knee osteoarthritis (OA). They used a dataset of knee radiographs and applied a deep learning approach using CNNs to detect and classify different stages of knee OA. The study found that the proposed method achieved high accuracy in detecting and classifying different stages of knee OA, which could potentially improve the efficiency and accuracy of OA diagnosis [2].

"Identification of the most important features of knee osteoarthritis structural progressors using machine learning methods" by Jamshidi et al (2020): This paper describes a study that uses machine learning methods to identify the most important features of knee osteoarthritis structural progressors. They used data from a large longitudinal study of knee OA patients, including clinical and radiographic data as well as MRI images. They used machine learning algorithms to identify which features were most predictive of structural progression in knee OA patients, including changes in cartilage thickness, bone shape, and bone density. The study found that changes in cartilage thickness were the most important predictor of structural progression in knee OA patients. These findings could have important implications for the development of new treatments and therapies for knee OA. [3].

"Machine Learning in Knee Osteoarthritis: A Review" by Christos Kokkotis et al (2020): The paper provides a comprehensive review of the use of machine learning techniques in the context of knee osteoarthritis (KOA). The authors provide an overview of the most common machine learning algorithms used in KOA research, including supervised and unsupervised learning, deep learning, and transfer learning. They also discuss the different types of data used in KOA research, such as radiographic images, MRI, and clinical data. They review the various applications of machine learning in KOA, including diagnosis and prediction of progression, risk stratification, treatment response, and surgical planning. They also highlight some of the challenges and limitations of using machine learning in KOA research, such as the need for high-quality and diverse data sets, the potentialfor algorithmic bias, and the difficulty of interpreting machine learning models [4].

"A Deep Learning Method for Predicting Knee Osteoarthritis Radiographic Progression from MRI" by Jean-Baptiste Schiratti et al (2020): This paper describes a deep learning approach to predict knee osteoarthritis radiographic progression from MRI images. They used a deep learning algorithm to predict radiographic progression of knee OA in patients, based on MRI images. The study found that the deep learning model achieved high accuracy in predicting knee OA progression, demonstrating the potential of machine learning in improving the accuracy and efficiency of knee OAdiagnosis and treatment [5].

"Predicting Early Symptomatic Osteoarthritis in the Human Knee Using Machine Learning Classification of Magnetic Resonance Images from the Osteoarthritis Initiative" by Ashinsky et al (2017): The paper presents a study that uses machine learning methods to predict early symptomatic osteoarthritis in the human knee using magnetic resonance images (MRI) from the Osteoarthritis Initiative. They used a large dataset of MRI images from individuals with and without early symptomatic OA, and applied machine learning classification algorithms to identify features in the MRI scans that were most predictive of early symptomatic OA. The study found that the use of machine learning algorithms significantly improved the ability to predict early symptomatic OA, and identified several MRI-based features that were highly predictive of disease progression. The findings could have important implications for the early diagnosis and treatment of OA, which could ultimately improve patient outcomes and quality of life [6].

METHODOLOGY

DEEP LEARNING

Deep learning is a type of machine learning that uses artificial neural networks with multiple layers to learn and make predictions from complex data. It can automatically extract relevant features from raw data, leading to impressive results in fields such as image recognition and natural language processing.

DATASET COLLECTION

The knee osteoarthritis dataset was collected via Kaggle, which is a popular platform for discovering datasets across various fields, including medicine. Kaggle provides a diverse range of datasets containing specific disease features, images, and csv files that can be used for disease identification.

The "Knee Osteoarthritis Dataset with Severity Grading" dataset is a dataset of knee X-ray images that have been labeled with severity grades according to the Kellgren-Lawrence grading system. The Kellgren-Lawrence grading system is a widely used classification system for knee osteoarthritis, which grades the severity of the disease on a scale from 0 to 4. In this dataset, each image is assigned a severity grade, with grade 0 indicating no osteoarthritis, and grade 4 indicating severe osteoarthritis. The dataset contains knee X-ray images, which were compiled from various sources. The images are commonly used for training and evaluating machine learning models for automatic grading and detection of knee osteoarthritis. The availability of this dataset has made it easier for researchers to develop and test machine learning algorithms for automatically grading and detecting knee osteoarthritis, which has the potential to improve the accuracy and efficiency.

DATA DESCRIPTION

The Knee Osteoarthritis Dataset with Severity Grading is a collection of knee X-ray images labeled with severity grades according to the Kellgren-Lawrence grading system. The dataset contains a total of 4,979 images of knee joints, each assigned a severity grade ranging from 0 to 4. Grade 0 represents no osteoarthritis, while grade 4 indicates severe osteoarthritis. The images are stored in JPEG format and have a resolution of 1024 x 1024 pixels. The dataset is commonly used for training and evaluating machine learning models for automatic grading and detection of knee osteoarthritis.

PREPROCESSING OF DATA

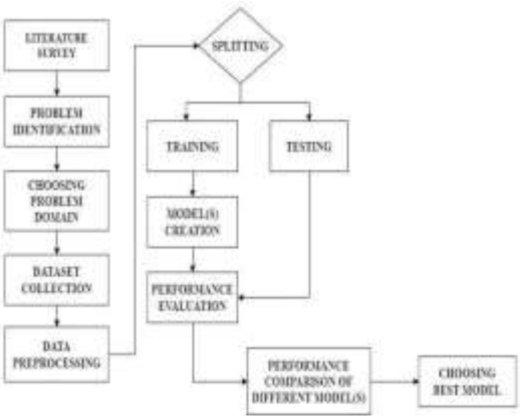
Preprocessing of the dataset involves several steps to prepare the data for use in machine learning algorithms. First, the images are resized to a uniform size to ensure consistency across the dataset. Then, the images are normalized to reduce the impact of lighting and contrast variations. Next, the images are converted to grayscale to simplify the data and reduce the computational load. Finally, the labels are converted to one-hot encoding to represent the severity grade as a vector, which is more suitable for training deep learning models. Additionally, data augmentation techniques such as rotation, flipping, and scaling are applied to increase the size and diversity of the dataset, which can improve theperformance of the models.

DATA SPLITTING

Data splitting is a common technique in machine learning where a dataset is divided into two or more subsets to be used for different purposes, such as training and testing a model. In the "Knee Osteoarthritis Dataset with Severity Grading," the dataset can be split into a training set and a testing set. The training set is used to train the machine learning model, while the testing set is used to evaluate the model's performance on new, unseen data. The ratio of the data split can vary, but a common split is 70/30 or 80/20, with the larger portion being used for training.

FEATURE SCALING

Feature scaling is a preprocessing step used for the Knee Osteoarthritis Dataset with Severity Grading. The pixel values of the images are scaled to a range between 0 and 1, which helps to improve the training process of machine learning models. This is because scaling ensures that each feature contributes equally to the final prediction, regardless of their original scale. Additionally, scaling can also help to prevent numerical instabilities and speed up thetraining process.



KNEE OSTEOARTHRITIS USING DL

Knee osteoarthritis prediction using deep learning involves training a neural network on a dataset of knee X-ray images with severity grading labels. The neural network can be designed to take the knee

X-ray images as input and predict the severity grade of osteoarthritis in the image. To improve the performance of the neural network, transfer learning can be applied using pre-trained models such as VGGNet. Transfer learning involves using a pre-trained model as a starting point and fine- tuning it to a new dataset. This technique has shown high accuracy in image recognition tasks. The dataset can be split into training, validation, and testing sets to evaluate the neural network's performance. Data preprocessing techniques such as normalization, grayscale conversion, and data augmentation can be applied to the dataset to improve the neural network's accuracy. Once the neural network is trained, it can be used to predict the severity grade of knee osteoarthritis in new X-ray images. The accuracy of the neural network can be evaluated by comparing its predictions to the actual severity grades. This approach has the potential to improve the diagnosis and treatment of knee osteoarthritis, which is a common and debilitating condition.

CONVOLUTIONAL NEURAL NETWORK

Convolutional Neural Networks (CNNs) have shown great potential for Knee Osteoarthritis prediction because they are designed to handle image analysis tasks effectively. The process of using a CNN for this task involves collecting a large dataset of knee X-ray images with their corresponding severity grades, and then dividing the dataset into a training set and a testing set. The training set is used to teach the CNN to recognize the patterns and features that distinguish between different severity grades, while the testing set is used to evaluate the performance of the model.

During the training process, the CNN uses a series of layers to analyze and extract features from the knee X-ray images. The first layers are convolutional layers that apply a set of filters to the image to detect specific features such as edges, lines, and curves. The next layers are pooling layers that reduce the dimensionality of the output from the convolutional layers, making the network more efficient. Finally, the fully connected layers perform the classification task by outputting a probability score for each severity grade. Once the CNN is trained, it can be used to predict the severity grade of new knee X-ray images. The CNN processes the new image and outputs a probability distribution across the different severity grades. The severity grade with the highest probability is then assigned to the new image. Using CNNs for Knee Osteoarthritis prediction could provide significant benefits, such as improving the accuracy and efficiency of diagnosis. This could lead to better treatment and management of the condition, potentially reducing the number of unnecessary surgeries or procedures and improving patient outcomes.

VGGNET IN CNN

VGGNet, or the Visual Geometry Group Network, is a deep convolutional neural network architecture developed by researchers at the Visual Geometry Group at the University of Oxford. It is known for its simplicity and effectiveness in image classification tasks, achieving state-of-the-art results on the ImageNet Large Scale Visual RecognitionChallenge (ILSVRC).

VGG16 is a type of Convolutional Neural Network (CNN) that has been successfully applied to a variety of image classification tasks, including medical image analysis. It consists of 16 layers, including 13 convolutional layers and 3 fully connected layers.

In the context of Knee Osteoarthritis prediction, VGG16 can be used as a pre-trained network, which means that it has already been trained on a large dataset of images (such as ImageNet) and can be

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, April : 2023

fine-tuned on the Knee Osteoarthritis dataset. This approach can save time and computational resources, as the network has already learned to recognize general features from images, such as edges, shapes, and textures.

To use VGG16 for Knee Osteoarthritis prediction, the dataset of knee X-ray images with their corresponding severity grades is first preprocessed, which involves resizing the images, normalizing the pixel values, and converting the images to grayscale. The dataset is then split into a training set and a testing set.

Next, the pre-trained VGG16 network is loaded, and the final fully connected layers are replaced with new layers that are tailored to the Knee Osteoarthritis prediction task. The new layers are then fine-tuned on the training set using backpropagation and stochastic gradient descent, with the goal of minimizing the prediction error. Once the network is trained, it can be evaluated on the testing set to assess its performance.

SOME CLASSES FROM THE DATASET:

The stages include ‘Normal’, ‘Doubtful’, ‘Mild’, ‘Moderate’, ‘Severe’. These are the names of the stages of the Knee Osteoarthritis disease in the dataset.

Stages in the Knee Osteoarthritis Disease

Knee Osteoarthritis (KOA) is a degenerative joint disease that typically progresses through several stages, each with varying degrees of severity. The stages of KOA are generally classified based on the extent of cartilage damage, as well as the presence of other symptoms such as pain and stiffness.

The stages of KOA are typically described as follows:

Stage 0 (Normal): This stage is characterized by a lack of radiographic evidence of joint damage, despite the presence of symptoms suchas pain and stiffness.

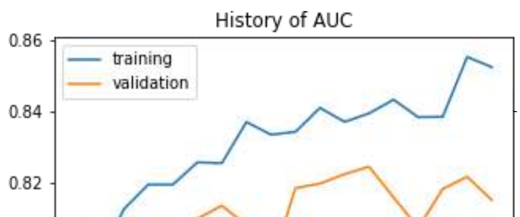
Stage 1 (Doubtful): In this stage, there is a small amount of joint space narrowing and possible osteophyte (bone spur) formation.

Stage 2 (Mild): In this stage, there is a moderate amount of joint space narrowing, as well as an increase in osteophyte formation. There may also be mild to moderate loss of cartilage, along with some joint deformity.

Stage 3 (Moderate): In this stage, there is a severe amount of joint space narrowing, as well as extensive osteophyte formation. There is also significant loss of cartilage, along with significant joint deformity.

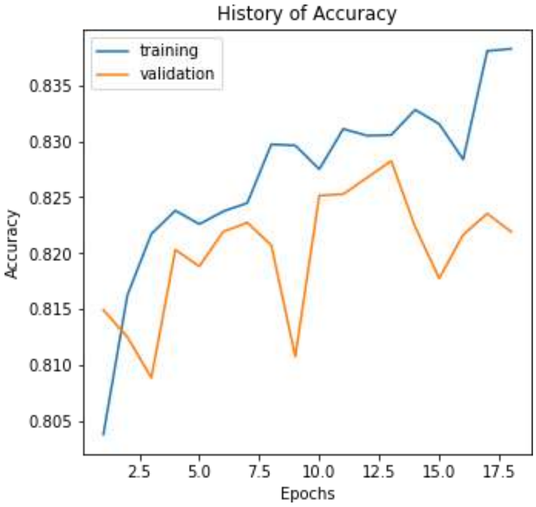
Stage 4 (Severe): This stage is the most severe, with complete loss of joint space and extensive osteophyte formation. There is also complete loss of cartilage, along with significant joint deformity and potential bone-on-bone contact.

Results



Accuracy is the measure of the overall correctness of the model's predictions, while recall indicates the model's ability to identify positive cases correctly. Precision reflects the model's ability to identify only the relevant positive cases accurately. Finally, F1 score is the harmonic mean of recall and precision, and it provides an overall measure of the model's performance in identifying positive cases correctly while also minimizing false positives.

To assess the model's effectiveness in predicting KOA, you would typically calculate the accuracy, recall, precision, and F1 score for the positive (i.e., KOA-afflicted) class. An ideal model would



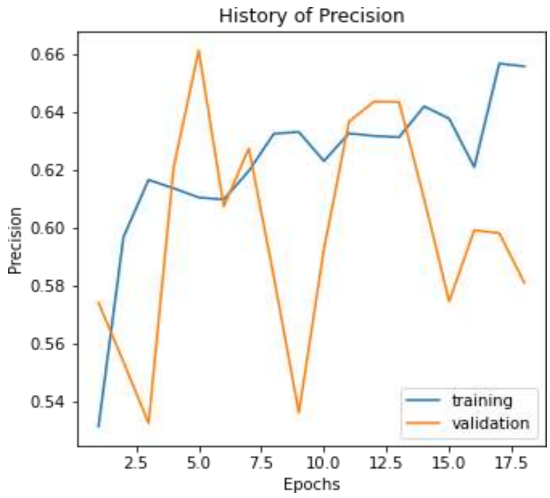
achieve high scores in all of these metrics, but the optimal values depend on the specifics of the dataset and the intended use of the model.

When evaluating a model's effectiveness in predicting KOA, the metrics of interest are accuracy, recall, precision, and F1 score. These metrics provide different perspectives on the model's performance and are useful in assessingthe model's overall quality.
The accuracy metric indicates the proportion of correctly classified cases over the total number of cases. In the case of KOA, accuracy reflects the percentage of correctly predicted cases of KOA, out of all cases in the dataset. An ideal model would achieve high accuracy, which means that it correctly identifies most cases of KOA and non-KOA.

Recall, also known as sensitivity, measures the proportion of true positives (i.e., correctly identified KOA cases) out of all actual positive cases (i.e., total KOA cases in the dataset). A high recall score indicates that the model is capable of correctly identifying most of theKOA cases in the dataset.

The area under the curve (AUC) is a common evaluation metric used in deep learning for classification problems, including knee osteoarthritis prediction. In the context of knee osteoarthritis prediction using deep learning, the AUC can be calculated by comparing the predicted severity grades of osteoarthritis with the actual severity grades in the testing set. A high AUC indicates that the deep learning model is able to accurately distinguish between different severity grades of osteoarthritis in knee X-ray images.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, April : 2023



Precision measures the proportion of true positives out of all predicted positives (i.e., total cases the model predicted as KOA). A high precision score indicates that the model is precise in identifying only the relevant KOA cases without including any false positives.

The F1 score is the harmonic mean of recall and precision, and it provides an overall measure of the model's performance in identifying KOA cases while minimizing false positives.

Optimal values for these metrics depend on the specifics of the dataset and the intended use of the model. For instance, if the model is used for screening purposes, high recall may be more important than high precision. On the other hand, if the model is used to diagnose patients, high precision may be more critical to avoid false positives. Therefore, it is essential to consider the specific use case of the modelwhen interpreting the values of these metrics.

The loss function measures how well the model's predicted output matches the true output. The goal of training a deep learning model is to minimize the loss function to improve the model's accuracy in makingpredictions.

A confusion matrix is a table that summarizes the performance of a classification model by showing the number of true positive, true negative, false positive, and false negative predictions made by the model. The rows of the matrix represent the actual class labels, and the columns represent the predicted class labels.

The 5x5 confusion matrix for the five stages of knee osteoarthritis is a table that summarizes the performance of a multi-class classification model that aims to predict the different stages of KOA.

The rows of the matrix represent the actual stage labels, and the columns represent the predicted stage labels. Each cell in the matrix represents the number of instances that were predicted to be in a certain stage but actually belong to a different stage.

The diagonal cells of the matrix represent the number of correct predictions (i.e., true positives) for each stage. The off-diagonal cells represent the number of incorrect predictions (i.e., false positives and false negatives) foreach stage.

The confusion matrix is a useful tool for evaluating the performance of a multi-class classification model and can be used to calculate various performance metrics such as accuracy, precision, recall, and F1 score for each stage of KOA.

Conclusion

Deep learning techniques have shown promising results in detecting knee osteoarthritis (KOA) from medical images, clinical data, and other sources. By using deep learning models, researchers have been able to achieve high accuracy in detecting and classifying the different stages of KOA.

The use of deep learning for KOA detection can help improve the accuracy and efficiency of diagnosis, which is important for early detection and treatment of the disease. However, it is important to note that deep learning models require a large amount of training data, and the quality of the training datais critical for achieving high accuracy.

Moreover, deep learning models are still not perfect, and they can suffer from certain limitations, such as overfitting, bias, and lack of interpretability. Therefore, it is essential to continue improving the models and evaluating their performance on different datasets to ensure their reliability and usefulness in clinicalpractice.

Overall, deep learning has the potential to revolutionize the way we diagnose and treat KOA, and further research in this field can lead to significant improvements in healthcare outcomes for patients suffering from thisdisease.

Future Enhancement

Future research in knee osteoarthritis (KOA) detection using deep learning could explore data augmentation, transfer learning, interpretability, multi-modal data integration, and real-time monitoring. These approaches could help improve the accuracy, efficiency, and reliability of KOA detection, and lead to better healthcare outcomes for patients. Specifically, researchers could investigate methods to increase the diversity and size of the training dataset, fine-tune pre-trained models, develop interpretable models, integrate multi- modal data, and monitor disease progression in real-time using wearable devices. These efforts could contribute to a better understanding of KOA and enable clinicians to provide earlier and more effective treatments for patients.

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