RESEARCH ARTICLE　　　　　　　　　　　　　　　　　　　　　　　**OPEN ACCESS**

AUTOMATED KNEE DEGENERATIVE ARTHRITIS REPORTS GENERATION THROUGH VISUAL DATA ANALYSIS

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ABSTRACT

Knee degenerative arthritis is a common medical condition that affects the knee joint.Knee Degenerative arthritis causes major disability in patients all over the world. The computerized reporting procedure requires effort and expertise. Manual diagnosis, segmentation of knee joints are still used in clinical practice. Manual diagnosis of this disease involves observing X-ray images of the knee area and classifying it under five grades using the Kellgren – Lawrence (KL) system. Despite the fact that they are time-consuming and sensitive to user variance. As a result, we have the proposed system employing the CNN model with Computer Vision to increase the clinical workflow efficiency and overcome the constraints of the generally used method. We can also implement the report generation system that generates medical reports based on X-ray image features. By extracting the relevant features such as joint space narrowing, and cartilage degeneration, the system generates detailed and objective reports.

INTRODUCTION

This study explores the creation of an automated system using visual data analysis to generate reports for patients with degenerative arthritis in the knee. Our method uses Convolutional Neural Network (CNN) methods to classify knee images into different stages of degeneration with great accuracy. Specifically, we use pre-trained models that include Inception. Additionally, we present a novel framework that utilizes exception reporting and CNN-based classification to generate detailed and informative diagnostic reports based on the stages of knee degeneration that have been observed. CNN algorithms have become more common for medical image analysis because of the ability to automatically extract complex information from images, allowing for accurate diagnosis and classification. Our method takes use of the abundance of learnt information by using pre-trained models like Inception, which are trained on large datasets, improving its ability to discern between normal and degenerative knee joints. The suggested model uses a multi-stage classification method to group knee photos into different phases of degeneration, which makes it easier to comprehend how a disease develops over time. Despite the fact that they are time-consuming and sensitive to user variance. As a result, we have the proposed system employing the CNN model with Computer Vision to

increase the clinical workflow efficiency and overcome the constraints of the generally used method. We can also implement the report generation system that generates medical reports based on X-ray image features. By extracting the relevant features such as joint space narrowing, and cartilage degeneration, the system generates detailed and objective reports. CNN algorithms are growing increasingly popular for medical image analysis because of their ability to automatically extract complex information from images, enabling accurate diagnosis and classification. Our method takes advantage of a great deal of gained data by using pre-trained models like Inception, which are trained on large datasets, increasing its ability to differentiate between normal and degenerative knee joints. In addition, the suggested framework uses a multi-stage classification method to organize knee photos into various stages of degeneration, which makes it easier to understand as a disease progresses over time. Our method offers providers with a significant insight into the severity and degree of knee degeneration.Also, the efficiency and relevance of reports are enhanced by the addition of exception reporting in the report generating process. Our approach focuses on abnormalities in knee joint morphology and identifies deviations from the norm to produce brief overviews that prioritize discoveries that are clinically significant. This helps to improve diagnostic accuracy and simplify the interpretation of images.
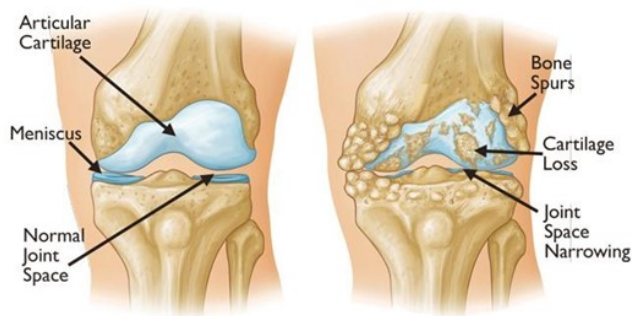
Figure 1. Classification of Knee Image

Using CNN algorithms for image classification and exception reporting based on multi-stage knee degeneration evaluation, this research study concludes with an innovative approach to automated knee degenerative arthritis reports creation using visual data analysis. Our approach provides an achievable way of quickly and accurately detecting knee arthritis through the use of deep learning and computer vision technologies, which will ultimately lead to improved patient outcomes and healthcare delivery.

MATERIALS AND METHODS

Problem Statement: Knee degenerative arthritis is common and has an enormous adverse effect on people's quality of life, radiologists' personal assessments and manual analysis of medical images are still an important part of the diagnostic process. This method takes a long time and is prone to errors and inconsistencies, which might delay diagnosis and result in poor treatment outcomes. The lack of standardized reporting systems makes it more difficult for healthcare providers to communicate with one another making it more difficult to trace the progression of condition over time.

Objective of the Project: The objective of this research project is to utilize Convolutional Neural Network (CNN) methods, particularly leveraging pre-trained models like Inception for image classification, to develop and evaluate an automated system for knee degenerative arthritis identification and reporting. By developing multi-stage classification with exception reporting methods, this system aims to accurately classify knee images into various stages of degeneration and produce detailed diagnostic reports. In order to improve patient care and healthcare delivery, the research aims to assess the performance of the proposed system in terms of classification accuracy, report generation efficiency, and clinical utility. Ultimately, the goal is to enhance the efficiency, consistency, and reliability of knee arthritis diagnosis and management.

Scope of the Project: The scope of the project involves developing, implementing, and assessing an automated system for reporting and detecting knee degenerative arthritis, with a special focus on visual data analysis through CNN algorithms. The study includes the investigation of pre-trained models such as Inception for imageclassification, with a focus on the classification of knee pictures into various phases of degeneration. The scope also includes creating a system that combines exception reporting and multi-stage classification to produce meaningful diagnostic reports.

Dataset: This dataset contains knee X-ray data for both knee joint detection and knee KL grading. The Grade descriptions are as follows: Grade 0: Healthy knee image.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, with mild sclerosis.Grade 4 (Severe): Large osteophytes, significant joint narrowing, and severe sclerosis.

Literature Survey: Kotti et al. [1] proposed a framework to compute the likelihood and degree to which a subject may have knee OA focusing on generic subject attributes (like age, sex, assessment of the

Knee Injury, Osteoarthritic Outcome Score (KOOS)) and kinematic data derived during a gait cycle to automatically classify and diagnose knee.

- Brahim et al. [2] proposed a computer aided diagnosis (CAD) system for early knee OA detection using knee X-ray imaging and machine learning algorithms.
- Dempster–Shafer theory of evidence, linear discriminant analysis and nearest neighbor classifiers.[3] proposed a fuzzy decision tree-based SVM (FDT-SVM) classifier to distinguish NL from OA knee gait patterns and investigate OA severity.
- Jose G et., al. [4] considered the case analysis and carried out on the basis of public available data from participants in the Osteoarthritis initiative analysis. There were two kinds of radiological grades used in this case study, the first is a quantitative score and the second is a semi-quantitative score, with radiological results evaluated by two classes of radiologists. To determine the future pain associated variables, A univariate logistic regression test was performed.
- Pedoia *et. al.* [5] used MRI and biomechanics multidimensional with aim to set up a multidimensional platform for improving OA outcome prediction and patient sub stratification. This approach was the first, which provided large-scale integration of compositional imaging and skeletal biomechanics.

METHODOLOGY

Proposed System: The proposed system uses computer vision and Convolutional Neural Networks (CNN) for image analysis and for report generation. In this system, CNNs are used to extract features from knee joint images, enabling the detection and classification of arthritic abnormalities. These extracted features are then fed into models that generate detailed medical reports in a contextually relevant manner. The computer vision and CNN technology not only accelerates the diagnosis process but also reduces the potential for human error, ultimately enhancing the quality of care and improving patient outcomes in the management of knee degenerative arthritis. The generated reports are not only accurate but also follow a logical flow.

Workflow of Proposed System
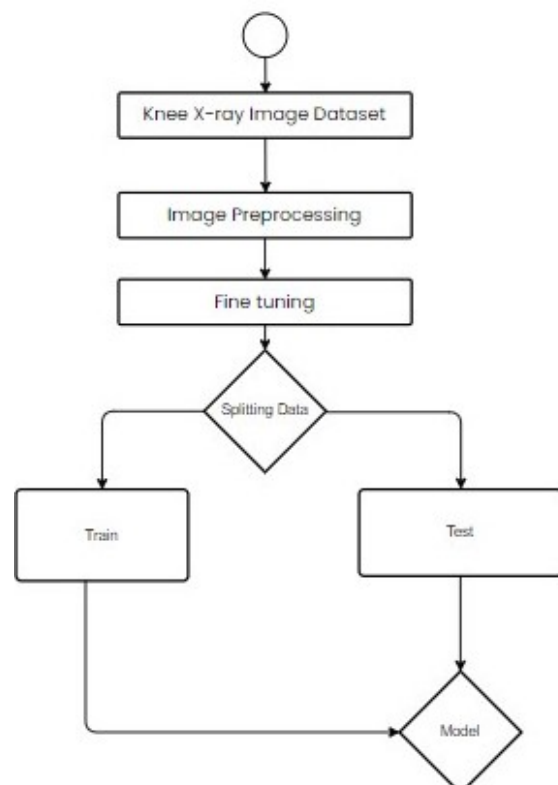
Data Collection: Collect an extensive set of knee joint images from include various stages of degenerative arthritis. To enable supervised learning for model training, ensure that the dataset has annotated labels that defines each knee image's stage of degeneration.

Image Preprocessing

- To enhance the quality and consistency, organize and preprocess the collected knee images using methods including noise reduction, and normalization.
- Use augmentation methods like rotation, flipping, and scaling to expand the dataset's uniqueness and stability.

Model Selection:

a) **Inception –V3** is a architecture of convolutional neural network (CNN) that was developed by Google researchers by combining convolutional layers with various filter sizes to collect features at different scales, it is intended to increase the efficiency and accuracy of image classification tasks. Each module in the Inception v3 architecture is made up of a number of convolutional layers, pooling layers, and other types of layers. These modules are set up in a hierarchy, with lower-level modules concentrating on the capture of low-level features like edges and textures and higher-level modules concentrating on the capture of more complex features like object components and complete objects.

b) **Xception:** Xception, short for "Extreme Inception," is a convolutional neural network architecture proposed by François Chollet in 2017 as an advancement over the Inception architecture. It is designed to achieve better performance and efficiency by introducing a novel approach called depthwise separable convolutions. Xception follows the same fundamental idea as the Inception architecture, which involves extracting features at multiple spatial scales using convolutional filters of different sizes. However, instead of using traditional convolutional layers, Xception employs depthwise separable convolutions.

Determining the knee severity using CNN: Using Convolutional Neural Networks (CNNs), a sort of deep learning algorithm which can automatically extract information from medical images, where we provide a novel method to determine the severity of Degenerative arthritis in the knee. We train and evaluate a CNN model for automated knee severity classification using a dataset of knee radiographs annotated with OA severity levels. By providing an efficient and objective method to determine the severity of knee degenerative arthritis, the suggested approach expects to improve patient outcomes and healthcare efficiency.

Classification of Knee using features extracted from pre-trained CNNs: Using features obtained from pre-trained CNNs, particularly Inception v3 and Xception, we provide an innovative strategy for knee OA severity classification in this research work. Our method begins by fine-tuning the images of OA severity using a dataset of knee images labeled with severity grades. From which, we extract meaningful representations of knee joints by extracting high-level features from the trained CNNs.

Fine-tuning the CNNs for classification and report generation: We introduce an approach for fine-tuning CNNs using Inception v3 and Xception for knee OA severity classification and automated report generation. The first step in our process is to improve the pre-trained CNNs using a collection of knee images that have been labeled with severity grades. We modify the CNN models to efficiently divide knee images into severity categories by iterative optimization, using transfer learning. Inception V3 is used to classify the Knee image and Xception is used to generate reports based on 5 stages of knee degenerative Arthritis.

Model Evaluation: We evaluate the effectiveness of the fine-tuned CNNs for knee OA severity classification using popular evaluation requirements such as accuracy, precision, recall, and F1-score. Precision quantifies the percentage of true positive predictions among

all positive forecasts, whereas accuracy quantifies the percentage of correctly classified occurrences. Recall, which is a sensitivity measure as well, counts the number of true positive predictions out of all the real positive cases. The harmonic mean of precision and recall, or F1-score, offers a fair evaluation of a classifier's performance. Inception V3 has provided the model evaluation with accuracy of 83% which Classifies the knee image with other images.
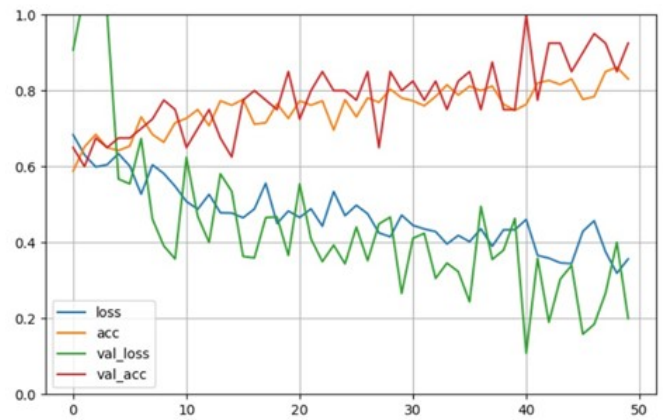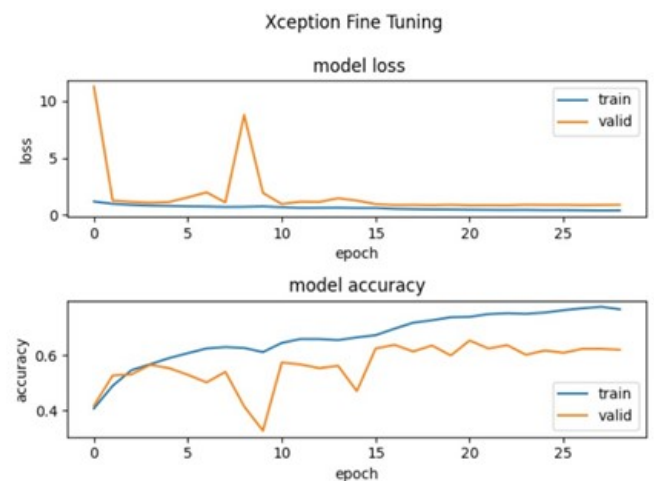

Figure 1. Model Evaluation for Classification of knee Images using Inception V3

Model loss and Model accuracy which are two fundamental metrics used to evaluate the performance of a trained model, using Convolutional Neural Network (CNN), for tasks like knee degenerative arthritis severity classification.

Categorical cross-entropy loss is a popular loss function for classifying the severity of degenerative arthritis. The difference between the true distribution of class labels and the expected probability distribution over classes is measured by this loss function. When data with high confidence are misclassified, the model is penalized more severely by the categorical cross-entropy loss.

	precision	recall	f1-score	support
0	0.73	0.80	0.76	328
1	0.36	0.36	0.36	153
2	0.69	0.56	0.61	212
3	0.70	0.74	0.72	106
4	0.81	0.96	0.88	27
accuracy			0.65	826
macro avg	0.66	0.68	0.67	826
weighted avg	0.65	0.65	0.65	826

The Model Evaluation using Xception pre trained model provide the accuracy of 65% with classification of knee images into 5 stages and

also generates the reports based on the severity of knee and by using grad cam visualization the knee degenerative arthritis is observed and evaluated.

GRAD-CAM Visualization: Gradient-weighted Class Activation Mapping (Grad-CAM) is a visualization technique that highlights the regions of input images most relevant to the model's predictions, generating heatmaps that improve the understanding of CNN models.

Users are able to better understand and have belief in the model's decision-making process by using Grad-CAM. Furthermore, the understanding of the model's predictions is evaluated by qualitative analysis of Grad-CAM heatmaps. We verify the indicated regions of interest's clinical importance by comparing the heatmaps with ground truth labels. We recommend using optimized CNN models to include Grad-CAM visualization into the knee OA severity classification process.
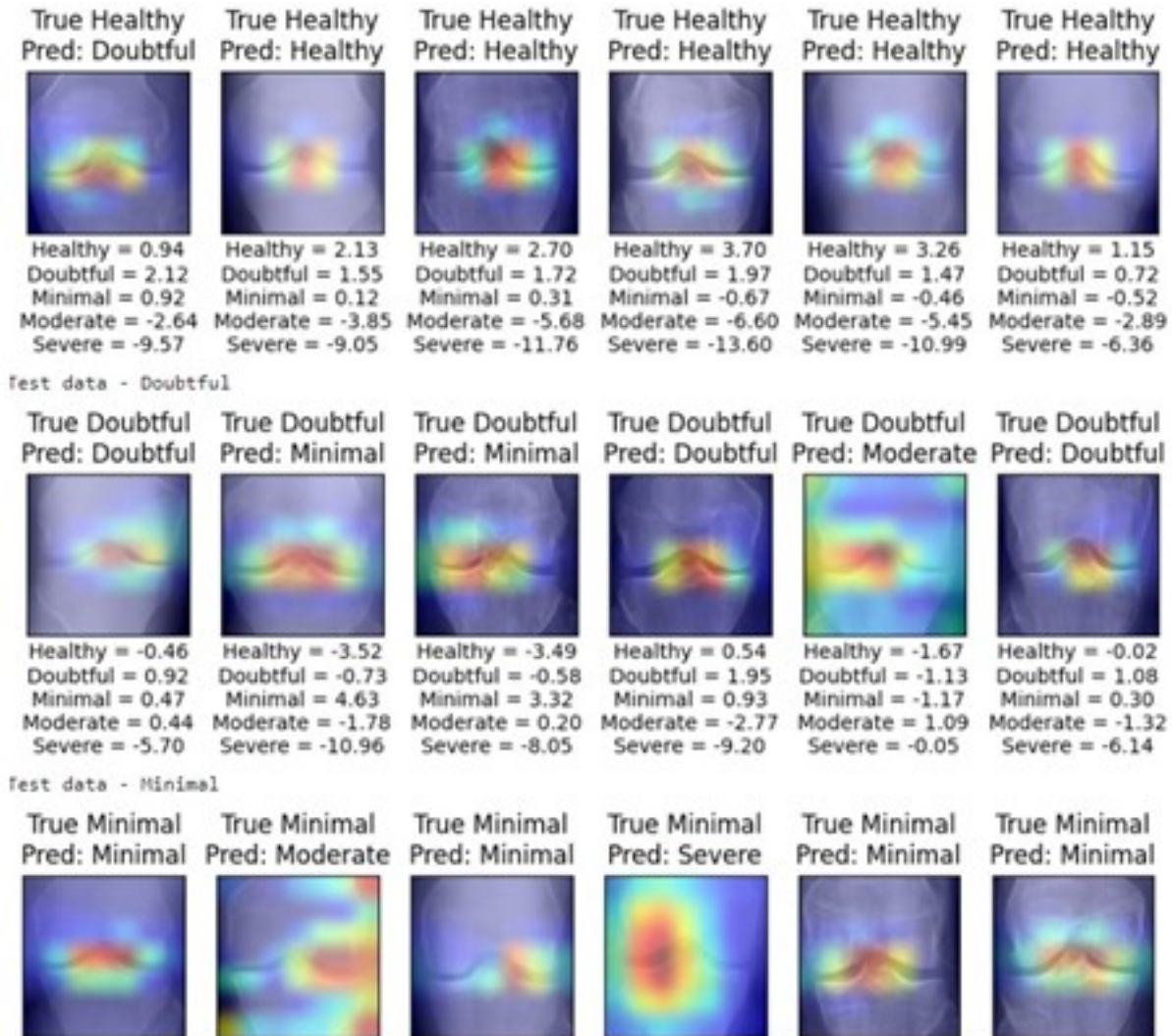
RESULTS

A. Detection of Knee Images

Test case no	Test Data	Expected outcome	Actual Outcome	Pass/Fail
1	A set of knee X ray images with Normal or degenerative arthritis	The model accurately identifies the knee images	If the image is not Knee image then it classified the image into not knee.	It produce Pass. If not Fail
2	A set of knee X ray images with Normal or degenerative arthritis	The model accurately identifies the knee images	If the image is Knee image then it classified the image into knee.	It produce Pass. If not Fail

B. Reports Generation Based on Classification of Knee Images into 5 grades

Test case no	Test Data	Expected outcome	Actual Outcome	Pass/Fail
1	A set of knee X ray images with classification based on 5 grades	The model accurately identifies the knee images	The image is classified into normal stage[class_0]	It produce Pass. If not Fail
2	A set of knee X ray images with classification based on 5 grades	The model accurately identifies the knee images	The image is classified into doubtful stage[class_1]	It produce Pass. If not Fail
3	A set of knee X ray images with classification based on 5 grades	The model accurately identifies the knee images	The image is classified into minimal stage[class_2]	It produce Pass. If not Fail
4	A set of knee X ray images with classification based on 5 grades	The model accurately identifies the knee images	The image is classified into moderate stage [class_3]	It produce Pass. If not Fail
5	A set of knee X ray images with classification based on 5 grades	The model accurately identifies the knee images	The image is classified into severe stage[class_4]	It produce Pass. If not Fail

Following the CNN model's training on knee images labeled with severity grades, we use Grad-CAM to produce heatmaps that highlight the input images with particular regions. By using Grad Cam Visualization we have evaluated and provides the regions where the knee has effected and produced reports based on the images. THE Report Generation is based on the Grad-Cam Analysis. By using Grad cam Visualization the Knee images categorized into 5 stages where the area of knee is effected and also identified.

CONCLUSION

In Conclusion, the application of the Inception v3 architecture to knee image identification is an important improvement in the area of medical imaging analysis. Our research has demonstrated that the model can distinguish knee images from non-knee images with impressive accuracy through testing and validation. This capacity has significant implications for clinical practice and offers an achievable way to speed up diagnostic procedures and improve the effectiveness of medical image analysis. The Inception v3 model has been successfully implemented, demonstrating its ability to transform healthcare delivery and give physicians useful tools to improve decision-making and enhance patient outcomes. Also,the use of the Xception model to provide reports for knee images that are categorized into five severity levels and combined with Grad-CAM visualization is an important step in the area of medical imaging analysis. Our research demonstrated the extent to which the model performs in classifying knee images and offers helpful details about the severity of osteoarthritis. Clinicians may enhance trust and confidence in diagnostic assessments by obtaining clarity into the model's decision-making process through the use of Grad-CAM visualization.

Future Scope: The Previous studies have assessed their algorithms using binary and multi-class classification metrics. We propose that it is more suitable to treat KL grades with Grad-cam analysis to generate reports on knee degenerative arthritis. Future work will focus on Simplifying the integration of AI-driven diagnostic tools into clinical workflows might be achieved by integrating the established models into the current EHR platforms. The project's future scope involves examining multimodal learning strategies, federated learning frameworks, ensemble learning methodologies, and advanced deep learning algorithms to improve knee image analysis systems' scalability, interpretability, and accuracy. The effort can further advance the study of medical imaging and the delivery of more efficient and personalized healthcare services by adopting such opportunities for research and development.

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