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**Knee Osteoarthritis Detection Using Machine Learning on Preprocessed X-ray Images.**

Group 18 Literature Review Document by

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# Introduction

Osteoarthritis is one of the most common forms of arthritis, which affects several people worldwide. This mostly occurs on the joints of hands, knees, hips and spine. This project focuses on osteoarthritis that occurs in knees. Studies show that more than 80% of adults over 55 years of age suffer with this disease ([Clinic, 2023](#35nkun2)). There are several ways to detect osteoarthritis in knees, this project focuses on detecting it from x-rays. The purpose of this project is to computerize the detection process. To implement this, this project uses four AI components to simplify and increase efficiency of the system. The components used in this project are CNN- Based Knee Region Extraction, Binary Classification for Osteoarthritis Detection, Decision Trees for Severity Classification and Random Forest based System for Treatment Recommendation. This system will not only detect osteoarthritis in knee, but also recommend suitable precautions and treatments according to the severity of the disease.

# Relevant Work

## CNN- Based Knee Region Extraction

Osteoarthritis occurs in the joints of hands, knees, hips and spine. Our system focuses on detecting Osteoarthritis on knees only. Therefore, this model will be used to check if the x-ray input into the system is of a knee. This model also focuses on feature extraction and improving the quality of the x-ray to allow the other models to work smoothly.

After the x-ray is uploaded it needs to be preprocessed before the data can be retrieved.to accomplish this in research done by [Zebari, Sadiq and Sulaiman](#kix.ompwl1fr433j) ([2022](#kix.ompwl1fr433j)). They have used a filter named Finite Impulse Response (FIR) which enhances the quality of knee trabecular texture.

Although we try to make every x-ray image consistent, it can vary from patient to patient, which causes the joint position of each x-ray to be different. To overcome this, research done by [Joseph, Kevin, Kieran, Noel (2017)](#kix.dcg9i34bhrjs) have used a fully convolutional neural network to detect ROI(region of interest) knee joint in a knee x-ray. They use a model which consists of 4 stages of convolutional layers followed by a max pooling layer, which allows to increase the clarity and quality of the x-rays.

Then we use CNN for feature Extraction in order to get the needed information from the knee x-ray. In the research done by [Zebari, Sadiq and Sulaiman(2022)](#kix.ompwl1fr433j) they also have used 2 dimensional CNN like most of the researches in this field. This architecture has multiple convolutional layers which take the image as input and the filters are performed on it. Among the several CNN feature classifiers used, KNN classifiers had the highest accuracy of 90.10%.

Also it is important to note that another research done by [Joseph, Kevin, Kieran and Noel(2016)](#ytsw9b3htxmt) used linear SVM and Sobel horizontal image gradings in order to detect knee joints which helps with diagnosing osteoarthritis. They also have used pre-trained CNNs for feature extractions on knee x-rays.

Another research done to compare theaccuracy between the machine and the surgeon by Schwartz et al., ([2020](#2tcz1yg5ajws)) states, CNN models were used to read x-rays. This shows us CNN data extraction decisions were more related to a surgeon’s decision.

This model allows us to confirm if the x-ray entered into the system is an x-ray of a knee joint, as our system focuses only on knee osteoarthritis detection.

## Binary Classification for Osteoarthritis Detection

After the X-ray uploaded into the system is confirmed to be an X-ray of the knee joint, this model is used to determine if the knee in the x-ray is normal or is affected by osteoarthritis. Since the outcome will be one of two possible results, a binary classification model has been used for this purpose.

Many researchers have used binary classification for this same purpose as well. According to research conducted by [Tariq, Suhail and Nawaz (2023)](#2s8eyo1) many researchers have combined the different grades of osteoarthritis (KL classes) of a dataset to make two classes and use this as a dataset to conduct binary classification. An example used to prove this is [Bayramoglu et al. (2020)](#17dp8vu)  divided their dataset into two classes and used a Logistic Regression classifier to conduct the classification. Furthermore, it is recorded in this research that six experiments were performed to determine the best model. The experiments were conducted by a Linear Support Vector Machine model, Logistic Regression model, Stochastic Gradient model, Perceptron, K Nearest Neighbors, Artificial Neural Network-based Multi-layer Classifier. After testing and validating, it was proven that the Logistic Regression had a higher accuracy in comparison to other models. The accuracy average was 84.5% ([Tariq, Suhail and Nawaz, 2023](#2s8eyo1)).

The research conducted by [Abdo et al. (2022)](#3rdcrjn) showed that there was excellent accuracy when using binary classification. In the two datasets used in this scenario, the binary classification model produced an accuracy of 83.50% and 85.50% respectively. [Sameh Abd El-Ghany, Elmogy and A. A. Abd El-Aziz (2023)](#26in1rg) used DenseNet169 to propose a model and compared it to the five Deep Learning approaches, which were InceptionV3, Xception, ResNet50, DenseNet121 and IndceptionResNetV2. Here, when training, the dataset was divided into two classes, one with osteoarthritis and one without osteoarthritis. Finally, they concluded that in binary classification, DenseNet169 had an accuracy of 93.78% and a F1-score of 89.27%. Another study by [Sozan Mohammed Ahmed and Mstafa (2022)](#lnxbz9) mentions that the primary focus of the study in classifying knee osteoarthritis was binary classification. Here, they too determined if the x-ray of the knee joint was normal or if it was affected by osteoarthritis. For this scenario, they proposed a DHL-II model and it generated an accuracy of 90.8% and an F1-score of 90.5% respectively.

It is important to note that all the above-mentioned research used several other models other than binary classification as well. However, as per this feature’s necessity, which is to only detect if the knee bone is normal or not, only the research regarding the use and accuracy of the binary classification model has been included in this section. The purpose of this feature is to reduce complexity when it comes to treatment and precaution recommendation. If the bone is normal, the system will directly access the model which will suggest precautionary measures ([2.4](#_tyjcwt)), however, if the knee is suffering with osteoarthritis, it will access the model which will determine the severity of the disease ([2.3](#_2et92p0)) first and then direct to ([2.4](#_tyjcwt)) to get treatment recommendations.

## 2.3 Decision Trees for Severity Classification

Decision trees is a machine learning approach which is popularly used in diagnosing knee osteoarthritis. It is used to predict the severity of osteoarthritis of patients by following the Kellgren-Lawrence Classification System.

There are many researches which have used decision trees for osteoarthritis. The research conducted by [Saman Shahid, Aatir Javaid(2022)](#qv0tuh8aiosq) showed that the decision model can predict joint pain in clinical variables and also was found that uric acid showed a positive correlation with joint pain. They created a classification decision tree model by using the decision tree rule, which separated the data into many categories in both classification and regression to reduce error as much as possible. The model performed well with an accuracy of 94% and proved that early diagnosis of joint pain through artificial intelligence will help reduce more orthopedic issues.

In another research conducted by [S.S. Gornale, P.U. Patravali, P.S. Hiremath (2020)](#jdx5w6a9zvem), showed that another classifier called K-NN performs better than the decision tree classifier. The classification accuracies were evaluated using cross-validation and are compared with expert opinions. The results from K-NN and decision tree undergo Chi-square test and t-test and are evaluated to find the agreement between the method findings and annotations of the experts. The accuracies of one expert using K-NN and decision tree were 99.80% and 95.75%.

A research which obtains their data through gait analysis is done by [Nigar Şen Köktaş, Neşe Yalabik, Güneş Yavuzer, Robert P.W. Duin (2010)](#hove4jndwlsd). Best six Gait parameters are selected using the Mahalanobis Distance algorithm and are used to create input vectors for multilayer perceptrons(MLP) at the end of the decision tree. By combining the decision tree and expert MLPs only 80% success rate is achieved.

Another research carried out by [Mezghani, M.; Hagemeister, N.; Ouakrim, Y.; Cagnin, A.; Fuentes, A.; Mezghani, N. (2021)](#zabdqmq4a5pt) predicts the impact of physical exercise program on knee osteoarthritis patients. The data for this research was collected in a cluster randomized controlled trial(RCT). They used the Classification and regression tree (CART) algorithm to build their decision tree. Two cross validation systems were used to evaluate the classification system, one being the K-fold cross validation and the other being Leave-one-out cross validation (LOOCV). The prediction accuracy when both sexes were taken together was up to 71% whereas when they were separated gave a rate of 84.4% for men and 75.5% for women.

## 2.4 Random Forests Based System for Treatment Recommendation

After confirming the grade of the disease from the relevant x-ray, this model is used to recommend treatments and precautions. Random forests will be used to implement this recommendation system.

Many researchers have used random forests for different sectors. According to the research conducted by [Nagaraj p et al (2022)](#e26ep49q7z1p) a random forest generates accurate predictions that are simple.. In comparison to the decision tree method, the random forest algorithm is more accurate at predicting outcomes. To prove that [Nagaraj p et al (2022)](#e26ep49q7z1p) has done research on the diabetes disease using the Mendeley dataset. The experiments were conducted using grid search, XG boost, and random forest. After testing it was proven that the random forest has the highest accuracy with 98% and 93% for the precision. [S. S. Bhat and G. A. Ansari (2021)](#zhcbpp5nmv2x) also has done similar research on diabetes treatment recommendation systems.

The research conducted by [Kevin Doubleday,Jin Zhou, Hua Zhou, Haoda Fu (2021)](#gtjxne93v21o) has done a comparison on the random forest and decision trees. The work proposed two methods of risk controlling such as a risk-controlled decision tree (RCDT) and risk controlled random forests (RCRF). In this experiment they have categorized the research into 5 categories. In the discussion of this research, they have concluded that the random forest model is the safest and easiest to understand with an accuracy of 92.1%, and the decision tree with a 86.4% accuracy. This work contributes to deciding proper treatment rules based on both efficiency and risk considerations.

The research conducted by [Kevin Doubleday et al (2018)](#t9jlte8pcmfk) has mainly focused on treatmenting diabetes disease using decision trees and random forest models. Here, they have proven that the random forest model can do the treatment for subcategories as well. They have categorized their dataset into sections as A.1, A.2, B.1, B.2, C.1, C.2. Accuracy for each level is concluded as 99.7%, 86.3%, 99.7%, 86.5%, 94.3% respectively.

In conclusion this treatment recommendation system is used to treat each and every level of osteoarthritis. It also includes that this system provides precautions for the non-diseased knees as well.

# Comparison Table of Relevant Work

| Research | Author | Year | Dataset | Model Used | Metric |
| --- | --- | --- | --- | --- | --- |
| CNN-Based Knee Region Extraction | | | | | |
| Automatic Detection of Knee Joints and Quantification of Knee Osteoarthritis Severity Using Convolutional Neural Networks | Joseph Antony,  Kevin McGuinness,  Kieran Moran,  Noel E. O’Connor | 2017 | bilateral PA fixed flexion knee X-ray images from the Osteoarthritis Initiative (OAI) and Multicenter Osteoarthritis Study (MOST) in the University of California, San Francisco | CNN, FCN | CNN accuracy  63.4% |
| Knee Osteoarthritis Detection Using Deep Feature Based on Convolutional Neural Network | Dilovan Asaad Zebari,  Shereen Saleem Sadiq,  Dawlat Mustafa Sulaiman | 2022 | from well-known local hospitals and health centers to evaluate, including 2000 computer-generated knee X-rays | CNN,SVM,  KNN | 90.01% Accuracy |
| Quantifying radiographic knee osteoarthritis severity using deep convolutional neural networks | Joseph Antony,  Kevin McGuinness,  Kieran Moran,  Noel E. O’Connor | 2016 | bilateral PA fixed flexion knee X-ray images, taken from the baseline (image release version O.E.1) radiographs of the Osteoarthritis Initiative (OAI) dataset containing an entire cohort of 4, 476 participants | a linear SVM and the Sobel horizontal image gradients as the features for detecting the knee joint centers.  CNN for assessing the severity of knee OA through classification and regression. | a linear SVM produced 95.2% 5-fold cross validation and 94.2% test accuracies. |
|  |  |  |  |  |  |
| Binary Classification for Osteoarthritis Detection | | | | | |
| Machine Learning Approaches for the Classification of Knee Osteoarthritis | Tayyaba Tariq, Zobia Suhail, Zubair Nawaz | 2023 | OsteoArthritis Initiative (OAI) | SVM, LR, SGD, KNN, MLP, Perceptron | LR accuracy (most accurate model): 84.5% |
| Estimating the severity of knee osteoarthritis using Deep Convolutional Neural Network based on Contrast Limited Adaptive Histogram Equalization technique | Amina A. Abdo, Wafa El-Tarhouni, Asma Fathi Adbulsalam, Abdelgader Bubaker Altajori | 2022 | Knee Osteoarthritis severity grading dataset (Dataset I)  Osteoarthritis Initiative (OAI) (Dataset II) | Binary Classification | Dataset I: 83.5%  Dataset II: 85.5% |
| A fully automatic fine tuned deep learning model for knee osteoarthritis detection and progression analysis | Sameh Abd El-Ghany, Mohammed Elmogy, A. Abd El-Aziz | 2023 | OsteoArthritis Initiative (OAI) | DenseNet169, InceptionV3, Xception, ResNet50, DenseNet121, InceptionResNetV2 | DenseNet169 (most accurate model): Accuracy: 93.78%  F1-score: 89.27% |
| Identifying Severity Grading of Knee Osteoarthritis from X-ray Images Using an Efficient Mixture of Deep Learning and Machine Learning Models | Sozan Mohammed Ahmed, Ramadhan J. Mstafa | 2022 | OsteoArthritis Initiative (OAI) | DHL-II | Accuracy rate: 90.8%, Average F1-score: 90.5% |
| Decision Trees for Severity Classification | | | | | |
| Application of Machine Learning Decision Tree in Diagnosing Joint Pain | Saman Shahid, Aatir Javaid | 2022 | Patients from the orthopedic department of Mansoorah Hospital Lahore, Pakistan | Decision tree | Accuracy (94%), Validation Accuracy (96.46%) |
| Automatic Detection and Classification of Knee Osteoarthritis Using Hu's Invariant Moments | S.S. Gornale, P.U. Patravali, P.S. Hiremath | 2020 | 2000 digital knee X-ray images. Can be found in Gornale and Patravali (2020) | Hu's invariant moments, and classification using K-NN and Decision Tree classifiers. | K-NN Classifier Accuracy (Expert I): 99.80%  Decision Tree Classifier Accuracy (Expert I): 95.75 |
| 3D Kinematics and Decision Trees to Predict the Impact of a Physical Exercise Program on Knee Osteoarthritis Patients | Mezghani, M.; Hagemeister, N.; Ouakrim, Y.; Cagnin, A.; Fuentes, A.; Mezghani, N. | 2021 | Cluster randomized controlled trial (RCT) approved by the institutional ethics committees of the University of Montreal Hospital Research Center | Classification And Regression Tree (CART) algorithm | For males: Using a 10-fold validation, accuracy 84.4%.  For females: Using a 10-fold validation, accuracy 75.5%. |
| A multi-classifier for grading knee osteoarthritis using gait analysis | Nigar Şen Köktaş, Neşe Yalabik, Güneş Yavuzer, Robert P.W. Duin | 2010 | Computerized gait analysis | Decision tree with Multilayer Perceptrons (MLP) at the leaves | Accuracy: 80% |
| Random forest System for Treatment Recommendation | | | | | |
| Risk controlled decision trees and random forests for precision Medicine | Kevin  Doubleday, Jin Zhou, Hua Zhou, Haoda Fu | 2021 | DURABLE dataset | Decision tree and random forest | rcDT to 86.4% and rcRF was 92.1% |
| Ensemble Machine Learning (Grid Search &  Random Forest) based Enhanced Medical Expert  Recommendation System for Diabetes Mellitus  Prediction | Nagaraj P, Muneeswaran V, Muthamil Sudar K, Naga Vardhan Reddy A, Deshik G, Charan Kumar Reddy C | 2022 | Mendeley datasets | Grid search and random forest algorithms | accuracy of 98% |
| A Recommendation System for Diabetes Detection and Treatment | Fatima Almatrooshi, Sumayya Alhammadi, Said A. Salloum, Iman Akour, Khaled Shaalan | 2020 | TunedIT.org | random forest | 79.2% accuracy |
| An algorithm for generating individualized treatment decision trees and random forests | Kevin Doubleday, Hua Zhou, Haoda Fu and Jin Zhou | 2018 | IPWE and AIPWE | Decision trees and random forest | ITR for Scheme A.1 99.7%, A.2 86.3%, B.1 99.7%, B.2 86.5%, C.1 94.3% |

# Summary

The purpose of this project is to apply machine learning concepts on preprocessed knee x-rays to detect osteoarthritis. This project will first focus on increasing the clarity and quality of the x-rays uploaded into the system, in order to improve the accuracy of diagnosing osteoarthritis. This project will not only detect knee osteoarthritis, but will detect the degree of the disease and provide suitable treatment plans as well. Furthermore, this project also focuses on providing precautionary measures to normal knees. Several machine learning concepts such as CNN, Binary Classification, Decision Trees and Random Forests will be used to implement this project.

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Can a Convolutional Neural Network Classify Knee Osteoarthritis on Plain Radiographs as Accurately as Fellowship-Trained Knee Arthroplasty Surgeons?

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