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Knee Osteoarthritis Progression & Classification Using Cartilage Damage Index & Machine Learning Algorithms: A Literature Review

Sanjay S[1], Revathi S A[2]

[1]*Student, Department of Computer Science & Engineering, R V College of Engineering, Karnataka, India*
[2]*Affiliated to VT University, Belagavi, Karnataka, India*

Abstract - *Considering the population from all over the world, one of the most leading common diseases which is basically seen in elderly population and which is also one of the foremost causes of disability is osteoarthritis. Frequency rate of knee Osteoarthritis (OA) is mounting by growing average age of over-all population. Osteoarthritis is a condition that affects a person's joints, usually knees. Age, mass, disturbance to joint due to recurrence actions in particular crouching and kneeling are common risk factors of knee Osteoarthritis (OA). Numerous issues including cytokines, leptin, and mechanical forces are pathogenic features of knee Osteoarthritis (OA). Patients with knee pain, which is the main source of knee Osteoarthritis (OA) should be considered with carefulness. The proportion of people suffering from knee OA are asymptomatic and the number of victim's identification of knee Osteoarthritis (OA) is not likely due to low understanding of radiographic examination. In this review, exploration of unseen biomedical data from knee MR descriptions and classification can be seen and which will in turn be able to achieve the objective of determining the progression of the knee Osteoarthritis, and the data set is obtained from osteoarthritis initiative(OAI) which is required in order to implement this application, and one of the main methods used here is Cartilage Damage Index (CDI), and kellgren-lawrence (KL) grading system is also used for providing the progression on the disease.*

Key Words: Knee Osteoarthritis (OA), Cartilage Damage Index (CDI), Kellgren-Lawrence (KL), Machine Learning (ML), Magnetic Resonance Image (MRI).

1.INTRODUCTION

Taking the current population into consideration, 10% of them is been affected by symptomatic Knee Osteoarthritis (OA) who are generally over the age of 60. Also, Osteoarthritis affects countries socioeconomic growth as well. Osteoarthritis is the second most shared rheumatologic delinquent and it is the most common joint illness with an incidence of 22% to 39% in India. Knee Osteoarthritis (OA) is more mutual in women than men. Nearly 45% of females over the age of 65 years have symptoms while 70% of those over 65 years show radiological evidence of Knee Osteoarthritis (OA). Over 9.6% of men and 18.0% of women aged over 60 years have symptomatic osteoarthritis all over the world and according to World Health Organization (WHO), 80% of those with osteoarthritis have restrictions in movement, and 25% of them cannot achieve their main daily activities of life.

Once the cartilage loss in the knee joint has reached its final stage, no treatment or whatsoever is available to completely heal or cure. Surgeries and other treatments are available which can be conducted, but will only be used to reduce the pain occurred by knee Osteoarthritis (OA). Before going in depth to understand about this disease, three main parts is present in the knee which are femur, patella and the tibia as shown in the figure-1, and knee Osteoarthritis(OA) can occur in any of these three region, wherein lateral compartment which is the outer part of the knee, medial compartment which is present in the middle layer of the knee and patellofemoral being the inner compartment of the knee as shown in the figure-2.

Fig-1: Basic parts of knee **Fig-2:** Compartments of knee

Therefore, here, different methods and techniques is used to identify the progression and presence of the OA in the person joint and also a unique grading system to depict the level of cartilage loss is also acquired. Initially, to detect the presence of the knee osteoarthritis disease, plain radiographs were literally being used as the diagnostic tool for osteoarthritis. This imaging is widely used because of its accessibility and reasonable price. One of the few problems faced by the usage of plain radiographs is the accuracy that is been achieved to detect the same, and as it is a manual work, the time used and consumed to predict the presence of the disease is conventionally more. So, to reduce the time-consumption and to improve the detection accuracy of the disease, one of the techniques used is cartilage damage Index (CDI). Cartilage thickness is restrained by the Cartilage Damage Index (CDI) which comprises of 60 points manifested on 3D MRI for each knee joint, and one of the most used method of categorizing the severity of the

osteoarthritis (OA) is the Kellgren- Lawrence grade system which comes with the inclusion of the 5 grades.

2. LITERATURE REVIEW

Michael Antony Bowes.et.al [1], in this paper, they have mainly illustrated on the difference between manual prediction of cartilage thickness and the automatic prediction of the same. A training set of 379 patient's single knee MRI images is been collected, including medial & lateral compartment and kellgren-lawrence (KL), use as the grade prediction system. All the images in these analyses used the Dual Echo Steady State MRI Sequences. The next steps undertaken here was to select the region of comparison, the compartments that were focused here were the medial femur & central medial tibia. And soon after this, comparison of the mean thickness from each region between the result or data obtained from an already existing set of MRI images and automated segmentation was conducted. Next is the manual segmentation method, here the thickness of the cartilage was measured in the biomarkers image set, implementing the labor-intensive segmentation of the femorotibial cartilage exteriors led by skilled professionals. One of the techniques and algorithms used here was AAM technology and AQ-cart which was mainly used to gain information of the mean thickness of the cartilage. Now, implementing the AQ-cart, all the individual image present is automatically segmented using 3D's AAM (is a technique used to fit the shape and grey level variants of a training set to a 3D image) of bone and cartilage. Once this method is applied, initially, a low-density, low-resolution is fitted into the model but at the termination of this procedure, voxels confined in the cartilage area are allocated with a non–linear regression function. Here, cartilage thickness is basically measured by Anatomically Corresponded Regional Analysis of Cartilage (ACRAC).

Yaodong Du.et.al [2], in this study, initially, dataset is been taken from the Osteoarthritis Initiative (OAI), the main aim depicted in this paper is to apply a novel OA cartilage damage quantification technique which customs informative locations on the knee. The locations that are designated from areas on articular exterior where cartilage damage is less recurrent. Now, 3D surfaces of both femur and tibia is been depicted to find the most informative location. Next, to represents the exterior of the distant femur and proximal tibia, the 3D surfaces that were obtained previously will be converted into a 2D coordinate system. In an CDI method, a total of 60 informative location are present out of which in this paper only 36 of those location is been used which will be further divided into 18 informative location of medial and lateral compartment of the knee (for both femur and tibia) and the remaining 24 location are present within the patella. The next process is to measure the Cartilage Index Information (CDI), in this, the very first step is to identify the most medial and lateral MR image slices within the knee. Next, these obtained images entitles onto a 2D co-ordinate system, this CDI technique specifies the MR image slices that hold the informative location. The next step is to trace the boundary of each slice of bone-cartilage surface manually. Finally, the application developed computes the CDI score summing the cartilage thickness, cartilage length and voxel size. Now after acquiring the CDI score, kellgren-lawrence grading system is used to predict the severity level of the cartilage loss suffering from the knee OA. Now to convert the CDI scores which is compatible to apply onto the grading system, they have used certain machine learning algorithm namely, SVM, Random Forest, ANN to take up this mapping task between CDI score and OA severity and the algorithm which provides the most accurate result will be indeed be used at the end to perform the same.

Ming Zang.et.al [3], in this paper the main aim is to extract and classify all the hidden biomedical images present in the knee and also to predict the severity of the same. Most of the procedures used in this paper is similar to that of the above paper described [2]. The main difference that is identified between the two papers were that Principal Component Analysis (PCA) analysis (PCA is a technique for reducing the dimensionality of such datasets, increasing interpretability but at the same time minimizing information loss) was used for feature extraction. Also, four machine learning algorithms were used here which were ANN, Random Forest, Support Vector Machine and Naïve Bayes used to predict the progression of the OA. Along with kellgren-Lawrence (KL) grading system, Joint Space Narrowing on Medial compartment (JSM) grade and Joint Space Narrowing on Lateral compartment (JSL) grading systems were also used to achieve better results. Finally, the results shown that medial compartment deliver added unique features than informative locations on lateral compartment, which can also be measured to select additional points from the medial compartment which in turn lessen the amount of points from the lateral compartment to expand the experimental CDI design.

Rania Almajalid.et.al [4], the objective of this paper is to extract and classify all the hidden biomedical informative location that is present in the knee and also to predict the progression on severity of the knee OA. All the work that is been done here is similar to that of the above mentioned paper [2], but some of the difference between the two papers are instead of including only the 36 CDI informative location or points onto the feature extraction, the remaining 24 CDI informative point on patella is also included in the feature space and tested out whether these 24 points from patella would actually increase the accuracy on a much bigger dataset. Kellgren-Lawrence grading system is also used for predicting the severity of the cartilage loss and here only ANN is been used to achieve the feat of conversion from CDI score to applying onto the grading system.

3. RESULTS & DISCUSSIONS

Here, in this application, to attain the accurate results, the usage of all the 36-dimensional feature set is also needed to

be taken into consideration along with the comparison between 18-dimensional feature sets of both medial and lateral compartment. Now, given the present existing grade system which is the KL grade, along with this, a machine learning algorithm too is to be implemented and applied to attain the best prediction performance which will in turn be used as a mapping function amongst the CDI feature space and the OA severity denoted by the respective grade prediction system. Below, are the table displayed which gives a better understanding of which algorithm gives out the best performance when encountered with the usage of 18-dimensional feature set of medial and lateral compartment along with all the 36-dimensional feature set combined to provide us the final summary.

Table -1: Top performance of each of the four classifiers on 18 medial features for KL grade [3].

Classifier	PCA variance	Precision (PPV)	Recall	F1-Score	AUC
ANN	Top 20%	0.714	0.737	0.708	0.731
SVM	Top 70%	0.5	0.707	0.586	0.691
Random Forest	Top 65%	0.653	0.697	0.655	0.702
Naïve Bayes	Raw data	0.687	0.687	0.700	0.742

Table -2: Best performance of each of the four classifiers on 18 lateral features for KL grade [3].

Classifier	PCA variance	Precision (PPV)	Recall	F1-Score	AUC
ANN	85%	0.556	0.556	0.556	0.525
SVM	90%	0.5	0.707	0.586	0.548
Random Forest	Raw Data	0.6	0.677	0.612	0.594
Naïve Bayes	Raw Data	0.612	0.657	0.625	0.521

Table - 3: Top performance of each of the four classifiers on both medial and lateral features [3].

Classifier	PCA variance	Precision (PPV)	Recall	F1-Score	AUC
ANN	Top 55%	0.712	0.717	0.714	0.761
SVM	Top 65%	0.703	0.717	0.624	0.651
Random Forest	Raw data	0.681	0.717	0.660	0.677
Naïve Bayes	Top 20%	0.699	0.727	0.685	0.724

Therefore, by accessing the table-1 & table-2, we can conclude with the following points:

- By using KL grade system, medial informative location possesses more vital and unique data than lateral compartment.
- From the results that are shown in the table-1, Naïve Bayes has the high value of AUC of 0.742 which tells us that by implementing Naïve Bayes higher performance can be gained on an 18-dimensional medial feature set.
- From table-2, Random Forest yields high score with an AUC of 0.594 which depicts that by applying this algorithm, high performance and accuracy can be gained on an 18-dimensional lateral feature set.

Only when the 36-dimensional feature is used, a higher performance and accuracy can be seen even when compared with using only either 18-dimensional feature set of medial or lateral compartment. Therefore, according to table-3, when combined both 18-dimensional feature sets of medial and lateral compartment, the best performing classifier under 36-dimensional feature set is ANN, hence when this classifier is used, the expected results are surely to be achieved.

3. CONCLUSIONS

To finally conclude and summarize, there are lot of techniques which can be used to classify and predict the severity of the knee OA, but here, the best method that can be applied for predicting the severity of the knee OA would be to use CDI, as it provides the most accurate classification and extracts all most all of the hidden biomedical slices present in the knee which will help in achieving a better picture of the cartilage loss and also helps in providing the accurate quantified CDI scores. All these accuracy can only be achieved when we apply and utilize all the 60 CDI points present where in 36 points belonging to medial and lateral compartment with inclusion of both femur and tibia and the remaining 24 points of the patella being used during the feature space process which is the PCA analysis, that helps in attaining the extraction of best feature set possible and will in turn help in achieving a better result. Now for the classification purpose which is between the medial tibiofemoral and lateral tibiofemoral compartment of the Knee OA, different grade prediction system exists, which are Kellgren-Lawrence(KL) grade prediction, Joint Space Narrowing on Medial compartment (JSM) grade and Joint Space Narrowing on Lateral compartment(JSL) grad

prediction systems, out of which only KL grade prediction is to be used which is the standard measure used worldwide. Once the CDI score is obtained, a Machine learning algorithm is to use as a mapping function between CDI score and OA severity according to the grade prediction system used which in this case is the KL grade. Therefore, by analyzing the results produced by each ML classifiers from the table-1 and table-2, we saw that Naïve Bayes for 18-dimensional medial feature set and Random Forest for 18-dimensional lateral feature set were considered as high performance classifiers, but as said before, to obtain the best performance and most accurate results 36-dimensional set is be used. Hence, according to table-3, we can see that ANN is the best classifier that can be used to attain the expected results scoring an AUC of 0.761 [3]. Therefore, when all of the above techniques are used and implemented, the expected feat and result will be guaranteed.

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