

# A Survey on Exploration and Classification of Osteoarthritis Using Image Processing Techniques

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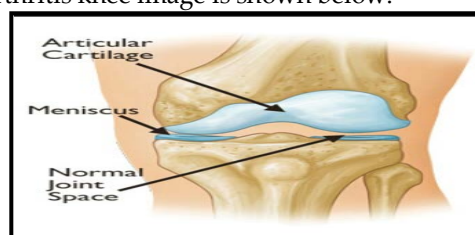
**Abstract:**-Osteoarthritis is one of the prime causes of infirmity in elderly and overweight people. Osteoarthritis is a joint disease that mostly affects the cartilage. Cartilage helps the easy glide of bones and obstructs them from rubbing each other. In Osteoarthritis cartilage is ruptured due to which bones rub each other causing severe pain. The current strategy for the evaluation of Osteoarthritis includes clinical investigation & medical imaging techniques. This paper introduces a survey focusing on the various medical imaging techniques for the assessment of Osteoarthritis. This paper also discovers the X-ray imaging & Magnetic Resonance imaging (MRI) techniques for detection and classification of Osteoarthritis in descriptive and comparative manner. Thus an integrated discussion of various segmentation techniques, feature extraction techniques and classification schemes regarding Osteoarthritis is done and surveyed in a scientific way

**Key Words:** Medical Imaging, X-ray, MRI, Osteoarthritis, Exploration techniques, classification, Image processing techniques

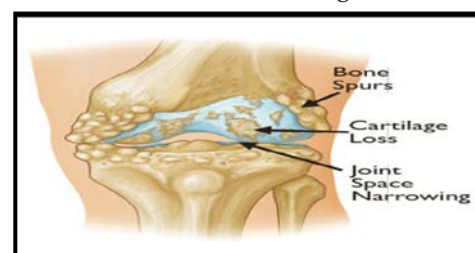
## 1. INTRODUCTION

Medical imaging [132][121][135][136] is the process of creating visual representations of the internal structures hidden by the skin and bones. It is the technique where we can reveal the interior of the body for clinical diagnosis and medical intervention [28]. It is the part of biological imaging and incorporates radiology which uses the imaging technologies of X-ray[67] [87] [92] [121] [126-130] [148] [153], Magnetic Resonance Imaging (MRI)[20][142][143], Ultrasound, Computed Tomography(CT) etc[18]. Osteoarthritis is one of the most common form of arthritis disease that is seen mostly in females [21][139], overweight and elderly people [2][5][27][110][146-150]. Osteoarthritis (OA) is a joint disease that mostly affects cartilage [2][15]. Cartilage is the protective connective tissue that covers the end of bones in a joint. Healthy cartilage allows easy glide of bone in the joint and prevents them from rubbing each other [12]. In Osteoarthritis the top layer of cartilage breaks down and wears away [140]. This allows the bones to rub each other causing pain [8][5][27][103]. It commonly affects the joint in the knee, hip, spine and feet. The most common cause of osteoarthritis of the knee is age. There are two types of

OA, Primary OA seen in aged people due to genetic reasons or aging. Secondary OA tends to show up earlier in life due to some injury, diabetes, obesity, athletics or patients with rheumatoid arthritis [27][28][110][162]. The sample of normal & affected Osteoarthritis knee image is shown below.



Normal Knee Image



Osteoarthritis Knee Image

The main symptoms of OA are pain and difficulty in joint motion, reduced function and participation restriction, Joint stiffness in the morning or after rest[160]. Currently evaluation of OA is based on clinical examination, symptoms [70][71][104][138] and simple radiographic assessment techniques (X-ray), MRI, CT etc. While several other methods have been proposed ,Kellgren-Lawrence (KL) system is validated method of classifying individual joints into 5 grades [1][24]. Table below shows the different grades of OA disease.

KL Grades	OA Analysis
Grade 0	No Radiographic features of OA present
Grade 1	Doubtful OA(narrowing of joint space)
Grade 2	Mild OA(definite narrowing of joint space)
Grade 3	Moderate OA (multiple osteophytes, sclerosis)
Grade 4	Sever OA ( large osteophytes, sever sclerosis, bone deformity)

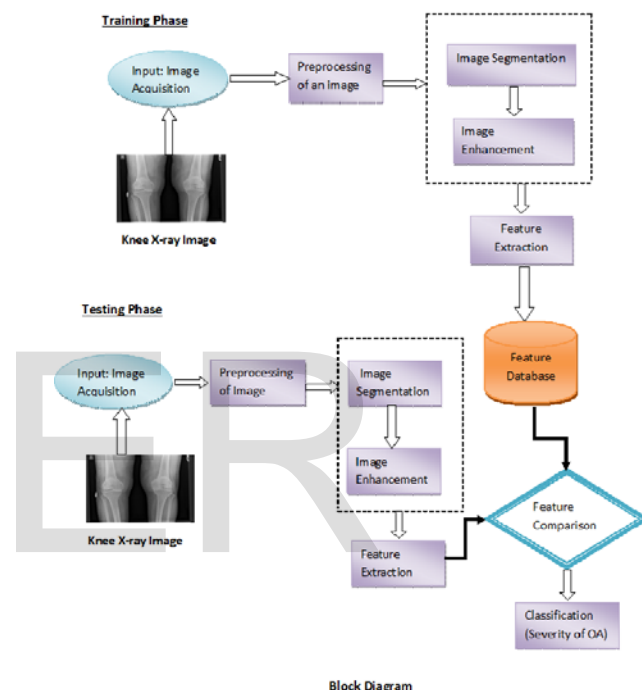
The common X-ray findings of OA include destruction of joint cartilage, joint space is diminished between adjoining bones [22][89][133][141] and bone spur formation [6][104][153][163]. MRI scans may be ordered when x- rays do not give clear reason for joint pain or when the x- ray suggests that other type of joint tissues can be damaged. The below sample image shows the knee anatomy of normal & affected OA[159].



The current methods used for clinical diagnosis of Osteoarthritis are not accurate enough to efficiently measure the quality & evolution of Osteoarthritis. Thus we require more significant methods & algorithms which are multi-factorial to access the parameters & progression of Osteoarthritis. In the rest of the paper, Section-2 describes the methodology for processing the images concerned to Osteoarthritis. Section-3 contains the review work related to medical imaging that includes different segmentation & feature extraction techniques used for the classification of Osteoarthritis based on X-ray imaging & Magnetic Resonance imaging. Finally conclusion along with challenges & future scope is made in Section-4 & Section-5 followed by qualitative references.

## 2 PROPOSED METHODOLOGY

Processing of the images to extract the features of interest in an automated way is an important task for varied applications. Any image under processing is subjected to the following steps below. The Pre-processing stage that enhances the quality of the image by restraining un- wanted distortions & highlight the data of interest. The feature extraction acquires the discrete components of the image under processing. The classification stage identifies the objects of image and groups according to the certain classes and helps in their efficient recognition.



**2.1 Image acquisition**[137] can be designated as the action of fetching an image from some source which is further processed to get new and better image [28][30].Some of the common devices used for retrieval of images are high resolution camera, image acquisition hardware, 2-D charged coupled device (CCD) camera etc.

**2.2.Pre-processing:**[82] [96] [97] [102] [136] [134] [137] [146] [147] enhances some important features relevant to understand the image. After collection of knee X-ray images, initially pre-processing techniques are used which are application dependent. Pre-processing enhances some important features by restraining undesirable distortions [30]. The distortions or noise in knee x-ray images are due to secondary radiation, film processing and handling and digitization. The noise in the knee x-ray images can be removed using filters like Gaussian filters, Wiener

filters, low-pass filters etc [96-98]. The processed images may undergo enhancement techniques to improve the quality of the image to great extent. It is an automated process based on mathematical functions. The technique can improve image quality in terms of shading, linear contrast adjustment, un-sharp mask filtering, median filtering and colour. Image enhancement techniques are divided into two major domains that are frequency domain and spatial domain methods [9].

**2.3 Image segmentation** [97-100][131][135] is the process where the image is partitioned into its constituent parts or objects that can be identified individually[158]. Through image segmentation we fragment the image in a series of region, based on features of image that are constant in each region, but differ from one region to another [17][18][19]. The exploration of Osteoarthritis is implemented through distinct segmentation techniques which may further help for the proper and clear diagnose of the disease grade wise (KL grading system). As per the study some of the image segmentation techniques used are:

- Region Based Methods [78][95][100][152][165]
- Deformable segmentation methods [79][90][100]
- Atlas based methods [77][130][134]
- Edge based segmentation method [78][98][101][112][145][150][156]
- Active Shape model [83-85][146][154-155][161][164][166]
- Watershed Segmentation[137]
- Pixel based segmentation[100]

As per the literature survey researchers have used various segmentation techniques with their own dataset, constraints and experimental setup for the investigation of Osteoarthritis. The different segmentation techniques used as per the survey are listed below in table 2.1

**2.4 Feature Extraction** [82][108][116] is one of the important module for image processing. In this stage we compute features of an image which results in recognition accuracy with very simple classification module. Some of the generic features are:

Morphological features focusing on the shape attributes [80][88][131][137]. Some of the standard feature extractions under morphological features are:

Zernike features [107][111][117]: These features helps in representing properties of an image with no overlap and to describe shape characteristics.

Shape features [76][83][85][88][108][111][151]: These include measuring the similarities between shapes represented by their features. Some of the shape parameters are area, eccentricity, perimeter etc.

Global feature descriptors [80][86][109][134][138][157] that summarizes the overall appearance or general description. The features included are

Statistical features [79][90][106][150]: Includes assembling, formulating, determination & clarification of data. The various statistical measures are mean, variance, skewness, median etc

Local texture descriptors [80][84][86][95][134][138][157] that concentrates on isolated contribution of small regions. Some of the important feature extraction algorithms are:

Haralick features [93][119]: These help in measuring the texture of the image in terms of entropy, angular second moment, correlation, inverse difference moment etc.

Tamura texture features [94][109][118]: These features includes contrast, directionality and coarseness of an image. The table 2.2 below lists the various features extraction techniques used for the investigation of OA as per the survey.

**2.5 Classification** [81][146] is a process of classifying whether the output image is OA affected or Normal. Different classifiers like K-Nearest Neighbour [77][81][84][86][123][124][147] Decision Tree [81], Support Vector Machine [80][86][94][95][122][137] Multilevel Slice, Minimum Distance, Maximum Likelihood [93] etc are used to classify the input image on the basis of features. The manifestation below (Table 2.3) gives the classification methods used to classify the disease.

2.6 Data Set used in the literary work: As per the literature survey there is no standard database available many authors have used their own data sets. The below table shows some of the data sets used in the literature.

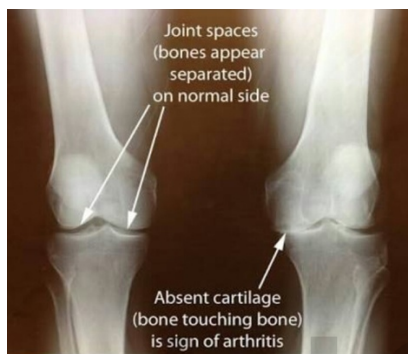
### 3 SYSTEMIZATION OF OSTEOARTHRITIS

In our preceding survey, researchers have investigated various methods on the detection and analysis of Osteoarthritis using different knee images like X-ray, MRI etc. Image segmentation method has a great importance in most medical imaging applications. In medical imaging the segmentation methods are classified into two basic groups: pixel based (includes thresholding, region growing region merging etc) and geometry based (includes deformable models, active contours active appearance models). There are several computer aided techniques like artificial intelligence, pattern recognition, machine learning techniques, feature extraction techniques etc which are widely used in the processing of medical images [19]. Therefore to know the proper progression & extremity of the disease

medical imaging is carried out in terms of X-ray imaging or Magnetic Resonance imaging.

### 3.1 Knee X-ray images for the Systemization of Osteoarthritis

A simple radiography a standard X-ray is carried out to create a two dimensional image of a bones that form the joint. Knee X- Ray is used to view the joint space, joint alignment, loose bones, bone spurs & fractures. Many experiments & algorithms were developed to detect & classify the Osteoarthritis using knee X-ray images. The anatomy of knee image is shown below.



“Normal & Osteoarthritis Knee joint X-ray”

Lior Shamir et al [1], have used joint detection algorithm and feature extraction technique to analyze the knee X-ray image. The algorithm finds the joint and separates it from rest of the images. The features were computed by Zernike features, Multi-scale histograms, first four moments, Tamura texture features etc. The features extracted were classified using weighted Nearest Neighbour rule. They have concluded that 95% of moderate OA was differentiated from normal OA and 80% of minimal OA was differentiated from normal.

Samir K.Bandyopadhyay[3], have used edge detection algorithm, to detect edges of Knee X-ray images in osteoarthritis. The features computed were femur, tibia and patella cartilage. The authors have concluded that the proposed algorithm gives sufficiently good results and is very effective in noisy and blur images.

Lior Shamir et al [4], have used systematic computer aided image analysis method. They have used WND-CHRM algorithm which first extracts the generic features of image and different other factors from polynomial decomposition of image. Initially X-ray of KL grade 0 was considered and later after 20 years of regular follow-up, the X-ray either developed OA or remained normal. The results showed that by using this method the prediction was from KL 0 to KL 3 with 72% of accuracy and from KL 0 to KL2 was 62% of accuracy.

M.Subramonium et al [8], have used a novel classification system for the classification of OA in knee X-ray images based on Local Binary Pattern(LBP).The classification is achieved by computing the histograms of LBP of knee X-ray images using K- Nearest Neighbour classifier. The distance measures used in their work are Euclidian distance, Manhattan distance etc. The authors have concluded with 95.24% of accuracy in detecting normal or abnormal knee image and 97.37% of accuracy in detecting medium or worst cases.

Prafull Sharma et al [11], have used different Image segmentation algorithms on X-ray bone images. The discrete step, Watershed segmentation and Otsu’s segmentation are used to analyze the abnormalities and problems associated with bone structures. They have concluded that discrete step algorithm provides quick and efficient results.

Bindushree R et al [12], have used different image processing techniques to measure the joint space width in knee x-ray images. Different techniques used are contrast enhancement, histogram equalization, canny edge detection algorithm and thresholding for extraction & computation of features. The authors have concluded that the Joint Space Width of the knee x-ray image is compared with the standard Width (4.8 for women & 5.7 for men) and that image is said to be normal case or osteoarthritis case.

Dian Pratiwi et al [14], have used artificial neural back propagation method for measuring the severity of Osteoarthritis disease. In their work the whole processing is divided into three steps, image processing, feature extraction and classification using artificial neural network process. They have concluded with 66.6% of classification rate.

Subromoniam M et al [32], have used computer aided diagnosis for the detection of OA using X-ray images. Haralick feature extraction technique for computation & SVM classifier with the kernel functions are used for the detection & classification of OA. They have concluded that the algorithm had a sufficient good result with accuracy of 99% in the diagnosis of bone disorders caused by OA.

Lior Shamir et al [35], have used image computing based method for quantitative analysis & morphological changes in the bone structure which is helpful in the progression of OA. The authors have used texture analysis & WND-CHRM classification technique for the analysis of disease. The features computed were high contrast features, Haralick features, Tamura features, statistical features & polynomial decomposition of image. The transform used are Fourier, Chebyshev, Wavelet & edge transform. The results showed that the bone texture

show no significant difference between KL grade 0 & KL grade 1. The bone structure alterations were observed clearly after grade 2 onwards.

Lilik Anifah et al [40], have used fully automated method to segment joint space area (JSA) for OA classification on impaired Knee X-ray images. In their proposed work right and left knee detection is performed using contrast limited adaptive histogram equalization (CLAHE) & template matching the row sum graph and moment methods are used to segment the joint space area of knee. In their work the whole method is divided into two steps, first step is to segment right & left knee and second step is to find JSA. The first step is again divided into four experiments; first experiment uses centre of mass, second uses only templates matching, third uses CLAHE & template matching and fourth combines all the above experiments. Similarly second step is divided into 2 experiments, first uses row sum graph & centre of mass method & second uses Gabor filter, row sum graph & centre of mass method. The results showed that experiment 4 in first step gave sufficiently good result with 100% accuracy and in second step experiment 2 gave 92.63% of accuracy for right knee and 87.37% for left knee.

Mahima Shanker Pandey et al [39] have used automated computer assisted method to detect OA based on joint space width (JSW) of knee x-ray images. In their work image is enhanced using Gaussian low pass filter & stretched using contrast stretch technique. The better quality image is obtained from which mean & variance is calculated using neighbouring pixel method. Lastly Euclidian distance formula is used on the binary format of the image to calculate the JSW which is compared with the normal value. They have concluded that among 80 images the success rate was up to 90% and 10% images failed as thresholding was not clear.

Jessie Thomson et al [41], have used fully automated computer aided system that identifies the outlines of the bones of knee joint of OA disease. The authors have Random Forest Regression Voting Constrained Local Model (RFCLM) and Statistical shape model for automated analysis. In their work two different classifiers are used to distinguish between the texture in knee structure of normal & affected OA. Features computed were texture features, shape features, simple pixel features etc. The experiment showed that combining shape & texture based classifiers resulted in 84.9% of accuracy as compared to shape alone.

Suvarna M.Patil et al[42], have created a model using Mamdani, Sugeno, Artificial neuro fuzzy inference system (ANFIS) method for the diagnosis of Osteoarthritis disease. The diagnosis of osteoarthritis is

based on the following symptoms age, morning stiffness, crepitus, bony tenderness, warmth to touch. The architecture consists of three layers, user, interface & FIS. They have concluded that among the three methods ANFIS is said to be efficient method with accuracy of 98%.

Emuoyibofarhe O.Justice [43], have used fuzzy based system to determine the severity of knee osteoarthritis. The system was implemented using MATLAB fuzzy logic toolbox. The symptoms are knee-pain, stiffness, crepitus & age. The Fuzzy logic controller comprises four components: a fuzzification interface, a knowledge base, decision making logic & de-fuzzification interface. The results show that the parameter "knee pain" & "stiffness" are directly proportional to variable "severity-level".

Somnath Bhattacharyya et al[44], have used Cellular Neural Network Algorithm, which is well suited for image processing. The algorithm finds the cysts & erosion present in the area of joints. The algorithm is divided into two step procedure. In the first step image is blurred with a diffusion type template. In the second step weighted difference of original & blurred image is calculated. They have demonstrated that the algorithm proved to be useful in fast & timely detection of the Osteoarthritis.

Lilik Anifah et al[45], have used Contrast Limited Adaptive Histogram Equalization (CLAHE) & template matching schemes. The Gabor kernel, row sum graph, moment methods and grey level centre of mass (GLCM) are used to get the joint space width area. The features computed were in terms of contrast, correlation, energy & homogeneity. The classification rate of 93.8% for KL grade 0, 70% for KL grade 1, 4% for KL grade 2, 10% for KL grade 3 & 88.9% for KL grade 4 was obtained.

T.F.Blessia et al [46], have used Fuzzy logic for the diagnosis of Osteoarthritis. The eight symptoms considered as input are pain, morning stiffness, grating sensation, bony tenderness, warmth in knee; bony outgrowth, joint space narrowing, C-reactive protein were computed & classified using artificial intelligence & fuzzy logic scheme. A 91% of accuracy rate is presented.

Matthias Seise et al [47], have used double contour active shape model (DCASM) for modelling & segmentation of femur & tibia bone for the analysis of Osteoarthritis using knee x-ray images. They have concluded that the initial results were promising, but with some failures which can be improved in future work.

Tati L.Mengko et al[48], have used machine vision system for osteoarthritis assessment. In their proposed method image segmentation uses edge detection

method to determine the region of joint space. The feature computed is the distance between femur & tibia bone. The classification of normal & affected OA is obtained from radiographic image using neural network that is later examined with the predefined diagnosis managed by the physician. They concluded with 50% sensitivity, 100% specificity & positive predictive value & 91.84% negative predictive value.

H. Oka et al[49], have used fully automated program KOACAD(Knee Osteoarthritis computer aided diagnosis) to quantify OA parameters on plain radiographs & investigate the association of parameters with knee pain. The parameters measured were joint space narrowing at medial & lateral sides, osteophytes formation & joint angulations. The result showed that the system automatically measured all the parameters in 1 s and revealed that medial joint space narrowing & angulations of knee joint is risk factor for the presence of pain where as lateral joint space narrowing & osteophytes are not under risk factor.

Hung-Chun Lee et al[50], have proposed a new strategy using distance based Active shape Models(ASM), to calculate the geometric parameters between tibia & femur from knee x-ray image. The whole methodology is divided into three steps: pre-processing, boundary finding & parameter calculating. They have concluded that the derived parameters are found to be satisfactory & useful in Knee OA detection. They have also concluded that average processing time for each image is about 0.5 seconds.

J.E.Schmidt et al[53], have presented a novel semi-automated method for measurement of joint space width(JSW). The images were analyzed using a MATLAB custom program. The image was cropped to include the knee joint & canny edge detection method was applied on the image. They have concluded that the semi automated method showed higher reproducibility ( $0.01\pm 0.44$ ) than manual method ( $0.08\pm 0.71$ ).

Lior Shamir [54], have developed image analysis method that can find correlations between radiographic findings & clinical indicators. The methods includes WND-CHRM algorithm using different feature extraction techniques (Haralick, Tamura, Shape, Statistical). The computed features are classified using weighted Nearest Neighbour scheme. They have concluded that the method demonstrated the satisfactory association between the radiographic findings & clinical indicators.

Sreeparna Banerjee et al[57], have described a class of analogy algorithms based on Cellular Neural Networks for detecting OA from hand x-ray images. Cellular Neural Network algorithms are useful when fast & robust pre-processing is required. The parameter

used for detection of OA is osteophytes or bone spurs. The algorithm uses standard CNN templates and spiculus seeker algorithm to isolate the osteophytes. They have resulted with 90% of accuracy rate.

Sreeparna Banerjee et al[60], have used Cellular neural network (CNN) based techniques for detecting indications of Osteoarthritis. The methodology incorporates image enhancement, region segmentation & line detection techniques. The CNN algorithms provide a combination of analog & logic operations for image processing in X-ray images that isolates the region of interest. The parameters used for the diagnosis of the disease are cysts & osteophytes in hand x-ray image. They have concluded that the CNN based techniques have proved to be successful in extracting the signs of the disease OA in X-ray images.

Lynchf et al[68], have used fractal signature analysis (FSA) for the assessment of OA using knee microradiographs. The FSA measures the fractal textures vertically & horizontally. They have demonstrated that the vertical structure has similar signature as that of normal knee joint, where as horizontal structure showed remarkable change in signature with respect to normal joint.

Subromonium. M et al[69], have developed the algorithm to compute the features from digital x-ray images using Local Ternary Pattern (LTP) and classifying them by using Support Vector Machine Classifier. 50 X-ray samples were used to evaluate the performance of the algorithm. They have concluded that the Linear & Polynomial functions gave 91.66% of specificity & 80% of sensitivity. RBF gave 94.59% of specificity & 66.66% of sensitivity

Chanda Ray et al[80], have used automatic clustering of X-ray images by K-means method on large feature vector & hierarchical technique is applied on k-means clustering. The clustering is done on multilevel features of X-ray images such as global level, local level & pixel level. They have concluded that the combination of k-means & hierarchical clustering produces very high level of accuracy.

Bram van Ginneken et al[84], have used active shape model segmentation method that is guided by optimal local features. The features are classified using non-linear k-NN classifier. The selection of features is automatic using training images. The sequential feature selection is based on forward & backward selection. They showed that the new method gives significantly better results as compared to old ASM method.

Gert Behiels et al[83], have proposed a improved search procedure for ASM on digital X-ray images & compare the original ASM method with the new technique by optimizing a Bayesian objective function.

They have compared both the techniques & results were listed.

Mohammad Reza Zare et al[86], have presented different methods for automatic classification of X-ray images with respect to image representation techniques. Their work includes two groups of image representations such as low level ( GLCM, LBP, canny edge operators , pixel values) & patch based( Bag of Words) are used. These features are further classified using Support Vector Machine (SVM) & k-NN classifiers. They have demonstrated that classification method constructed from LBP & Bag of Words gave good performance as compared to others.

S. Botha-Scheepers et al[70], have studied & evaluated the sensitivity to detect joint space narrowing on OA affected knee radiographic images using fixed flexion radiography & compared the effect of Medial tibial Plateau(MTP) alignment on sensitivity of joint space narrowing(JSN). Their study showed that fixed flexion radiography showed changes in JSW over two years.

P. Ravaud et al[91], have studied the evaluation of knee X-ray based on patients position and X-ray beam direction & inclination. The ideal radiographs were compared with radiographs of modified procedure. Their study resulted that the change in X-ray beam direction is noticeable were as there is no any modification in Joint space width.

Hillary J. Braun et al[92], the studied & analysed the different imaging techniques used for OA. Imaging modalities includes radiography, magnetic resonance images, optical coherence tomography (OTC) & ultrasound (US). Radiography is used for the examination of bony structures, OCT is used for evaluation of Articular cartilage, US is used for synovial & ligaments. MRI includes visualization of all intra articular structures & pathologies. They have concluded that the combination of the above techniques provides excellent information in gaining the status of disease.

J I Lei-feng et al[105], have used non-invasive method for the detection & diagnosis of knee OA using Electromyogram (EMG) signals. The extraction techniques uses Kalman filter which is used to calculate the system state from time series & signal processing is carried out to train RBF neural network. They have concluded that the accuracy rate of each muscle was approximately above 82%.

Pooja P. Kawathekar et al[144], have used distance based active shape model to calculate the parameter causing OA in knee X-ray images. The features include local binary pattern for the evaluation of parameters & the computed features are classified using K- Nearest Neighbour scheme. The classification of affected &

normal OA is stored in first database. Further classification is carried out on abnormal case to find out the worst & medium case. The method includes CLAHE technique & Gabor kernel classification scheme. They have concluded with accuracy rate of 93.8% for KL-0, 70% for KL-1, 4% for KL-2, 10% for KL-3 & 88.9% for KL-4.

Thomas Janvier et al[113], have used region of interest (ROI) scheme using knee X-ray of OA for extracting bone texture features. The texture features were computed using Fractal analysis method. They have concluded that ROI helps in better diagnosis of disease.

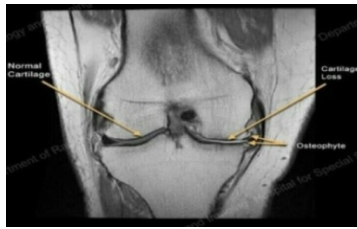
P. Podsiadlo et al[114], have developed a method to find the textures of trabecular bone in normal & affected OA radiographic images. The Hust Orientation transform(HOT) method is used to calculate the texture features like Fractal Dimensions(FD), Fractal Dimensions in Vertical(FDv), Fractal Dimensions in Horizontal(FDh), Texture Aspect ratio(Str). They have concluded that the parameters FD, FDv, FDh showed significantly lower values & Str showed higher values in affected OA.

Virginia Byers Kraus et al[115], have used fractal signature analysis for evaluation of sub chondral bone texture in a knee radiographs to predict the progression of OA. The statistical shape modelling technique is used for measurement of medial compartments of knee. They have concluded that, the method used can be efficient means for identifying the risk factors in knee OA.

X-ray imaging is most commonly used tool for the evaluation of Osteoarthritis. From the survey many methods have been proposed & distinct approaches are applied for the detection of Osteoarthritis. The comparative analyses with promising results used different experimental setup were made by researchers. But still there is scope for developing more robust and precise algorithm that is suitable for evaluating the disease in early stage with high classification rate.

### 3.2 Magnetic Resonance Images for the Systemization of Osteoarthritis

Magnetic resonance imaging (MRI) is a non-invasive medical test that physicians use to diagnose and treat medical conditions. MRI of the knee provides detailed images of structures within the knee joint, including bones, cartilage, tendons, ligaments, muscles and blood vessels, from many angles. In Osteoarthritis MRI is done for the detection of cartilage area, cartilage thickness, area of patella cartilage, femur and tibia cartilage, chondrocytes, trabecular bone etc. The image shown below is a simple OA affected knee MRI image.



Sample of Knee MRI Image

Bhagyashri L.Wagaj et al [2], have used pixel segmentation method to diagnose the osteoarthritis disease. The segmented image obtained is used to calculate the area of cartilage and to estimate the image is OA affected or Normal. They have concluded that among 32 images, 16 were normal OA (full classified) and 16 with affected OA (1 misclassified).

Dipali D.Deokar et al [5], have used new automatic knee OA detection system, based on feature extraction and artificial neural network. The features computed were GLCM texture, statistical features, shape features etc by using different image processing algorithms. The technique consists of four stages pre-processing, segmentation, feature extraction and classification. They have concluded 98.5% of classification accuracy rate.

M.S Mallikarjun Swamy et al [6], have used MRI images for cartilage thickness measurement and visualization that is useful in early detection and progression of the Osteoarthritis disease. This work reviews knee joint Articular segmentation methods, visualization, thickness measurement, volume measurement using different segmentation methods. The features are classified as pixel based or model based methods. They have come with the result by adopting thickness measurement in 2D and visualization in 3D. The authors have also concluded that there is still scope to develop a method which is efficient in time & complexity for segmentation, visualization & better quantification.

Chao Jin et al [7], have used medical infrared Thermography for knee feature extraction. The features were computed for patella analysis. Support vector machine (SVM) classifier is used to perform the further analysis. They have concluded that the SVM classifier has an accuracy of 85.51% in detecting normal and abnormal cases.

Nadeem Mahmood et al[9], have used different image segmentation and edge detection methods for the visualization of knee cartilage image. Different edge detection algorithms used are Sobel, Prewitt, Robert, Zero Cross and Canny Edge detection algorithms. The result showed that canny edge detection algorithm works well with the given images as compared to other methods.

Mahesh B.Nagarajan et al [10], have used visualization and texture analysis to characterize chondrocyte patterns in the presence and the absence of Osteoarthritic damage. The Minkowski functional (MF) and gray level co-occurrences matrices (GLCM) are used for texture analysis. They have concluded that best classification performance was observed with MF as compared to GLCM.

M Lakshmi et al [13], have used image processing techniques on MRI of knee to get the thickness of cartilage for the detection of osteoarthritis. The various algorithms like Otsu's algorithm, Vertical edge detection, and automatic region detection, Euclidian & connected component are used. They have used adaptive histogram equalization, contrast enhancement, Gaussian filter, & edge detection techniques on knee MRI. This work resulted in estimating the articular cartilage thickness for the detection of knee OA.

Thomas P et al [15], have used methods for evaluating the progression of osteoarthritis through dynamic functional imaging. The image processing techniques are used for quantifying cartilage loss and computational methods for generating 3D maps of cartilage thickness. They have concluded that the functional joint imaging can be used as a powerful diagnostic tool for the detection of knee disorders.

Shawli Bardhan et al [16] have used medical infrared Thermography for the temperature analysis and early detection of abnormalities due to inflammation. Medical infrared Thermography is fast imaging techniques that records & monitor the flow of body temperature by receiving the infrared emitted from the skin surface. This work had a sufficient good result in analyzing the body temperature & detecting inflammatory disorders.

Markus Walther et al [21], have used power Doppler sonography (PDS) in the diagnosis of synovial tissue of the knee joint of OA affected patients. The PDS findings are compared with histopathology findings. The samples of synovial tissues are collected and analyzed using digital image evaluation system. The result showed that PDS is more reliable diagnostic method for qualitative grading of vascularity of synovial tissue.

Gabrielle Blumenkrantz et al [23], have proposed advancement in cartilage imaging, measurement of relaxation time, computation of cartilage volume & thickness are presented using knee MRI image. Different quantitative and mapping techniques are used and they have resulted that these techniques can provide information beyond morphological changes in Articular cartilage.



Olivier Beuf et al [25], have used high resolution MRI to evaluate the trabecular bone structure of different stages of OA affected patients. The images of patients without OA, with mild OA and with sever OA was collected and different features like trabecular bone volume fraction, trabecular number, trabecular separation and trabecular thickness were computed. They have concluded that the calculations made on trabecular bone structure shows significant variations in patients with varying degrees of OA.

Meenaz H.Shaik et al [26], have used different image segmentation techniques to analyze the knee MRI images and extract the data from them. The different techniques used are thresholding, region based, clustering, Markov random field, artificial neural network, deformable and atlas guided method. The authors have made the comparison of all the segmentation methods and listed the results.

Wei Chun Lin et al [31], have used vibroarthrographic (VAG) signals to detect OA. In their work the system consists of goniometry, electronic stethoscope to detect knee VAG signals and signal processing system as a system kernel. Statistical analysis & Fourier transform were obtained & partition indices were calculated. The processed VAG signals are compared with predicted & observed results & they have concluded with 89.52% of sensitivity & specificity of 67.50% and total accuracy of 81.52%.

Ahmet Alkan et al [33], have used methods like segmentation, fuzzy-c means clustering & SVM classifier to analyze the severity of OA through KL grading system. In their work the features of interest were cross-sectional fat (CSFA), muscle (CSMA), Femur (CSFEMA) & bone (CSBA) & they have achieved 72% of accuracy rate.

Pierre Dodin et al [34], have used automated system for quantification of knee bone marrow lesion (BML) for the detection of OA. The method includes four steps; selection of structured bright areas corresponding to BML's, geometric filtering, segmentation of BML & quantification of BML. The comparison between automated method and manual BML segmentation showed excellent result.

B.G.Ashinsky et al [36], have used pattern recognition & multivariable regression method in the classification of human Articular cartilage. The Weighted Neighbour distance using compound hierarchy of algorithms representing morphology (WND-CHRM) method to perform binary classification on normal & OA affected MRI. Feature extraction includes Wavelet, Chebyshev, Edge and Fourier transforms. Various features computed were texture features, statistical features & polynomial decomposition of raw image. They have concluded that

the classification between normal & OA yielded accuracy between 36% & 70% where as multiple linear tests square regression method had an accuracy of 86%.

Jeffrey W.Prescott et al[51], have proposed fully automated method for the segmentation of femur bone based on anatomical constraints. The method is implemented using morphological operations to extract femur medulla & cortex. The algorithm separates medulla from cortex using segmentation method & to know how these properties may be related to OA. The results showed that there is significant association between gender & femur CSA. There was strong relationship between femur CSA &KL grades for females. But no any significant association was found in male.

Neila Mezghani et al[52],have developed an automatic computer method to discriminate Asymptomatic(AS) from OA knee gait patterns using 3-D ground reaction force(GRF) measurements. The method extracts the features from GRF vectors & than classify it through nearest neighbour rule using set of reference characteristics. The characteristics were coefficients of polynomial expansion & coefficients of wavelet decomposition. They have achieved a discrimination rate of 91% with wavelet decomposition.

Jose G et al[55], have used fully automated method for segmenting knee cartilage & bone. The method is used to develop multiple anatomical knee atlases for MRI datasets. These atlases are morphed & matched to each subject of MR images to segment cartilage & bone simultaneously. In their work advanced image analysis is used to classify each voxel according to voxel classification. The methodology includes image acquisition, atlas creation, image segmentation, segmentation accuracy, image quantification & quantification performance. The authors have concluded that the fully automated segmentation method produces accurate cartilage thickness, volume, shape measurement & thickness valuable for the study of OA.

Sanjeevkumar Kubakkaddi et al[56], have used simple & automatic method for segmentation of Articular cartilage. The algorithm calculates the thickness of femur & tibia cartilage together at joint location to analyze the damage of cartilage. The method uses Adaptive histogram equalization which is further subjected to Gaussian low pass filters and zero crossing detection technique to find the thickness of cartilage. The image is further contrast enhanced for making boundaries more clearly for thresholding. After thresholding Canny edge detection is applied to find the edges of cartilage. The authors were successful in calculating the thickness of cartilage valuable for classifying OA.

Peter M. M. Cashman et al[58], have described an automated techniques for visualization & mapping of Articular cartilage in MR images of Osteoarthritis Knee. The aim of their work is to develop & validate software for automated segmentation & thickness mapping of articular cartilage from 3-D gradient echo MR images of knee. The methodology includes acquisition, Segmentation, 3-D rendering, Image enhancement Thickness mapping & Trackback. The authors demonstrated the feasibility of automated segmentation method & detection possible down to the sub micrometer level.

Sang Hyun Park et al[59], have used fully automatic method to segment bone compartments in MR images of knee joint for research on knee osteoarthritis. The proposed method efficiently utilizes shape & intensity parameters that are obtained from pre-segmented data and applies branch and mincut to configurations of shape templates. The iteration includes translation, rotation & scale parameters for shape prior configuration & greedily selecting the optimal. They have concluded that branch and mincut has increased accuracy & efficiency compared to only when shape priors are applied.

Jeffrey W. Prescott et al[61], have used automated method to segment the adipose tissue of thigh muscle using MR images. The morphological constraints & thresholding is applied to carry out the segmentation. They have concluded with specificity of 67% & sensitivity of 82%.

M. S. Swanson et al[62], have developed semi-automated segmentation method to access the lateral meniscus in normal & OA knee. The method was applied on knee MR images of normal & affected OA. The meniscus region was calculated through Gaussian fit model. The conditional dilation & post-processing is carried out after thresholding that excludes the area surrounding the meniscus for better accuracy. The results showed 80% for normal participants & 75%, 67%, 64% for participants with established Knee OA.

Jenny Folkesson et al[63], have presented a fully automated method for cartilage segmentation using Voxel classification for knee MR images. Training & evaluation of the method is performed on data set consisting of 139 scans of knee status ranging from normal to sever OA. The segmentation method includes two steps: first step consists of shifting the coordinates of scans to get the cartilage centre of mass for segmentation & in second step scan is classified using sample expanding algorithm. The outcome is combined & the largest component is selected as cartilage segmentation. They have concluded that the automatic segmentation of scan is approximately 10

min where as trained radiologist takes around two hours to segment the cartilage.

Jurgen Fripp et al[64], the authors have presented a segmentation scheme that automatically and accurately segments all the cartilages from magnetic resonance (MR) images of non pathological knees. The method involves the automatic segmentation of the bones using a three-dimensional active shape model, the extraction of the bone-cartilage interface (BCI), and cartilage segmentation from the BCI using a deformable model that utilizes localization, patient specific tissue estimation and a model of the thickness variation. The method obtained robust results and provided a good estimate of the "global" affine deformation between the images. Authors have predicted the method has only limited sensitivity and specificity for cartilage segmentation.

J. McBride et al[65], In this work, authors have analyzed gait biomechanical data using neural network models to predict the level of joint deterioration and the level of pain in participants suffering from knee osteoarthritis. The results demonstrated a strong correlation between gait kinetics and joint deterioration and level of pain in OA affected individuals.

Chuah Zhi En et al[66], have used an artificial neural network (ANN) based classifier to classify the knee MR image of OA affected individuals. The methodology includes data set of 150 MR images which is undertaken Discrete Wavelet Transform-Based (DWT) Feature extraction and the computed features are classified using Artificial Neural Network classifier. The proposed method obtained 98.5% classification accuracy on training the images and 94.67% of classification accuracy on testing the images of the selected datasets.

Chueh-Loo Poh et al[72], have used knee MRI images to visualize the Articular cartilage thickness using 2D wear map. The authors describe user interface that comprise an interactive function (Track Back) function that allows physician to examine the radiological information. The methodology consists of image acquisition, segmentation & thickness measurement. The 2-D visualization of cartilage thickness is carried out using Wear map & Track back functions. They have concluded that the methods used have the ability to accurately visualize the thickness of cartilage.

C.-L. Poh et al[73], have developed web based user interface that allows doctors to view 2-D segmentation images & 3-D Articular cartilage thickness measurement plots in knee MRI images. The user interface was developed using Java & Scalable Vector Graph (SVG). The paper includes cartilage measurement, 2-D 3-D reconstruction & 3-D slicing.

They have successfully showed the flexibility & effectiveness of the interface.

Chueh-Loo Poh et al[74], have used web based user interface that facilitates the storage display & manipulation of multiple data types across biological continuum that comprises system viscera, tissue, cells, proteins & genes. Web based interface is used to display data & allow interaction by means of Scalable Vector graphics (SVG). Web development language based on Extensible Mark-up Language (XML). They have concluded that the interface provide detail & rapid interpretation of data.

Tong Kuan Chuah et al[75], have investigated quantitative texture analysis of MR images for detection of cartilage related bone marrow lesion (BML). The parameters used for texture analysis were mean intensity, standard deviation, smoothness, third moment, uniformity & entropy. These parameters were calculated in both 2-d & 3-D & were compared between healthy & affected group. They have concluded that the third moment is strong parameter to be used for distinguishing two groups.

Liang Shan et al[76], have proposed fully automatic 3-label segmentation method for bone segmentation (femur & tibia segmentation) using MR images. The method is based on convex optimization problem by embedding label assignment into higher dimensions. The results show the beneficial behaviour of the 3-label segmentation method compared to binary segmentation method.

Liang Shan et al[77], have developed fully automatic atlas based cartilage segmentation method. The method builds the bone cartilage atlas for femur & tibia & uses the resulting atlas to guide femur & tibia segmentation. The atlas generated should help increase segmentation robustness, mitigate, noise effects & focus segmentation on region of interest. The femoral & tibial regions are classified using k-NN classifiers. The classification rate of 78.2% was achieved for femoral cartilage & 82.6% for tibial cartilage.

Jincheng Pang et al[78], have presented active contour algorithm based on level set framework. The algorithm is designed to segment femur & tibia using Bone Marrow Lesion (BML) protocol. The active counters are divided into two classes: region based & edge based. The method demonstrated that the combination of new couple prior shaped & directional edge force provides improved segmentation performance & requires less manual interactions.

Heiko Seim et al[90], have used method for fully automatic segmentation of bones & cartilages using knee MR images. The femoral & tibial bone surfaces are reconstructed based on statistical shape model & graph based optimization. The calculations made on femoral

& tibia bones were average & root means square values. For cartilage quantization volumetric overlap & volumetric difference were measured. They have experimented on 40 MR images & obtained good results.

C R Donoghue et al[120], have used Laplacian Eigen map embeddings to learn the imaging biomarkers of knee MRI. The authors have used region of interest & combined them with embeddings obtained. The results showed better improvement as compared to the previous methods used in literature.

James Cheong et al[125], have used semi automated segmentation method to find the cartilage thickness in Knee MRI of OA patients. The two different segmentation methods used are canny edge & active shape model (ASM) scheme. They have concluded that both the methods gave standard segmentation & measurement accuracy.

Magnetic Resonance imaging provides detail & clear visualization of internal soft tissues. MRI is ordered by physicians only when there is some joint tissue damage. In our survey many researchers have used MRI images to know the progression of OA using different methods & algorithms.

#### 4. CHALLENGES & ISSUES

Various image processing techniques are proposed for the detection and classification of Osteoarthritis. The choice of appropriate technique for specific task is important. Therefore depending on specific task we may need to develop efficient and robust algorithm. This is possible only when there is detail discussion between biologists and specialists of image processing techniques. As per the International Association for the Study of Pain, the articular cartilage is one of the trademarks of OA, but still there is vague understanding of how the various structural changes of other joint tissues interact or how they account for the prevalence of pain, especially knee pain. Similarly, the variance of pain explained both by independent structural changes as well as their sum and interactions remain poorly defined. They also mention that minimum joint space width (JSW) is the standard metric, but use of location-specific JSW has been reported as still challenging issue [168]. Some of the other important issues raised by researchers related to image processing techniques include fuzzy boundaries, high dimensional indexing, multi dimensional images and hybrid techniques with respect to computer vision and machine learning concepts. Along with these issues there are some algorithms which are still open to lot of improvement for making them effective in desired area of medical images.

## 5 CONCLUSION & FUTURE DIRECTIONS

Analysis of MRI, X-ray images is done manually by the physician that is time consuming, subjective & unpredictable. The complexities associated with the medical images make it difficult to analyze them in an effective way. A knee X-ray image is very much prone to unwanted distortions that cause problem in analyzing the bone structures. To overcome these problem there are various automated and semi-automated techniques like image segmentation, feature extraction, image enhancement etc that provides a quick and efficient method to analyze the abnormalities and problems associated with the bone structures.

The anatomical structure of knee includes tibia, femur, patella, meniscus, cartilage etc. The said parameters play a vital role in causing Osteoarthritis. Along with these anatomical structures some other physiological indicators & behavioural parameters like gender, weight, blood group, age, CRP content & occupation are also the cause for OA as predicted by some researchers.

In future there is still scope to develop a fully automated method which may be efficient in time, has less computational complexities, reduced manual interactions, better visualization & quantification. Some of the future works are:

- Manual methods are time consuming & fully automated methods are very complex. Thus we need to develop a hybrid method for the better evaluation of the disease.
- In future we need to develop a tool that is associated to Osteoarthritis pain, for example whether the pain is related to joint tissue, neuropathic pain, muscular pain etc.
- Redefining the parameters and classification criteria with respect to Osteoarthritis may help us to identify whether the patient is at high or low risk to develop OA.
- The feature extraction algorithms must be enhanced to extract the modified boundary of the images, which will be helpful for the clear identification of cartilage, femur or tibia edges.
- Robust and coherent algorithms need to be developed for the accuracy improvement in the assessment of OA.

Hence an attempt has been made to put just another small brick into the wall of research on image processing techniques for the detection and classification of Osteoarthritis. So it is important footstep in computer aided analysis to identify the extremity of Osteoarthritis.

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## REFERENCES:

- [1] Lior Shamir, Shari M.Ling,William W.Scott, Angelo Bos, Nikita Orlov, Tomasz Macura, D.Mark, Luigi Ferrucci, Ilya G.Goldberg "Knee X-ray Image Analysis Method for Automated Detection of Osteoarthritis", IEEE Transactions on Biomedical Engineering, ©2008.
- [2] Bhagyashri L.Wagaj, M.M.Patil "Osteoarthritis Disease Detection with the help of Image processing technique", International Journal of Computer Applications (0975-8887) ,Conference on Emerging Applications of Electronic System, Signal Processing and Computing Technologies 2015.
- [3] Samir K.Bandyopadhyay "An Edge Detection Algorithm for Human Knee Osteoarthritis Images", Journal of Global Research in Computer Science, Volume 2, No. 4, ISSN-2229-371X, April 2011.
- [4] Lior Shamir, Shari M.Ling,William W.Scott, Marc Hochberg, Luigi Ferrucci, Ilya G. Goldberg " early Detection of Radiographic Knee Osteoarthritis using Computer Aided Analysis", National Institutes of Health(NIH) Public Access, Osteoarthritis Cartilage , Volume 17, Issue 10,October 2009.
- [5] Dipali D.Deokar, Chandrashekar G.Patil "Effective feature Extraction Based Automatic knee Osteoarthritis Detection and Classification using Neural Network", International Journal of Engineering and Techniques, ISSN:2395-1303, Volume 3, Issue 3, PP: 134-139, , May-June 2015.
- [6] M.S.Mallikarjuna Swamy, Mallikarjun S.Holi "Knee Joint Articular Cartilage Segmentation, Visualization and Quantification using Image Processing Techniques", International Journal of Computer Applications (0975-8887), Volume 42, No.19, pp: 36-41, March 2012.
- [7] Chao Jin, Yang Yang, Zu Jun Xue, Ke-Min Liu,Jing Liu "Automated Analysis Method for Screening Knee Osteoarthritis using Medical Infrared Thermography", Journal of Medical and Biological Engineering , Volume 33, Issue 5, pp:471-477, Feb 2012.
- [8] M. Subramoniam and V. Rajini "Local Binary Pattern Approach to the Classification of Osteoarthritis in Knee X-ray Images", Asian Journal of Scientific Research, Volume 6, Issue 4, pp: 805-811, ISSN: 1992-1454, 2013.
- [9] Nadeem Mahmood, Asadullah Shah, Ahmad Waqas, Adamu Abubakar, Shafia Kamran, Syed Baqar Zaidi " Image Segmentation Methods and Edge Detection: An Application To Knee Joint Articular Cartilage Edge Detection", Journal of Theoretical and Applied Information Technologies, ISSN-1992-8645,Volume 7, No.1, pp:87-96, , January 2015.
- [10] Mahesh B. Nagarajan, Paola Coan,Markus B. Huber, Paul C.Diemoz, Christian Glaser and Alex Wismuller "Computer Aided Diagnosis in Phase Contrast Imaging X-ray Computed Tomography for Quantitative Characterization of ex vivo

- Human Patellar Cartilage", IEEE Transactions on Biomedical Engineering, Volume 60, No.10, October 2013.
- [11] Prafull Sharma, Joshua Madhukar Singh " A Novel Approach towards X-ray Bone Image Segmentation using Discrete Step Algorithm", International Journal of Emerging Trends & Technology in Computer Science, Volume 2, Issue 5, pp:191-195, ISSN 2278-6856 September-October 2013.
- [12] Bindushree R, Sanjeev Kubakaddi, Nataraj Urs " Detection of Knee Osteoarthritis by Measuring the Joint Space Width in Knee X ray Images", International Journal of Electronics & Communication, ISSN 2321-5984, Volume 3, Issue 4, pp:18-21, April 2015.
- [13] M. Lakshmi Kumara and N. Prabakaran "Automatic Detection of Cartilage Thickness for Early Detection of KOA", Asian Research Publishing Network (ARPN) Journal of Engineering and Applied Sciences, ISSN 1819-6608, Volume 10, No.7, pp: 3112-3115, April 2015.
- [14] Dian Pratiwi, Diaz D.Santika, Bens Pardamean "An Application of Back propagation Artificial Neural Network Method for Measuring the Severity of Osteoarthritis", International Journal of Engineering & Technology, Volume 11, No.3, June 2011.
- [15] Thomas P. Andriacchi, Philipp L.Lamg, Eugene J. Alexander, Bedra E. Hurwitz "Methods for Evaluating the progression of Osteoarthritis", Journal of Rehabilitation Research & Development, Volume 37, No.2, pp:163-170, March/April 2000.
- [16] Shawali Bardhan, Mrinal Kanti Bhowmik, Satyabrata Nath, Debotosh Bhattacharjee "A review on Inflammatory pain detection in Human body through Infrared Image Analysis", ©2015 IEEE.
- [17] Critina Stolojescu Crisan, Stefan Holban "A Comparison of X-Ray Image Segmentation Techniques", Advances in Electrical and Computer Engineering, Volume 13, No.3, pp: 85-92, 2013.
- [18] Critina Stolojescu Crisan, Stefan Holban "An Interactive X-Ray Image Segmentation Technique for Bone Extraction", International Work-Conference on Bioinformatics & Biomedical Engineering (IWBBIO), Volume 2, 2014.
- [19] Y.Sun, E.C. Teo, Q.H.Zhang " Discussion of Knee Joint Segmentation", International Conference on Biomedical & Pharmaceutical Engineering (ICBPE), 2006.
- [20] Julio Carballido Gamio, Jan S. Bauer, Keh Yang Lee, Stefanie Krause, Sharmila Majumdar " Combined Image Processing techniques for characterization of MRI cartilage of the Knee", Proceedings of the 2005 IEEE Engineering in Medical & Biology 27th Annual Conference, ©2005 IEEE.
- [21] Markus Walther, Harry Harms, Veit Krenn, Stephan Radke, Trutz Peter Faehndrich and Frank Gohlke " Correlation of Power Doppler Sonography with Vascularity of the synovial tissue of the knee joint in patients with osteoarthritis and rheumatoid arthritis", Arthritis and Rheumatism, Volume 44, No.2, pp:331-338, February 2001.
- [22] Eijin Sasaki, Eiichi Tsuda, Yuji Yamamoto, Shugo Maeda, Ryo Inoue, Daishuke Chiba, Hiroshi Fujita, Ippei Takahashi, Takashi Umeda, Shigeyuki Nakaji, Yasuyuki Ishibashi " Serum Hyaluronic acid concentration predicts the progression of joint space narrowing in normal knees and established knee osteoarthritis- a five year prospective cohort study", Arthritis Research & Therapy, 2015.
- [23] Gabrielle Blumenkrantz & Sharmila Majumdar "Quantitative Magnetic Resonance Imaging of Articular Cartilage in Osteoarthritis", European Cells & Materials, ISSN 1473-2262, Volume 13, pp: 75-86,, 2007.
- [24] J. H. Kellgren & J. S. Lawrence "Radiological Assessment of Osteoarthritis", Annals of Rheumatic Disease, Volume 16, Issue 4, pp: 494-502, 1957.
- [25] Olivier Beuf, Shrinka Ghosh, David C. Newitt, Thomas M.Link, Lynne Steinbach, Michael Ries, Nancy Lane, Sharmila Majumdar " Magnetic Resonance Imaging of Normal Osteoarthritis Trabecular Bone Structure in the Human knee", Arthritis and Rheumatism, Volume 46, No:2, pp:385-393, February 2002.
- [26] Meenaz H. Shaikh, Shraddha Panbude, Anuradha Joshi "Image Segmentation Techniques and its applications for knee joints: a survey", International Journal of Scientific Research (IOSR) Journal of Electronics & Communication Engineering, ISSN: 2278-2834, Volume 9, Issue 5, pp: 23-28, Sep-Oct 2014.
- [27] "Background Paper 6.12 Osteoarthritis", Priority Medicines for Europe and the World " A public health approach to innovation" update on 2004 background paper written by Saloni Tanna updated by Rachel Wittenauer, Lily Smith, Kamal Aden, January 2013.
- [28] Seiichi Uchida "Review Article: Image Processing & Recognition for Biological images", Development growth & Differentiation, Volume 55, pp: 523-549, 2013.
- [29] Taru Manyanga, Maria Froese, Ryan Zarychanski, Ahmed Abou-Setta, Carol Friesen, Michael Tennenhouse, Barbara L Shay " Pain Management with acupuncture in osteoarthritis: a systematic review & meta analysis", Biomed Central (BMC) Complementary & Alternative Medicine, Volume 14, 2014.
- [30] Rafael C. Gonzalez, Richard E. Woods "Digital Image Processing", ISBN 81-7808-629-8, ©2002 by Pearson Education, Inc.
- [31] Wei-Chun Lin, Tsair-Fwu Lee, Shu-Yuan Lin, Li-Fu Wu, Hung-Yu Wang, Liyun Chang, Jia-Ming Wujing-Chuan Jiang, Chiu-Ching Tuan, Mong-Fong Horng, Chin-Shiuh Shieh, Pei-Ju Chao "Non-invasive knee osteoarthritis diagnosis via Vibroarthrographic Signal Analysis", Journal of Information & Multimedia Signal Processing, ISSN2073-4212, Volume 5, No.3, pp: 497-507, July 2014.
- [32] Subromoniam M, Barani S & Rajini V " A non-invasive computer aided diagnosis of osteoarthritis from digital X-ray images", Biomedical Research, ISSN0970-938X, Volume 26, Issue 4, pp:721-729, 2015.
- [33] Ahmet Alkan "Analysis of knee osteoarthritis by using fuzzy c-means clustering and SVM classification", Scientific Research & Essays, ISSN 1992-2248, Volume 6, Issue 20, pp:4213-4219, September 2011.
- [34] Pierre Dodin, Francois Abram, Jean Pierre Pelletier, Johanne Martel Pelletier " A fully automated system for quantification of knee bone marrow lesions using MRI and Osteoarthritis initiative cohort", Journal of Biomedical Graphics and Computing, Volume 3, No.1, pp:51-65, 2012.
- [35] Lior Sharmir, Salim Rahimi, Nikita Orlov, Luigi Ferrucci, Ilya G. Goldberg "Progression analysis and stage discovery in continuous physiological process using image computing", Hindawi Publishing Corporation, EURASIP journal on Bioinformatics and Systems Biology, Article ID 107036, 2010.
- [36] Mustapha Bouhrara, Vanessa Lukas, Ilya Goldberg, David Retier " Machine learning classification of OARSI- scored human articular using magnetic resonance imaging", Osteoarthritis & Cartilage, pp:1-9, 2015.
- [37] Jorge Antonio, Parraga Alava "Computer Vision & Medical Image Processing: A brief survey of application areas", 16th Argentine Symposium on Artificial Intelligence (ASAI 2015), ISSN 2451-7585, 2015.

- [38] Chetana Kurve, S.L.Lahudkar "Review of improvement of accuracy in analysis of articular cartilage", International Journal of Engineering and Technical Research, Volume 3, Issue 2, ISSN: 2321-0869, February 2015.
- [39] Mahima Shanker Pandey, Rajitha B,SuneetaAgarwal " Computer Assisted Automated Detection of Knee Osteoarthritis using X-ray Images", Science& technology The International Quarterly Journal, ISSN 2394-3769, Volume 1, Issue 2,PP:74-79, April 2015.
- [40] Lilik Anifah, Ketut Eddy Purnama, Moch Hariadi, Mauridhi Hery Purnomo "Automatic Segmentation of Impaired Joint Space Area for Osteoarthritis Knee X-ray Image using Gabor Filter based Morphology Process", IPTEK, The Journal of Technology & Science, Volume 22,Issue 3, pp:159-165, August 2011.
- [41] Jessie Thomson, Terence O'Neill, David Felson, Tim Cootes "Automated Shape & Texture Analysis for Detection of Osteoarthritis from Radiographs of the Knee", Springer International Publishing Switzerland, pp: 127-134, 2015.
- [42] Suvarna M.Patil, Ravindra R.Mudholkar " Exploring ANFIS Model for Osteoarthritis Disease Classification", International Journal of Current Engineering & Technology , Volume 4, No.3, E-ISSN 2277-4106,P-ISSN 2347-5161,2015.
- [43] Emuoyibofarhe O.Justice "Fuzzy -Based system for determining the severity level of knee Osteoarthritis", International Journal of Intelligent Systems and Applications (IJISA), ISSN: 2074-904X, pp: 46-53, 2012.
- [44] Somnath Bhattacharyya, Sreeparna Banerjee "CNN algorithm for Detection of Cysts in X-ray Images of Osteoarthritis", Paper ID 132; International Conference on Biomedical Engineering & Assistive Technologies (BEATS 2010), IEEE-EMBS/IMS Delhi Chapter held on Dec 17-19 at NIT, Jalandar.
- [45] Lilik Anifah, Ketut Eddy Purnama, Mochamad Hariadi, Mauridhi Hery Purnomo " Osteoarthritis Classification Using Self Organizing Map Based on Gabor Kernel & Contrast-Limited adaptive Histogram Equalization" ,The Open Biomedical Engineering Journal,2013.
- [46] T.F.Blessia,S.Singh, A.Kumar,J.J.Vennila "Application of Knowledge Based System for Diagnosis of Osteoarthritis", Journal of Intelligence, Volume 4, No:4,pp:269-278,Issn -1994-5450,2011.
- [47] Matthias Seise,Stephen J.McKenna, Ian W.Ricketts & Carlos A. Wigderowitz "Segmenting the Tibia & Femur from Knee X-ray Images", Medical Image Understanding & Analysis, pp:103-106,2005.
- [48] Tati L.Mengko,Rachmat G, Wachjudi, Andriyan B.Suksmono, Dony Danudirdjo "Automated Detection of Unimpaired Joint Space for Knee Osteoarthritis Assessment", @2005 IEEE.
- [49] H. Oka, S. Muraki, T. Akune., A. Mabuchi T., H. Yoshida., S. Yamamoto, K. Nakamura N. Yoshimura And H. Kawaguchi "Fully automatic quantification of knee osteoarthritis severity on plain radiographs ",Osteoarthritis and Cartilage, Volume 16, pp:1300-1306 ,@2008 Osteoarthritis Research Society International.
- [50] Hung-Chun Lee, Jiann-Shu Lee, Mark Chi-Jeng, China-Hsiang Wu, Yung Nien Sun "Automatic assessment of Knee Osteoarthritis Parameters from Two-Dimensional X-ray Image", @2006 IEEE.
- [51] Jeffrey W.Prescott, Michael Pennell, Thomas M.Best, Mark S.Swanson, Furqan Haq, Rebecca Jackson, Metin N.Gurcan " An Automated Method to Segment the Femur for Osteoarthritis Research",31st Annual International Conference of the IEEE EMBS,@ 2009 IEEE.
- [52] Neila Mezghani, Sabine Husse, Karine Boivin, Katia Turcot, Rachid Aissaoui, Nicola Hagemester, and Jacques A de Guise "Automatic Classification of Asymptomatic and Osteoarthritis Knee Gait Patterns Using Kinematic Data Features and the Nearest Neighbour Classifier", IEEE Transactions On Biomedical Engineering, Vol. 55, No. 3, March 2008.
- [53] J. E. Schmidt K. K. Amrami A. Manduca and K. R. Kaufman" Semi-Automated Digital Image Analysis Of Joint Space Width In Knee Radiographs", Skeletal Radiology , Volume 34, Issue 10, pp:639-643, 2005.
- [54] Lior Shamir "A Computer analysis method for correlating knee X-ray with continuous indicators", International Journal of Computer Assisted Radiology & Surgery(CARS), Volume 6, pp:699-704, 2011.
- [55] Jose G.Tamez-Pena, Joshua Farber, Patricia C.Gonzalez, Edward Schreyer, Krika Schneider, Saara Totterman " Unsupervised segmentation and quantification of automated knee features: data from the Osteoarthritis initiative", IEEE Transactions on Biomedical Engineering, Volume 59, No.4, April 2012.
- [56] Sanjeevkumar Kubakkaddi, K.M.Ravikumar, Harini DG "Measurement of Cartilage Thickness for Early Detection of Knee Osteoarthritis (KOA)", 2013 IEEE Point-of-Care Healthcare Technologies (PHT) Bangalore, India, 16 - 18 January, 2013.
- [57] Sreeparna Banerjee, Satyajit Bhunia and Gerald Schaefer "Osteophyte Detection for Hand Osteoarthritis Identification in X-ray Images using CNNs", 33rd Annual International Conference of the IEEE EMBS Boston, Massachusetts USA, September 3, 2011.
- [58] Peter M. M. Cashman, Richard I. Kitney, Munir A. Gariba, and Mary E. Carter "Automated Techniques for Visualization and Mapping of Articular Cartilage in MR Images of the Osteoarthritic Knee: A Base Technique for the Assessment of Micro damage and Sub-micro Damage", IEEE Transactions On Nano Bioscience, Vol. 1, No. 1, March 2002.
- [59] Sang Hyun Park, Soochahn Lee, Hackjoon Shim, Il Dong Yun, Sang Uk Lee, Kyoung Ho Lee, Heung Sik Kang, Joon Koo Han", Fully Automatic 3-D Segmentation Of Knee Bone Compartments By Iterative Local Branch-And-Mincut On MR Images From Osteoarthritis Initiative (OAI)", @ 2009 IEEE.
- [60] Sreeparna Banerjee, Gerald Schaefer and Ioannis K. Vlachos" Cellular Neural Network Based Algorithms In The Early Detection Of Hand Osteoarthritis", FUZZ-IEEE 2009, Korea, August 20-24, 2009.
- [61] Jeffrey W. Prescott, Mike Priddy, Thomas M. Best, Michael Pennell, Mark S.Swanson, Furqan Haq, Rebecca D. Jackson, Metin N. Gurcan" An Automated Method to Detect Interstitial Adipose Tissue in Thigh Muscles for Patients with Osteoarthritis", 31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota, USA, September 2-6, 2009.
- [62] M. S. Swanson, J. W. Prescott, T. M. Best, K. Powell, R. D. Jackson, F. Haq and M. N. Gurcan "Semi-Automated Segmentation To Assess The Lateral Meniscus In Normal And Osteoarthritic Knees", Osteoarthritis Research Society International Osteoarthritis and Cartilage, Volume 18, Issue 3,pp:344-353,2009.
- [63] Jenny Folkesson, Erik B. Dam, Ole F. Olsen, Paola C. Pettersen, and Claus Christiansen "Segmenting Articular Cartilage Automatically Using A Voxel Classification Approach", IEEE Transactions On Medical Imaging, Vol. 26, No. 1, January 2007.

- [64] Jurgen Fripp, Stuart Crozier, Simon K. Warfield and Sébastien Ourselin "Automatic Segmentation and Quantitative Analysis of the Articular Cartilages From Magnetic Resonance Images of the Knee", *IEEE Transactions On Medical Imaging*, Volume. 29, No. 1, January 2010.
- [65] J. McBride, S. Zhang, M. Wortley, M. Paquette, G. Klipple, E. Byrd, L. Baumgartner, And X. Zhao "Neural Network Analysis of Gait Biomechanical Data for Classification of Knee Osteoarthritis". *Biomedical Sciences & Engineering Conferences (BSEC)*, ISBN-978-1-61284-411-4, pp:1-4, @2011 IEEE.
- [66] Chuah Zhi En and Tan Tian Swee "Computer-Aided Knee Osteoarthritis Classification System Using Artificial Neural Network (ANN)", *Journal of Medical Imaging and Health Informatics*, Volume. 3, pp: 561-565, 2013.
- [67] J. E. Dacre And E. C. Huskisson "The Automatic Assessment Of Knee Radiographs In Osteoarthritis Using Digital Image Analysis", *British Journal of Rheumatology*, Volume 28, pp: 506-510, 1989.
- [68] Lynchf, D J Hawkes and J C Buckland-Wright "Analysis of texture in microradiographs of osteoarthritis knees using the fractal signature", *Physics in Medicine & Biology*, Vol. 36, NO 6, pp: 709-722, 1991.
- [69] Subramonium.M & Rajini.V "Support Vector Machine Approach for the Diagnosis of Arthritis from Digital X-ray Images Using Local Ternary Pattern", *Indian Journal of Applied Research*, Volume 3, Issue 9, Sept 2013.
- [70] S. Botha-Scheepers, M. Kloppenburg, H. M. Kroon ,M.-P. Hellio Le Graverand, F. C. Breedveld "Brief report Fixed-flexion knee radiography: the sensitivity to detect knee joint space narrowing in osteoarthritis", *Osteoarthritis & Cartilage*, *Osteoarthritis Research Society International*, Volume 15, pp: 350-353, 2007.
- [71] M.B. Kinds , P.M.J. Welsing, E.P. Vignon , J.W.J. Bijlsma , M.A. Viergever ,A.C.A. Marijnissen , F.P.J.G. Lafeber "A systematic review of the association between radiographic and clinical osteoarthritis of hip and knee", *Osteoarthritis & Cartilage*, *Osteoarthritis Research Society International*, Volume 11, pp: 768-778, 2011.
- [72] Chueh-Loo Poh,, Richard I. Kitney and Shahid Akhtar "Web-Based Multilayer Viewing Interface for Knee Cartilage", *IEEE Transactions On Information Technology In Biomedicine*, Vol. 13, No. 4, July 2009.
- [73] C.-L. Poh and R. I. Kitney "Cartilage Thickness Visualization Using 2D Wear maps And Trackback" *Proceedings Of The 29th Annual International Conference Of The IEEE EMBS*, August 23-26, 2007.
- [74] C.-L. Poh and R. I. Kitney" Viewing Interfaces For Segmentation And Measurement Results", *Proceedings of The 2005 IEEE Engineering In Medicine And Biology 27th Annual Conference*, Shanghai, China, September 1-4, 2005.
- [75] Tong Kuan Chuah, Chueh Loo Poh, Kenneth Sheah "Quantitative Texture Analysis Of MRI Images For Detection Of Cartilage-Related Bone Marrow Edema" *33rd Annual International Conference of the IEEE EMBS Boston*, Massachusetts USA, August 30 - September 3, 2011.
- [76] Liang Shan, Christopher Zach, Marc Niethammer "Automatic Three-Label Bone Segmentation from Knee MR Images", *Biomedical Imaging*, ISBN- 978-1-4244-4125-9, pp:1325-1328,@2010 IEEE.
- [77] Liang Shan, Cecil Charles "Automatic Atlas-based Three-label Cartilage Segmentation from MR Knee Images", *Biomedical Image Analysis*, pp: 241-246, 2012.
- [78] Jincheng Pang, Jeffrey B. Driban, Timothy E. McAlindon, Jose G. Tamez-Pena, , Jurgen Fripp, and Eric L. Miller "On the Use of Coupled Shape Priors for Segmentation of Magnetic Resonance Images of the Knee", *IEEE Journal Of Biomedical And Health Informatics*, Vol. 19, No. 3, May 2015.
- [79] Jurgen Fripp, Stuart Crozier, Simon Warfield "Automatic Initialization of 3D Deformable Models for Cartilage Segmentation", *Proceedings of the Digital Imaging Computing: Techniques and Applications (DICTA 2005)* , © 2005 IEEE.
- [80] Chhanda Ray, Krishnendu Sasma "A New Approach for Clustering of X-ray Images", *IJCSI International Journal of Computer Science Issues*, ISSN: 1694-0784, Vol. 7, Issue 4, No 8, July 2010.
- [81] S.K.Mahendran and S.Santhosh Baboo "Automatic Fracture Detection Using Classifiers- A Review", *IJCSI International Journal of Computer Science Issues*, ISSN: 1694-0814, Vol. 8, Issue 6, No 1, November 2011.
- [82] Ernest L. Hall,Richard P. Kruger, Samuel J. Dwyer, David L. Hall, Robert W. McLaren And Gwilym S. Lodwick " A Survey Of Pre processing And Feature Extraction Techniques For Radiographic Images", *IEEE Transactions On Computers*, Vol. C-20, No. 9, September 1971.
- [83] G.Behiels, D. Vandermeulen, F.Maes, P.seutens, P.Dewaele "Active Shape Model Based Segmentation of Digital X-ray Images", *Second International Conference*, Cambridge, UK, September 19-22, ISBN- 978-3-540-66503-8, Volume 1679, pp: 128-137, 1999.
- [84] Bram van Ginneken, Alejandro F. Frangi, Joes J. Staal, Bart M. ter Haar Romeny, and Max A. Viergever "Active Shape Model Segmentation with Optimal Features", *IEEE Transactions On Medical Imaging*, Vol. 21, No. 8, August 2002.
- [85] Gert Behiels, Dirk Vandermeulen, Paul Suetens "Statistical Shape Model-Based Segmentation Of Digital X-Ray Images", @2000 IEEE.
- [86] Mohammad Reza Zare, Woo Chaw Seng, Ahmed Mueen "Automatic Classification Of Medical X-Ray Images", *Malaysian Journal of Computer Science*. Vol. 26, Issue 1, 2013.
- [87] Charles Peterfy & Manish Kothari "Imaging Osteoarthritis: Magnetic Resonance Imaging Versus X-ray", *Current Rheumatology Reports*, ISSN 1523-3774, Volume 8, pp:16-21, 2006.
- [88] Tong-Yee Lee and Chao-Hung Lin "Feature-Guided Shape-Based Image Interpolation", *IEEE Transactions On Medical Imaging*, Vol. 21, No. 12, December 2002.
- [89] D. E. Dupuis, B. D. Beynonn, M. J. Richard , J. E. Novotny ,J. M. Skelly and S. M. Cooper "Precision And Accuracy Of Joint Space Width Measurements Of The Medial Compartment Of The Knee Using Standardized MTP Semi-Flexed Radiographs", *Osteoarthritis & Cartilage*, *Osteoarthritis Research Society International*, Volume 11, pp: 716-724, 2003.
- [90] Heiko Seim, Dagmar Kainmueller, Hans Lamecker, Matthias Bindernagel,Jana Malinowski, and Stefan Zachow "Model-based Auto-Segmentation of Knee Bones and Cartilage in MRI Data", *Medical Image Analysis for the Clinic: A Grand Challenge*, Beijing ,2010.
- [91] P. Ravaut, G.-R. Auleley, C. Chastang, B. Rouselin.T L. Paolozzi,F B. Amor and M. Dougados "Knee Joint Space Width Measurement: An Experimental Study Of The Influence Of Radiographic Procedure And Joint Positioning", *British Journal of Rheumatology*, Volume 35, pp:761-766, 1996.

- [92] Hillary J. Braun, Garry E. Gold "Diagnosis of osteoarthritis: Imaging", *Bone*, Volume 51, Issue 2, pp: 278-288, 2012.
- [93] Olcay Sertel, Jun Kong, Gerard Lozanski, Arwa Shana'ah, Umit Catalyurek, Joel Saltz, Metin Gurcan "Texture Classification Using Nonlinear Color Quantization: Application To Histopathological Image Analysis", ©2008 IEEE.
- [94] T. Woloszynski, P. Podsiadlo, G. W. Stachowiak, M. Kurzynski "A signature dissimilarity measure for trabecular bone texture in knee radiographs", *Medical Physics*, Volume 37, 2010.
- [95] J. Zhang And M. Marsza\_Lek "Local Features and Kernels for Classification of Texture and Object Categories: A Comprehensive Study", *International Journal of Computer Vision*, @2006 Springer.
- [96] Sugandha Agarwal, Yash Joshi, O.P. Singh, Deepak Nagaria "Analysis of Linear Filtering Techniques on X-Ray Image", 5th International Conference on Computer and Communication Technology, @2014 IEEE.
- [97] Bing Luo, Zhongyu Sun, Min Xue, Hongbo Liu "Improved Noise Reduction Algorithms for Medical X-Ray Images", @2013 IEEE.
- [98] Tarek A. Mahmoud, Stephen Marshall "Medical Image Enhancement Using Threshold Decomposition Driven Adaptive Morphological Filter", 16th European Signal Processing Conference (EUSIPCO 2008), Switzerland, August 25-29, 2008.
- [99] Lijun Yin, Anup Basu, Ja Kwei Chan "Scalable Edge Enhancement With Automatic Optimization For Digital Radiographic Images", @ 2004 Pattern Recognition Society.
- [100] H.C. Chen, C.H. Wu, C.J. Lin, Y.H. Liu, and Y.N. Sun "Automated Segmentation for Patella from Lateral Knee X-ray Images", 31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota, USA, September 2-6, 2009.
- [101] Shubhangi D.C, Raghavendra S.Chinchansoor, P.S.Hiremath "Edge Detection of Femur Bones in X-ray images - A comparative study of Edge Detectors", *International Journal of Computer Applications*, ISSN-0975 - 8887, Volume 42-No.2, March 2012.
- [102] Pierre Gravel, Gilles Beaudoin, and Jacques A. De Guise "A Method for Modeling Noise in Medical Images", *IEEE Transactions on Medical Imaging*, Vol. 23, No. 10, October 2004.
- [103] Jorge I. Galvan-Tejada, Jose M. Celaya-Padilla, Victor Trevino, Jose G. Tamez-Pena "Knee Osteoarthritis Pain Prediction from X-ray Imaging: Data from Osteoarthritis Initiative", ©2014 IEEE.
- [104] C. B. Chang, I. Han, S. J. Kim, S. C. Seong, T. K. Kim "Association between radiological findings and symptoms at the patella femoral joint in advanced knee osteoarthritis", *The Journal Of Bone And Joint Surgery* ©2007 British Editorial Society.
- [105] Ji Lei-feng, Li Yu-rong "Diagnosis of knee osteoarthritis based on Kalman filter", ©2012 IEEE.
- [106] Nora Baka, Bart L. Kaptein, J. Erik Giphart, Marius Staring, Marleen de Bruijne, Boudewijn, P.F. Lelieveldt, Edward Valstar "Evaluation of automated statistical shape model based knee kinematics from biplane fluoroscopy", *Journal of Biomechanics*, Volume, pp:122-129, 2014.
- [107] P. Bhaskara Rao D. Vara Prasad Ch. Pavan Kumar "Feature Extraction Using Zernike Moments", *International Journal of Latest Trends in Engineering and Technology (IJLTET)*, ISSN: 2278-621X, Vol. 2 Issue 2, March 2013.
- [108] Yang Mingqiang, Kpalma Kidiyo and Ronsin Joseph "A Survey of Shape Feature Extraction Techniques", *Pattern Recognition Techniques, Technology and Applications*, Book edited by: Peng-Yeng Yin, ISBN 978-953-7619-24-4, pp. 626, November 2008.
- [109] Yogapriya Jaganathan and Ila Vennila "A Hybrid Approach Based Medical Image Retrieval System Using Feature Optimized Classification Similarity framework", *American Journal of Applied Sciences*, ISSN: 1546-9239, Volume 10 Issue 6, pp: 549-562, 2013.
- [110] Stephanie de Graaff, Jos Runhaar, Edwin H Oei, Sita M Bierma-Zeinstra, Jan H Waarsing "The Association Between Knee Joint Shape And Osteoarthritis Development In Middle-Aged, Overweight And Obese Women", *Erasmus Journal of Medicine*, Volume 4, No 2 - March 2015.
- [111] B.Jyothi, Y.Madhavee Latha, P.G.Krishna Mohan, V.S.K.Reddy "Medical Image Retrieval Using Moments", *International Journal of Application or Innovation in Engineering & Management (IJAIEEM)*, ISSN 2319 - 4847, Volume 2, Issue 1, January 2013.
- [112] Mason Ainouri, Jasim Al Saei, Manaf Younis, Fadi Bouri, Mohamed Ali Al Habash, Mohammed Hamza Shah and Mohammed Al Dosari "Comparison of Edge Detection Algorithms for Automated Radiographic Measurement of the Carrying Angle", *Journal of Biomedical Engineering & Medical Imaging*, Volume 2, Issue 6, Dec 2015.
- [113] Thomas Janvier, Hechmi Toumi, Khaled Harrar, Eric Lespessailles, Rachid Jennane "ROI impact on the characterization of knee osteoarthritis using fractal analysis", ©2015 IEEE.
- [114] P. Podsiadlo L. Dahl, M. Englund, L. S. Lohmander and G. W. Stachowiak "Differences in trabecular bone texture between knees with and without radiographic osteoarthritis detected by fractal methods", *Osteoarthritis and Cartilage*, volume 16, pp:323-329, 2008.
- [115] Virginia Byers Kraus, Sheng Feng, Sheng-Chu Wang, Scott White, Maureen Ainslie, Alan Brett, Anthony Holmes and H. Cecil Charles "Trabecular Morphometry by Fractal Signature Analysis Is a Novel Marker of Osteoarthritis Progression", *Arthritis & Rheumatism*, Vol. 60, No. 12, pp 3711-3722, December 2009.
- [116] Elizabeth A. Messent, Rupert J. Ward., Carol J. Tonkin and Christopher Buckland-Wright D.Sc "Tibial cancellous bone changes in patients with knee osteoarthritis: A short-term longitudinal study using Fractal Signature Analysis", *Osteoarthritis and Cartilage*, volume 13, pp: 463-470, 2005.
- [117] Shan Li, Moon-Chuen Lee and Chi-Man Pun "Complex Zernike Moments Features for Shape-Based Image Retrieval", *IEEE Transactions On Systems, Man, And Cybernetics—Part A: Systems And Humans*, Vol. 39, No. 1, January 2009.
- [118] B.S. Manjunathi and W.Y. Ma "Texture Features for Browsing and Retrieval of Image Data", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 18, NO 8, August 1996.
- [119] Alice Porebskil, Nicolas Vandenbroucke & Ludovic Macaire "Haralick feature extraction from LBP images for color texture classification", @2008 IEEE.
- [120] C R Donoghue, A Rao, A M J Bull and D Rueckert "Learning Osteoarthritis Imaging Biomarkers Using Laplacian Eigen map Embeddings With Data From The OAI", @2014 IEEE.
- [121] Jian Tang, Xiangdong Jiao "Research Progress of Digitized Medical X-ray Imaging System", *International Conference on*



- Computer Science and Information Processing (CSIP), @2012 IEEE.
- [122] Pazit Levinger , Daniel T.H. Lai , Rezaul Begg , Kate Webster, Julian Feller and Wendy Gilleard "The application of multiclass SVM to the detection of knee pathologies using kinetic data: a preliminary study", @2007 IEEE.
- [123] Li Xiong, Subramanyam Chitti, Ling Liu "Mining Multiple Private Databases Using a k-NN Classifier", Symposium on Applied Computing (SAC) Proceedings of 2007, ISBN:1-59593-480-4, pp:435-440, March 2007.
- [124] N. Suguna, and Dr. K. Thanushkodi "An Improved k-Nearest Neighbor Classification Using Genetic Algorithm", IJCSI International Journal of Computer Science Issues, ISSN: 1694-0814, Vol. 7, Issue 4, No 2, July 2010.
- [125] James Cheong, David Suter and Flavia Cicutini "Development of Semi-automatic Segmentation Methods for Measuring Tibial Cartilage Volume", Proceedings of the Digital Imaging Computing: Techniques and Applications, @2005 IEEE.
- [126] M. Sardaescu, N. Paragios, N. Komodakis, R. Raymond, P. Hernigou, and A. Rahmouni "Knee Reconstruction Through Efficient Linear Programming", Biomedical Imaging, ISBN-978-1-4244-2002-5, pp:664-667, @2008 IEEE.
- [127] G. Neumann, D. Hunter, M. Nevitt, L. B. Chibnik, K. Kwok, H. Chen, T. Harris, S. Satterfield and J. Duryea "Location specific radiographic joint space width for osteoarthritis Progression", Osteoarthritis and Cartilage, volume17, pp:761-765, 2009.
- [128] J. Duryea, Li, C. G. Peterfy, C. Gordon and H. K. Genant "Trainable rule-based algorithm for the measurement of joint space width in digital radiographic images of the knee", American Association of Physicists in Medicine, Medical Physics, Vol. 27, No. 3, March 2000.
- [129] W.M. Reichmann , J.F. Mailefert, D.J. Hunter, J.N. Katz , P.G. Conaghan , E. Losinav "Responsiveness to change and reliability of measurement of radiographic joint space width in osteoarthritis of the knee: a systematic review", Osteoarthritis and Cartilage, volume19, pp: 560-556, 2011.
- [130] R. D. Altman & G. E. Gold "Atlas of individual radiographic features in osteoarthritis, revised", Osteoarthritis and Cartilage, volume15, pp: A1-A56, 2007.
- [131] K.Sreedhar and B.Panlal "Enhancement Of Images Using Morphological Transformations", International Journal of Computer Science & Information Technology (IJCSIT), Volume 4, No 1, Feb 2012.
- [132] G.Anil Kumar, Nistala V.E.S.Murthy "Analysis of Medical Image Processing and its Applications in Healthcare Industry", International Journal Computer Technology & Applications, ISSN: 2229-6093, Volume 5 Issue 3, pp: 851-860, 2014.
- [133] Ismail Anas , Tabari Abdulkadir Musa , Isyaku Kabiru , Abdulkadir Adekunle Yisau , Idris Sulaiman Kazaure , Suwaid Muhammad Abba , Saleh Muhammad Kabir "Digital radiographic measurement of normal knee joint space in adults at Kano, Nigeria", The Egyptian Journal of Radiology and Nuclear Medicine, Volume 44, pp:253-258, 2013.
- [134] Kelvin K. Leung, Mark Holden, Nadeem Saeed, Keith J. Brooks, Jacky B. Buckton, Ann A. Williams, Simon P. Campbell, Kumar Changani, David G. Reid, Yong Zhao, Mike Wilde, Daniel Rueckert, Joseph V. Hajnal, and Derek L. G. Hill "Automatic Quantification of Changes in Bone in Serial MR Images of Joints", IEEE Transactions on Medical Imaging, Vol. 25, No. 12, Dec-2006.
- [135] Ingrid Scholl, Til Aach, Thomas M. Deserno, Torsten Kuhlen "Challenges of medical image processing", Computer Science Res Dev, Volume 26, pp: 5-13, © Springer-Verlag 2010.
- [136] Ying Shen and Weihua Zhu " Medical Image Processing using A Machine Vision-based Approach", International Journal of Signal Processing, Image Processing and Pattern Recognition Vol. 6, No. 3, June, 2013.
- [137] Til Aach , Ulrich Schiebel and Gerhard Spekowius "Digital Image Acquisition and Processing in Medical X-Ray Imaging", Journal of Electronic Imaging, Institute of Imaging & Computer Vision, ISSN 1017-9909 ,Volume 8, Issue 1, pp: 7-22, 1999.
- [138] Jukka Hirvasniemi "Novel X-Ray-Based Methods for Diagnostics of Osteoarthritis", University Of Oulu, Institute of Clinical Medicine and Department of Applied Physics, 2015.
- [139] Flavia Cicutini, Andrew Forbes, Kevin Morris, Sandy Darling, Michael Bailey & Stephen Stuckey "Gender differences in knee cartilage volume as measured by magnetic resonance imaging", Osteoarthritis and Cartilage, volume7, pp: 265-271, 1999.
- [140] D.J. Hunter, M.A. Bowes , C.B. Eaton , A.P. Holmes , H. Mann, C.K. Kwok, R.A. Maciewicz J. Samuels, J.C. Waterton "Can cartilage loss be detected in knee osteoarthritis (OA) patients with 3-6 months' observation using advanced image analysis of 3 T MRI?", Osteoarthritis and Cartilage, volume18, pp: 677-683, 2010.
- [141] Steven A. Mazzuca, Kenneth D. Brandt, and Kenneth A. Buckwalter "Detection of Radiographic Joint Space Narrowing in Subjects with Knee Osteoarthritis", Arthritis & Rheumatism, Vol. 48, No. 2, pp 385-390, February 2003.
- [142] Ehsan Saadat & Sharmila Majumdar "Magnetic Resonance Imaging of Cartilage—Detecting Early Degeneration and Monitoring Post-operative Improvement", US Musculoskeletal Review, 2007.
- [143] Hari Krishnan G, Dr. Ananda Natarajan R & Dr. Anima Nanda "Predicting Osteoarthrosis Disease Stages using Imaging Technique", International Journal of Research in Engineering and Technology (IJRET), ISSN 2277 – 4378, Vol. 2, No. 4, 2013.
- [144] Pooja P. Kawathekar & Kailash Karande "Severity analysis of Osteoarthritis of knee joint from X-ray images: A Literature review", @2014 IEEE.
- [145] Bhavyashree K G, Sheela Rao N "Determination and Analysis Of Arthritis Using Digital Image Processing Techniques", International Journal of Electrical, Electronics and Data Communication, ISSN: 2320-2084, Volume-2, Issue-9, Sept.-2014.
- [146] Mayuresh Kulkarni "X-ray Image Segmentation using Active Shape Models", A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of B.Sc. In Electrical Engineering at The University Of Cape Town, 21 October 2008.
- [147] Jenny Folkesson "Statistical Classification and Level Set Methods in Medical Image Analysis Quantitative Evaluation of Articular Cartilage in Knee MRI", University of Copenhagen Faculty of Science Department of Computer Science 2007.
- [148] Margot B Kinds "Checking radiographic joint damage in early osteoarthritis", Thesis defense: January 24th 2012.
- [149] Joselene Marques "Osteoarthritis Imaging by Quantification of Tibial Trabecular Bone", PhD Thesis, Faculty Of Science University Of Copenhagen, 2012.
- [150] Ngo Quang Long "Image Processing On Medical Application: Automatic Methods To Calculate The Area Of

- An Articular Cartilage On A Magnetic Resonance Image", School of Engineering, University of Tasmania, July 2011.
- [151] Sheyyed Mohammad Mohammadi, Mohammad Sadegh Helfroush & Kamran Kazemi "Novel Shape Texture Feature Extraction For Medical X-Ray Image Classification", International Journal of Innovative Computing, Information & Control, Issn:1349-4198, Volume 8, issue 1, Jan 2012.
- [152] S. Kubilay, Roger S. Gaborski, Lori L. Barski, Dave. H. Foos, Kevin J. Parker "Segmentation Of Bone & Soft Tissue Regions In Digital Radiographic Images Of Extremities", Medical imaging, Proceedings of SPIE, volume 4322, 2001.
- [153] Wing P Chan, Philipp Lang, Michael P Stevens, Kenneth Sack, Sharmila Majumdar, David W Stoller, Christa Basch, Harry K Genant "Osteoarthritis Of Knee: Comparison Of Radiography, CT & MR Imaging Access Extent & Severity", American Journal of Roentgenology (AJR), Volume 157, Issue 4, pp:799-806, October 1991.
- [154] T. F. Chan, L. A. Vese, "Active contours without edges" IEEE Transactions on Image Processing, Volume 10, Issue 2, pp. 266-277, 2001.
- [155] V. Caselles, R. Kimmel, G. Sapiro, "Geodesic active contours", International Journal on Computer Vision, Volume 22, Issue 1, pp. 61-79, 1997.
- [156] S. S. Gornale, Gautam Kudle, "Performance Analysis of Edge Detection Methods for Medical Images", Proceedings of National Conference on Advancement in Information Technology and Internet Security, SIBAR Pune 4-5 Jan, 2008. ISBN 10:81-840-27-5, 13:978-81-8404-427-0, PP 27-36.
- [157] Mihran Tuceryan and Anil K Jain, "Texture Analysis", Chapter 2.1, PP:01-40, The Handbook of Pattern Recognition and Computer Vision (2nd Edition), by C H Chen, L. F Pau, P.S.P. Wang, PP:207-248, World Scientific Publishing C., 1998.
- [158] Sagar Jamborkar and S. S. Gornale et al., "A Novel Approach for Segmentation of Good Normal and Bad Quality Fingerprint Image" International IEEE-TENCON 14th -17th, November 2006, HONG-KONG.
- [159] Eckstein F, Boudreau R, Wang Z, Hannon MJ, Duryea J, Wirth W, Cotofana S, Guermazi A, Roemer F, Nevitt M, John MR, Ladel C, Sharma L, Hunter D J, Kwok CK, Investigators OAI. "Comparison of radiographic joint space width and magnetic resonance imaging for prediction of knee replacement: A longitudinal case-control study from the Osteoarthritis Initiative" Eur Radiol, ©European Society of Radiology 2015.
- [160] Riddle DL, Jiranek WA. "Knee Osteoarthritis Radiographic Progression And Associations With Pain And Function Prior To Knee Arthroplasty: A Multicenter Comparative Cohort Study", Osteoarthritis Cartilage. Volume 23, pp:391-396.
- [161] Tony F. Chan and Luminita A. Vese "Active Contours Without Edges", IEEE Transactions On Image Processing, Vol. 10, No. 2, February 2001.
- [162] A Batsis, A J Zbehlík, LK Barre, JPW Bynum, D Pidgeon & SJ Bartels "Impact of obesity on disability, function, and physical activity: data from the Osteoarthritis Initiative", Scandinavian Journal of Rheumatology, ISSN: 0300-9742, 2015.
- [163] Michael A Bowes, Graham R Vincent, Christopher B Wolstenholme, Philip G Conaghan "A Novel Method For Bone Area Measurement Provides New Insights Into Osteoarthritis And Its Progression", Annals of the Rheumatic Diseases The Euler Journals, Volume 74, pp: 519-525, 2015.
- [164] Vicent Caselles Ron Kimmel Guillermo Sapiro "Geodesic Active Contours", International Journal of Computer Vision, Volume 22, Issue 1, pp: 61-79, 1997.
- [165] Nobuyuki Otsu "A Threshold Selection Method from Gray-Level Histograms", IEEE Transactions on Systems, Man and Cybernetics, Volume 9, No. 1, January 1979.
- [166] Yang Xiang, Albert C.S. Chung, Jian Ye "An Active Contour Model for Image Segmentation Based On Elastic Interaction", Science Direct, Journal of Computational Physics, Volume 219, pp: 455-476, 2006.
- [167] Leo Breiman "Random Forests" Machine Learning, Volume: 45, pp: 5-32, 2001 © 2001 Kluwer Academic Publishers. Manufactured in The Netherlands.
- [168] Frank W. Reomer "Joint Imaging", © FACT SHEET No. 15 2016 International Association for the Study of Pain.

**Table 2.1 Segmentation Techniques for OA Detection**

SI No	Author Name	Segmentation Techniques	Results
1.	Samir K.Bandyopadhyay [3] (2011)	Edge detection method is used for the diagnose of the disease that includes Contrast enhancement & thresholding for patella feature point extraction	Reduced computational complexities & has significantly good result
2.	Prafull Sharma et al [11] (2013)	Segmentation of X-ray bone image using Watershed, Otsu's and Discrete step algorithms are used along with Image sharpening, edge detection and morphological operations	The algorithm provides quick and efficient result to analyze the problems related to bone structures.
3.	Bindushree R et al[12] (2015)	Canny edge algorithm contrast enhancement, histogram equalization, thresholding are used on knee x-ray images.	The joint space width obtained is compared with standard value and classified as normal or affected OA.
4.	Lilik Anifah et al [40] (2011)	Contrast limited adaptive histogram equalization (CLAHE) & template matching methods are used to segment the joint space area of knee.	Experiment 4 gave 100% accuracy and in second step experiment 2 gave 92.63% of accuracy for right knee and 87.37% for left knee.
5.	Mahima Shanker Pandey et al [39] (2015)	The computer automated system is used for the identification of OA using Gaussian low pass filter & neighbouring pixel method. The thickness measurement is carried out using Euclidian distance measure.	The segmentation method used demonstrated 90% of accuracy in detecting OA disease.
6.	Jessie Thomson et al [41] (2015)	Statistical shape model & RFCL model is used to find the outlines of the bones of knee joint.	The experiments gave overall classification rate of 84.9% of accuracy.
7.	Tati L.Mengko et al[48] (2005)	Edge detection method is used to determine the region of joint space in OA.	50% sensitivity, 100% specificity & positive predictive value & 91.84% negative predictive value.
8.	Hung-Chun Lee et al[50] (2006)	Active shape Models (ASM) is used for evaluating knee x-ray image.	Parameters computed are found to be satisfactory & useful in Knee OA detection.
9.	Chhanda Ray et al [80] 2010	Automatic clustering of X-ray images is done by K-means method	K-means & hierarchical clustering produces very high level of accuracy
10.	J I Lei-feng et al[105]2012	Non invasive method is used for detection of OA using Kalman filter.	Accuracy rate of each muscle was approximately above 82%.
11.	Pooja P. Kawathekar et al[144]2014	Distance based active shape model method is used to calculate the parameter causing OA.	Accuracy of 93.8% for KL-0, 70% for KL-1, 4% for KL-2, 10% for KL-3 & 88.9% for KL-4 was achieved.
12.	Bhagyashri L. Wagaj et al [2](2015)	Pixel based segmentation & texture filter based method is used to classify the disease.	Among 32 images 16 were classified as normal OA with 100% accuracy & 16 images as OA affected with 96.87% of accuracy
13.	Nadeem Mahmood et al [9] (2015)	Edge detection methods like Sobel, Prewitt Robert, Zero cross & Canny edge methods were used to visualize knee joint cartilage.	Canny edge detection method works well with the given images as compared to other methods.
14.	M.Kakshmi Kumara et al[13] (2015)	Otsu's algorithm, Vertical edge detection method, Automatic region detection method, Euclidian algorithm & connected component algorithm are used.	Cartilage thickness of knee was successfully carried out.
15.	Ahmet Alkan [33] (2011)	Fuzzy c-means clustering & morphological filtering operations are used for MRI segmentation.	Results demonstrated 72% classification accuracy rate
16.	Jeffrey W.Prescott et al[51] 2009	Fully automated segmentation & Morphological techniques are used to compute femur medulla & cortex.	Strong relationship between femur CSA & KL grades for females was achieved.
17.	Sanjeevkumar Kubakkaddi et al[56] 2013	Adaptive histogram equalization method is used for segmentation of Articular cartilage.	Thickness of cartilage was successfully computed
18.	Jeffrey W. Prescott et al[61] 2009	Automated method is used to segment the adipose tissue of thigh muscle using MR images.	Specificity of 67% & sensitivity of 82% was obtained.

19.	Jurgen Fripp et al[64] 2010	Bone-cartilage interface (BCI) was computed using active shape model & deformable model.	The robust results provided a good estimate of the "global" affine deformation between the images
20.	James Cheong et al[125] 2005	The two methods canny edge & active shape model (ASM) scheme are used for diagnosis of OA.	Both the methods resulted in standard segmentation & measurement accuracy.

Table 2.2 Feature Extraction Techniques for OA analysis

Sl no	Authors name	Feature Extraction	Results
1.	Lior Shamir et al [1] (2008)	Detection of OA based feature extraction techniques. The features computed were Zernike features, Multi scale histograms, Tamura texture features, Haralick feature, statistical features	95% of moderate OA and 80% of minimal OA was differentiated from normal.
2.	Lior Shamir et al [4] (2009)	The features computed were Random transform features, Chebyshev Statistics, Gabor filter, Multi-scale histograms, First 4 moments, Tamura texture features, Edge statistics features.	Prediction of moderate OA after 20 years gave 72% of accuracy & mild OA gave 62% of accuracy
3.	Subramoniam M et al [32](2015)	Haralick feature extraction technique & SVM classifier with kernel function is used for detection & classification of OA.	Classification rate of 99% in the detection of OA is achieved.
4.	Lior Shamir et al [35] (2010)	High Contrast features, Haralick features, Tamura features and Statistical features are used & classified using Weighted Nearest Neighbour classifier.	Bone texture shows no significant difference between KL grade 0 & KL grade 1. The bone structure alterations were observed clearly after grade 2 onwards.
5.	Subromonium.M et al[69] (2013)	Local ternary Pattern (LTP) is used for assessment of OA using x-ray images. The LTP features were computed & classified using Support Vector Machine (SVM) approach.	Linear & Polynomial functions gave 91.66% of specificity & 80% of sensitivity. RBF gave 94.59% of specificity & 66.66% of sensitivity.
6.	Virginia Byers Kraus et al[115] 2009	Statistical Analysis of fractal signatures was performed to predict the progression of knee OA. Features were computed using statistical shape modelling technique	Accuracy rate of 75% was obtained related to joint space narrowing.
7.	Dipali D.Deokar et al [5] (2015)	Artificial Neural Networks & feature extraction techniques are used to detect knee OA. Grey level Co-occurrence Matrix (GLCM) textural features, Statistical feature, Shape feature were computed	92% of accuracy rate was achieved in detecting the disease
8.	B.G.Ashinsky et al [36](2015)	MRI classification is proposed using Pattern recognition & multilevel regression with WND-CHRM method. Texture features, statistical features, Polynomial decomposition of raw image were computed.	86% of accuracy rate was obtained.
9.	Neila Mezghani et al[52] 2008	The gait patterns technique is used for 3D images of knee OA. Features were computed using GRF vectors & classified using Nearest Neighbour rule.	91% of classification rate was obtained.
10.	Tong Kuan Chuah et al[75] 2011	Quantitative texture analysis using MR images. Features computed were mean intensity, standard deviation, smoothness, third moment, uniformity & entropy	Third moment is strong parameter to be used for distinguishing two groups.

**Table 2.3 Classification methods for OA exploration**

Sl No	Authors name	Classification Technique	Result
1.	M.Subramoniam et al [8] (2013)	Classification of OA based on Local binary pattern (LBP) is used. Euclidian, Cosine, Manhattan, correlation features using K-nearest neighbour classifier	Correlation distance measure produces 93% classification rate among all the cases.
2.	Dian Pratiwi et al [14] (2011)	Classification technique based on Artificial neural network is used to measure the severity of Osteoarthritis disease.	66.6% of accuracy rate is achieved.
3.	Sreeparna Banerjee et al[60] (2009)	Cellular neural network (CNN) based techniques is used for detecting and classification of Osteoarthritis	Cysts & osteophytes were successfully diagnosed using CNN technique.
4.	B.G.Ashinsky et al [36](2015)	MRI classification is proposed using Pattern recognition & multilevel regression with WND-CHRM method.	86% of accuracy rate was obtained.

**Table 2.4 Dataset used in the literature**

Sl.No	Author Name	Data Set/Sample size	Remark
1.	Lior Shamir [1]	350 X-Ray Images	Created own database
2.	Bhagyashri L.Wagaj [2]	32 MRI joint images were collected	Created own database
3.	Lior Shamir [4]	150 weight bearing Knee X-Ray images	Created own database
4.	Dipali D.Deokar [5]	100 Testing & 50 images for Training Respectively	Created own database
5.	M. Subramoniam [8]	50 Knee X-Ray images	Created own database
6.	Dian Pratiwi [14]	60 X-Ray images	Created own database
7.	Wei-Chun Lin [31]	144 MRI images	Created own database
8.	S M, Barani [32]	130 digital X-Ray images	Created own database
9.	Ahmet Alkan [33]	103 MRI images	(www.oai.ucsf.edu)
10.	Lior Sharmir [35]	45 X-Ray images for Training & 150 for Testing	Created own database
11.	Jessie Thomson [41]	31 X-Ray & MRI of right Knee	Created own database
12.	M.S Pandey [39]	100 Knee X-Ray images	Created own database
13.	Lior Shamir [54]	300 X-Ray images	Created own database
14.	Tati L.Mengko [48]	53 Knee X-Ray images	Created own database
15.	Hung Chun [50]	60 X-Ray images	Created own database
16.	Jeffrey W.Prescott [51]	103 MRI images	(www.oai.ucsf.edu)
17.	Chuah Zhi En [66]	200 MRI images for Training & 150 for Testing	(www.oai.ucsf.edu)
18.	H.Oka [49]	1979 radiograph Images	Created own database
19.	Jenny Folkesson [63]	139 MRI images	Created own database
20.	Subramonium.M [69]	50 X-Ray images	Created own database
21.	Lilik Anifah [45]	303 and 50 for Training & 258 for Testing Respectively	Created own database
22.	Lilik Anifah [40]	98 X-Ray impaired images	(www.oai.ucsf.edu)
23.	Bhagyashri L.Wagaj [2]	64 MRI images	Created own database
24.	Jessie Thomson [41]	500 X-Ray images	(www.oai.ucsf.edu)
25.	Neila Mezghani [52]	42 radiograph images	Created own database
26.	J. E. Schmidt [53]	31 bilateral Knee radiographs were obtained	Created own database
27.	Tong Kuan Chuah [75]	168 slices of MRI images	Created own database
28.	Chhanda Ray [80]	150 X-Ray images	Created own database
29.	S. Botha-Scheepers [70]	193 X-Ray images	Created own database
30.	P. Ravaud [91]	10 X-Ray images	Created own database
31.	Shubhangi D.C [101]	100 Scanned X-Ray images	Created own database
32.	C. B. Chang [104]	170 X-Ray images	Created own database
33.	Thomas Janvier [113]	1054 X-Ray images	(www.oai.ucsf.edu)
34.	Virginia Byers [115]	159 X-Ray images	Created own database
35.	C R Donoghue [120]	1131 MRI images	(www.oai.ucsf.edu)
36.	Flavia Cicuttini [139]	28 MRI images	Created own database

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