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Early detection of Knee Osteoarthritis using SVM Classifier

Sanjeevakumar Kubkaddi[1*], Dr. K M Ravikumar[2]
Research Scholar, Jain University [1] ,Principal
Bangalore, India, Phone
S.J.C.INSTITUTE OF TECHNOLOGY, Chikkaballapur, India,
Kubakaddi@gmail.com , kmravikumar@rediffmail.com

Abstract— Osteoarthritis of Knee (KOA) is the most commonly found arthritis types. It is distinguished by wearing away of cartilage which is meant to ensure smooth movement between bones in joints. As a result of the wearing away, bones slide and rub against each other and this leads to swelling, pain and eventual loss of motion. Early detection of KOA can help ensure retarded progression of the ailment. Estimation of the thickness of articular cartilage is important in determining the stage of development of KOA. The estimated cartilage thickness along with the four textural features such as contrast, correlation, energy, homogeneity and three statistical features such as mean, median, variance (totally eight) is fed as training features to SVM to automatically classify the images into KOA and non-KOA cases. The results obtained from SVM with RBF kernel, SVM with linear kernel is 95.45% and SVM with polynomial kernel is 87.8%.

Index Terms— Knee Osteoarthritis, SVM, MRI.

I. INTRODUCTION

Worldwide, over 71 million people are affected by osteoarthritis, a degenerative disease causing mechanical abnormalities in joints. This disease is distinguished by degeneration of articular cartilage. Knee osteoarthritis is becoming more common among women, obese and older people. The percentage of people affected with OA is higher in older age groups. In India, for people older than 60 years, OA prevalence is estimated to be 43% in women and 25% in men [1]. Cartilage is the ultra-slippery thin layer of high-quality hyaline material that covers the ends of bones that smoothen the movements of the joint. It is found covering the patella femoral and tibia femoral joints of knee. The tibia femoral joint experiences pressure due to body weight. In OA, the cartilage degradation leads to the bone friction which leads to wear, swelling and pain and ultimately leads to loss of motion of the joint [2]. OA may be caused due to repetitive strain, knee injury, obesity, ligament tears genetics, meniscus injury and fractures causing misalignment leading to increased wear and tear. KOA symptoms can be handled by early diagnosis and treatment.

The anatomy of knee can be well distinguished using MRI, and this makes it possible to quantify thickness of many parts of articular tissues that are of interest in diagnosing arthritis. Suitable image processing methods are applied on MRI for clear quantification of degradations.

In this work, we don't use the quantification directly, but supply the quantities as inputs to SVM algorithm which classifies the given MRI image into KOA and non KOA cases.

Active contour methods, Geometric Active Contours (GAC), Chan-Vese method are usually used for cartilage segmentation. Gradient Vector Flow (GVF) method is widely used for cartilage segmentation [3] [4]. There also is a method named Vector Field Convolution (VFC) for cartilage segmentation. Active contour methods based on localized versions of the Chan-Vese functional have been proposed. An automatic method to quantify the thickness of cartilage in tibia femoral joint of knee has also been proposed [5].

In the present work, SVM classifier to automatically classify MRI images into KOA and non KOA cases is proposed. The SVM algorithm takes the inputs from the segmentation algorithm and processes the data intelligently to classify images into KOA and non-KOA.

II. METHODOLOGY

A set of 213 images have been used in the present work. The images are known KOA cases and normal ones. 150 among them are for training and 63 for testing. Firstly features such as thickness, mean, median, variance, contrast, energy, correlation, homogeneity are extracted from the images and fed as input to the SVM classifier. Based on the training set, the rest of the 63 images are classified by the SVM into normal and KOA cases with certain prediction accuracy. The flow chart of the methodology is given in Figure 1.

1) *Image enhancement*

The input MRI images are preprocessed using few image enhancement methods such as contrast stretching, Histogram equalization and Gaussian Filtering. Figure 2 shows the input MRI KOA image.

a) *Contrast stretching* attempts to improve the contrast by distributing range of image intensity values to cover a wide range. This helps in better view of different anatomical boundaries of the knee.

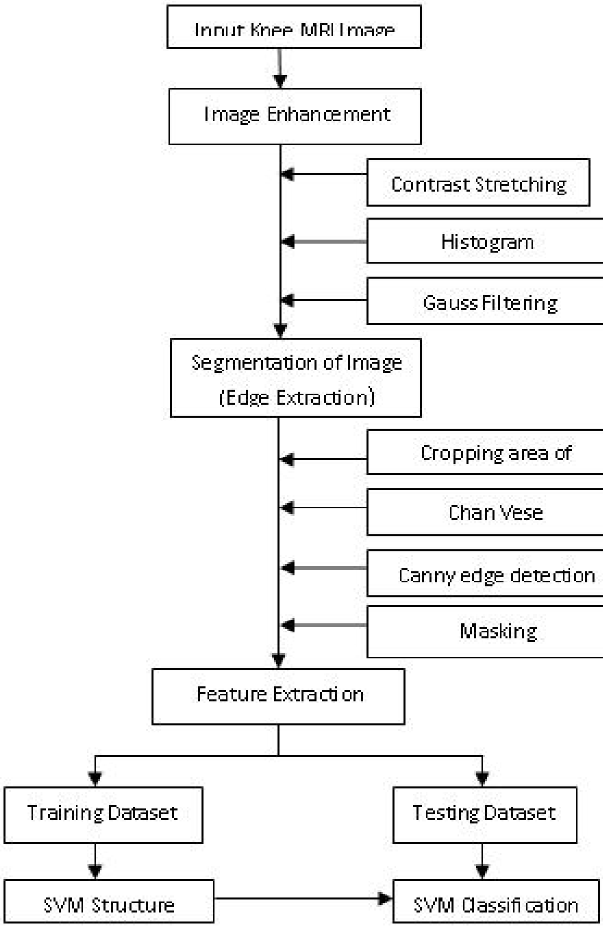

Figure 1: Flowchart of the proposed system

Figure 2: Input MRI Knee Osteoarthritis image

b) *Histogram equalization* enhances the contrast by adjusting the image intensities.

Figure 3: Histogram Equalized Image

c) *Gaussian low-pass filter* is created by using fspecial function. fspecial returns a correlation kernel, which is the suitable form to use with imfilter function. It is used to remove unnecessary high frequency edges around the cartilage.

Figure 4: Filtered Image

2) *Segmentation*

The purpose of segmentation is to separate the edge from a given image. Edge is defined as the outer boundary of the cartilage. Edge detection is carried out using the Chan Vese algorithm which works on the principle of energy minimization [6]. Before invoking the Chan Vese algorithm, the desired area of interest in the image is cropped as shown in figure 5.

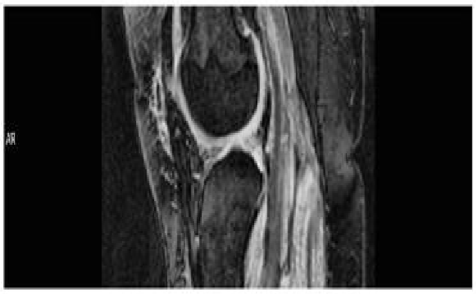

Figure 5: Region of Interest

The objective of the Chan-Vese algorithm is to minimize the energy function F (c1,c2,C) defined by:

$$F(c1,c2,C) = \mu.\text{Length}(c) + v.\text{Area}(\text{inside}(c)) + \lambda 1 \int |u0(x,y) - c1|^2 dx\,dy + \lambda 2 \int |u0(x,y) - c2|^2 dx\,dy \qquad (1)$$

Where, the first term stands for energy inside C, and the second term for the energy outside C also, $\mu \geq 0$, $v \geq 0$, $\lambda 1$ $\lambda 2 \geq 0$ are fixed parameters [5]. Figure 6 shows the segmented image after cropping.

Figure 6: Segmented Image

After Chan Vese segmentation canny edge detection is used followed by masking to improve edge detection results.

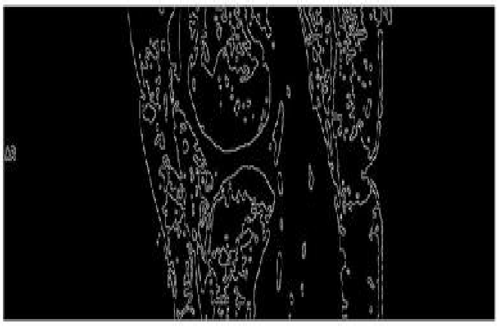

Figure 7: Canny Edge Detected image

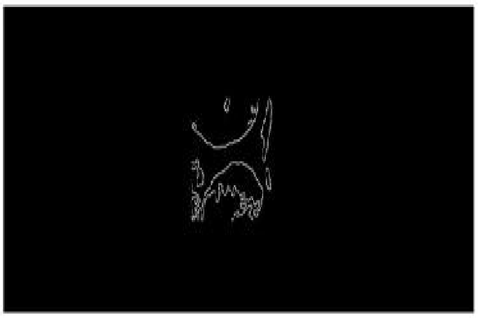

Figure 8: Masked Image

3) Feature extraction

The cartilage thickness is the parameter of interest and all other parameters are supporting parameters. The cartilage thickness is determined as the minimum straight line distance among two white pixels in a black and white picture.

GLCM Matrix of an image is determined which gives textural features such as contrast, correlation, energy and homogeneity [6].

We also determine the statistical features of the cropped image such as: mean, median, variance. The four textural features and three statistical features along with the thickness (totally eight) are fed as training features to the SVM classifier.

a) Gray level Co-occurrence Matrix (GLCM)

The GLCM is a tabulation of how frequently different combinations of pixel brightness values (grey levels) occur in an image. According to the number of intensity points (pixels) in each combination, statistics are categorized into first-order, second order and higher statistics. The Gray Level Co-occurrence Matrix (GLCM) is a method of extracting second order statistical texture features. Following equations shows features extracted from GLCM Matrix [6].

Contrast $= \sum_{i,j} (i - j)^2 \, p(i, j)$ (2)

Correlation $= \sum_{i,j} (i - \mu)(j - \mu) / \sigma^2 \, p(i, j)$ (3)

Energy $= \sum_{i,j} p(i,j)^2$ (4)

Homogeneity $= \sum_{i,j} p(i,j) / \{1 + (i - j)^2\}$ (5)

b) Statistical Features

The statistical features extracted from cropped image are mean, median and variance. The following equations describe these features [6].

Mean $\mu = \sum_{i,j} p(i,j)$ (6)

Variance $\sigma^2 = \sqrt{\sum_{i,j} (i - \mu)^2 \, p(i,j)}$ (7)

Median $= \sum_{i,j} \{p(i,j) / (i,j)\}$ (8)

4) Classification by SVM Classifier

Support vector classification is a binary classifier. It is categorized as linearly separable, linearly inseparable and non-linearly separable. The aim of SVM modeling is to find the optimal hyperplane that separates clusters of vector into two groups. The original optimal hyperplane algorithm was a linear classifier. Then, nonlinear classifiers were developed by applying the kernel trick to maximum margin hyperplanes. This permits the algorithm to fit the maximum-margin hyperplane in a transformed feature space. Data points which lie on the hyperplane are called as Support Vectors (SVs) as shown in Figure 7. These support vectors are vital for calculating the margin width [7].

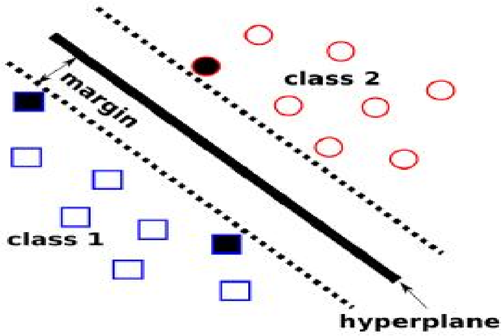

Figure 9: Working of SVM

The SVM iterations are continued until the accuracy of prediction converges into a narrow band spread around 98% as shown in figure 10.

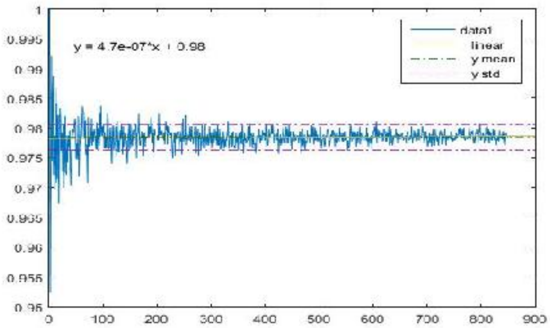

Figure 10: Accuracy Convergence

III. Results

Knee joint MR Images were collected from hospital. The database consisted of 213 images out of which 147 images were used for training the SVM classification system and the remaining 66 images were used for testing the classification performance. The training dataset consists of 9 normal knee images and 138 osteoarthritis knee images. Testing dataset consisted of 63 KOA images and 3 normal images. The classification performances of different classifiers are described below:

Classifier	Accuracy
SVM with RBF kernel	95.45%
SVM with linear kernel	95.45%
SVM with polynomial kernel	87.8%

IV. Conclusion

Knee Osteoarthritis is the most common condition which affects the age group. The early detection of this condition helps in better treatments at earlier stages. This paper presents an automatic early detection of knee osteoarthritis using SVM classifier. It considers the fact that cartilage thickness estimation decides the development stage of KOA. Hence along with thickness other supporting textural and statistical features are considered for training the system. The textural features are contrast, energy, correlation, homogeneity and statistical features are mean, median and variance. The result obtained from SVM with RBF kernel, SVM with linear kernel is 95.45% and SVM with polynomial kernel is 87.8%. The system can be further enhanced for improved performance by considering more training set and different classifiers can also be used.

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Sanjeevakumar Kubakaddi is Research Scholar and proprietor of itie Knowledge Solutions Bangalore, company focusing on Biomedical, Embedded product development and technology training. He received his Bachelors in 1995, Master of Technology (M. Tech) in 2002. He is a renowned trainer in the areas of DSP, Image Processing and expert in Matlab®, Simulink® and Texas Instruments DSP. (sanjeev@itie.in)

Dr. K M Ravikumar, M.Tech., Ph.D, was born in the year 1975. **C**ompleted his Bachelor's Degree in Electronics & Communication Engineering from Bangalore University in 1999. Obtained Post Graduate degree in Biomedical Instrumentation in 2002 and Doctoral Degree in the year 2011 from Visvesvaraya Technological University, Belgaum. Published and presented 24 International technical papers and 6 national technical papers in renowned journals. He is currently serving as the Principal of S J C Institute of Technology, Chickballapur. He has worked as Special Officer, VTU-Regional office, Mysore. He is the recipient of many prestigious awards including Bharatratna Pandit Jawaharlal Nehru Gold Medal Award, National citizenship Gold Medal Award, Outstanding faculty award & Best Educationist Award. (kmravikumar@rediffmail.com).