Analysis and Implementation of Knee Osteoarthritis Grade Classification Algorithm Using SVM

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Abstract-*This Osteoarthritis (OA) is an inflammatory disease causing pain, swelling, stiffness, and loss of function in joints; it is difficult to diagnose in early stages. An early diagnosis and treatment can delay the onset of severe disability. X-ray imaging offers a potential approach to detect changes in degree of inflammation. X-ray images of knee joints were collected from 20 normal subjects and 20 patients diagnosed with Osteoarthritis (OA). These images were divided into blocks and texture analysis algorithm was applied for statistical feature extraction. Finally classification is done using Support Vector Machine (SVM) Classifier for decision making. Results indicate that: (i) X-ray images can be useful for detecting patients with the disease, (ii) The extracted features are the best statistical texture feature to describe image information about Osteoarthritis, (iii) the best feature and classifier to differentiate between normal subjects and patients with OA are the Skewness, Kurtosis, Standard Deviation and Energy.*

Keywords-Osteoarthritis (OA); X-ray images; Skewness; Standard Deviation; Energy; Supoort Vector Machine (SVM)

I. INTRODUCTION

The Osteoarthritis (OA) is related with function of knee joints which is vital dieses nowadays. According to medical studies it is difficult to diagnose in early stages and early diagnosis and treatment can prevent the onset of severe disability [1]. X-ray imaging offers potential information to detect changes in degree of change in knee joints. Apart from the significant pain that is associated with it as well as OA treatment is also quite expensive in terms of human, financial and time resources. So, improvement of existing methods for early stage detection and treatment of OA are necessary.

Osteoarthritis detects by joint swelling by the conventional examination technique. But in early stages of the disease, patients may suffer this without any apparent joint swelling and with negative results. In these cases, techniques such as x-ray imaging or Magnetic Resonance (MR) imaging may leads to the morphologic changes or hyperemia in the form of synovial thickening or enhancement and allow a much earlier diagnosis of OA. But MRI is quite expensive in India and has excessive wait times [2]. X-ray is less expensive, but time consuming. The study results with identification of Osteoarthritis disease degree of severity and predictor.

The information of the X-ray image may be useful as a measure of inflammatory load and degree of change. The algorithm identifies given knee x-ray image from Normal or Patients of knee osteoarthritis [3]. In the present paper we demonstrate the Image analysis of X-ray and its classification that can be useful in early diagnosis of OA and this can initiation of complementary therapy early in the course of the disease which can diminish disease progression and, in some patients, even lead to drug free remission [4].

The goal of this research paper is to develop a low-cost, reliable, non-invasive technology which can provide a quantitative assessment of OA in short time, and allowing one to monitor therapy accurately and effectively. The paper is arranged as follows section 1 introduces the research or basic topology of work being carried out. Section 2 describes related work done in the area of knee osteoarthritis analysis, section 3 describes the actual methodology and algorithm applied on knee database classification for feature extraction and classifier section 4 explains the experimental data obtained through algorithm and empirical variation of features with the help of graphs. Where as in section 5, Overall accuracy of an algorithm is discussed and finally paper is concluded.

II. RELATED WORKS

A. Related Workdone

From last decade a lot of work is done in the field of Medical Image Processing and specially using X-ray images for different diseases identification such as Chest X-ray image for identification of problems related to chest and finding minor bone breakages which are impossible to get through naked eyes. Following are the some related work done in previous years and some recent research going on in this field.

In the work carried by Bhavyashree et al. [5] describes estimation of severity of knee osteoarthritis using MRI images of knee for analysis. The image is first pre-processed with B-splines creation for better segmentation. Then the edges are fine-tuned with canny and log edge detectors. Finally they calculated the distance between the edges in order to find cartilage thickness. The thickness is measured as the number of the pixels between edges. Then depending on the thickness value they decide abnormality about arthritis. This is a reliable and efficient way to determine arthritis based on threshold cartilage thickness value.

A.Allag et al in paper [6] implemented Wavelet expansions and wavelet transforms which had proven to be very efficient and highly effective in analyzing a very wide class of signals and phenomena. The first part of their work deals with image restoration of formulation and the second part extend to the concepts to two dimensional signal analysis with discrete wavelet transform. Finally, the applications of the DWT to image restoration are applied and compared with Fourier based techniques. The paper explains the studies done to investigate the discrete wavelet transform (DWT) and its application to X-Ray image denoising.

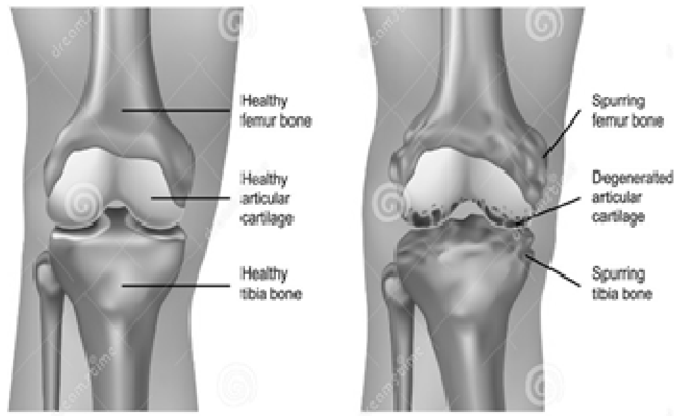
Arpita Mittal [7] demonstrates application of image processing techniques for identification of most common disease i.e. Rheumatoid Arthritis (RA) that is also related with knee and by using x-ray images for analysis. In this paper Fingers and Knee images of the patient having RA have been analyzed through Morphological Image processing techniques.

Monique Frize et al [8] Used statistical and model based texture analysis approach to detect Rheumatoid arthritis (RA) changes to the degree of inflammation. In 18 normal subjects and 13 patients diagnosed with Rheumatoid Arthritis (RA), thermal images were collected from joints of hands, wrists, palms, and knees. Regions of interest (ROIs) were manually selected from all subjects and all parts imaged, which cannot be true for all cases. For each subject, values were calculated from the temperature measurements: Mode/Max, Median/Max, Min/Max, Variance, Max-Min, (Mode-Mean), and Mean/Min. The problem with their database that data sets did not have a normal distribution, therefore non parametric tests (Kruskal-Wallis and Ranksum) were applied to assess if the data from the control group and the patient group were significantly different. The results obtained are quite useful in arthritis identification at early stages as they have used thermal images to detect the patients with the disease.

A. Ross and M. Sunder [9] implements the Block based texture analysis for iris classification and matching where goal of their paper is to analyze the texture of iris and determine if they can be quantitatively measured and assigned into multiple categories.

B. Basic Concept of Osteoarthritis

Primary osteoarthritis, not resulting from injury or disease, is mostly a result of natural aging of the joint. With aging, the water content of the cartilage increases, and the protein makeup of cartilage degenerates. Eventually, cartilage begins to degenerate by flaking or forming tiny crevasses. In advanced osteoarthritis, there is a total loss of the cartilage cushion between the bones of the joints. Repetitive use of the worn joints over the years can irritate and inflame the cartilage, causing joint pain and swelling. Loss of the cartilage cushion causes friction between the bones, leading to pain andlimitation of joint mobility. Inflammation of the cartilage can also stimulate new bone outgrowths (spurs, also referred to as osteophytes) to form around the joints. Osteoarthritis occasionally can develop in multiple members of the same family, implying a hereditary (genetic) basis for this condition and as shown in Figure 1.



(a) (b)

Fig 1. (a) Normal and (b) osteoarthritis affected knees

Similarly it can have different stage due to different level of failures in cartilage and severity of osteoarthritis, shown as in Figure 2.

(A) (B) (C) (D) (E)

Fig. 2. Stages of knee osteoarthritis, (A) 1 grade OA, (B) 2 grade OA, (C) 3 grade OA, (D) 3 grade OA and (E) 4 grade OA

From above Figure 2 we can see that the effect of osteoarthritis is primarily on the middle of knee and remaining information in x-ray becomes useless or redundant. So, the basic idea in our methodology is segment or to do block wise texture analysis and feature extraction of knee x-ray image. The procedure and flow is as explain in following section.

III. PROPOSED METHOD

The image texture analysis methods promises good results, But from last few years the use of texture analysis has become very common in the field of image analysis and due to redundancy in image data like same image background the features showed to be redundancy in features extracted so in this study we purpose a novel approach for analysis of texturefeature for X-ray image which can be useful to prevent image redundancy in data.

As shown in the flow chart X-ray images were obtained and this input X-ray image is divided into 9 blocks of similar size. The blocks which contain useful information regarding knee joint part only picked for further processing of feature extraction the important blocks are considered for feature extraction in our case are Block 4, 5 and 6. The texture feature extraction algorithm is applied to extract features like Skewness, Kurtosis, Standard Deviation and Energy for the block 4, 5 and 6. Using these features the Support Vector Machine (SVM) is trained with 15 samples for training and 5 samples for testing and validation of a normal subjects and patients. The steps followed during algorithm are as shown in figure 3.

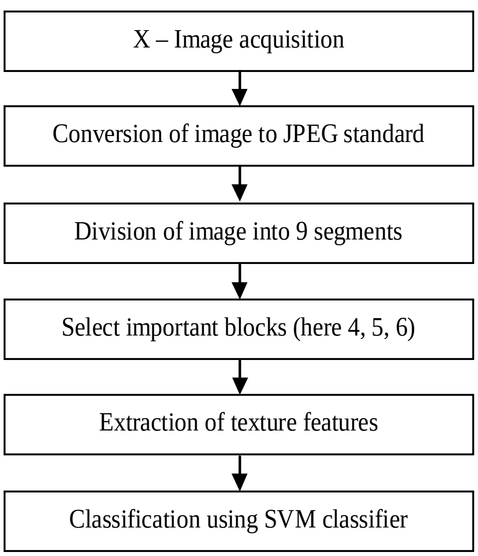


Fig. 3. Flowchart of Methodology

The detail explanation of feature extracted and about classifier is as follows.

B. Dividing Image Into Blocks

First the image divided into blocks can be visualized as shown in Figure 4.

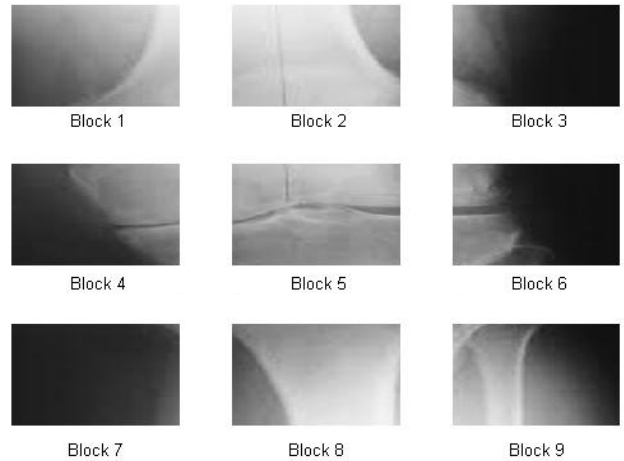


Fig. 4. Knee image Divided into equal 9 blocks

Here blocks 4, 5 and 6 are the Region of Interests which can be useful for finding an important information or vital feature. The extracted features are as follows.

C. Texture Feature Analysis

Texture feature in an image processing and computer vision field characterizes the surface and structure of a given object or region. Basically, an image is a combination of pixels and texture is defined as an entity having group of mutually related pixels within an image. This group of pixels is also termed as texture primitives or texture elements (texels) [10]. A texture is usually characterized by the two dimensional variations in the intensities present in the image. This shows that though there is no precise definition of texture exists in the literature, but there are a number of intuitive properties of texture which are generally assumed to be true as given below:

(i) Texture is a property of areas; the texture of a point is undefined. So, texture is a contextual property and its definition must involve gray values in a spatial neighbourhood. The size of this neighbourhood depends upon the texture type, or the size of the primitives defining the texture.

(ii) Texture constitutes the spatial distribution of gray levels. The two-dimensional histograms or co-occurrence matrices are popular texture analysis tools.

(iii) Texture in an image can be said at different scales or levels of resolution.

(iv) A texture is professed when significant individual “forms” are not present [11].

Textures are a pattern of non-uniform spatial distribution of differing image intensities, which focus mainly on the individual pixels that make up an image. Texture is defined by quantifying the spatial relationship between materials in an image [12]. Image texture has a number of apparent qualities which play important role in describing texture. Following the properties are playing an important role in unfolding texture: are uniformity, regularity, density, linearity, directionality, direction, coarseness, roughness, phase and frequency [13].Seeing that the texture is a quantitative measure of the arrangement of intensities in a region, the methods to characterize texture plunge into four major categories: Statistical, Structural, fractals, Signal processing.

Statistical type includes techniques like grey-level histogram, grey-level co-occurrence matrix, auto-correlation features, and run length matrices [12]. The first-order texture measures or grey texture are calculated from the original image values. They do not mull over the relationships with neighbourhood pixel. Intensity value concentrations on all or part of an image represented as a histogram is a histogram based approach to texture analysis. Features resulting from this approach comprise moments for instance mean, standard deviation, average energy, entropy, skewness and kurtosis [8, 9].

1. Skewness is a measure of the asymmetry of the data around the sample mean.

$$S = \frac{E(x-\mu)^3}{\sigma^3}$$ -------------Equation .no. (1)

Where μ is the mean of x, σ is the standard deviation of x, and E (t) represents the expected value of the quantity t.

If skewness is negative, the data are spread out more to the left of the mean than to the right. If skewness is positive, the data are spread out more to the right. The skewness of the normal distribution (or any perfectly symmetric distribution) is zero.

2. Kurtosis is a measure of how outlier-prone a distribution is. The kurtosis of the normal distribution is 3. Distributions that are more outlier-prone than the normal distribution have kurtosis greater than 3; distributions that are less outlier-prone have kurtosis less than 3. The kurtosis of a distribution is defined as

$$k = \frac{E(x-\mu)^4}{\sigma^4}$$ -------------Equation .no. (2)

Where μ is the mean of x, σ is the standard deviation of x, and E (t) represents the expected value of the quantity t.

3. Standard Deviation

The standard deviation of a data vector image data x can be defined as

$$\boldsymbol{Std} = \left(\frac{\mathbf{1}}{(\boldsymbol{n}-\mathbf{1})}\sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{n}}(\boldsymbol{x_i}-\overline{\boldsymbol{x}})^{\mathbf{2}}\right)^{\mathbf{1}/\mathbf{2}} \quad \boldsymbol{where} \quad \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

-------Equation .no. (3)

The result is the square root of an unbiased estimator of the variance of the population from which X is drawn, as long as X consists of independent, identically distributed samples and If X is a matrix, Std returns a row vector containing the standard deviation of the elements of each column of X.

4. Energy

Returns the sum of squared elements in the Gray Level Co-occurrence Matrix (GLCM). Range = [0 1]. Energy is 1 for a constant image.

$$\boldsymbol{E} = \sum_{\boldsymbol{i},\boldsymbol{j}} \boldsymbol{X}\,(\boldsymbol{i},\boldsymbol{j})^{\mathbf{2}}$$ -------------Equation .no. (4)

Energy is also known as uniformity, uniformity of energy, and angular second moment.

In a x-ray image, edges and sharpness of image contribute significantly more information and internal structure or texture of knee image can be useful for the feature extraction. Figure 5-8 shows the graph of the different texture features of block 5 in the images of normal subjects and osteoarthritis patients.

D. SVM Clasifier

In machine learning, support vector machines (SVMs, also support vector networks) are supervised learning models with associated learning algorithms that analyze data and recognize patterns, used for classification and regression analysis. The basic SVM takes a set of input data and predicts, for each given input, which of two possible classes forms the input, making it a non-probabilistic binary linear classifier. Given a set of training examples, each marked as belonging to one of two categories. An SVM training algorithm builds a model that assigns new examples into one category or the other[15].

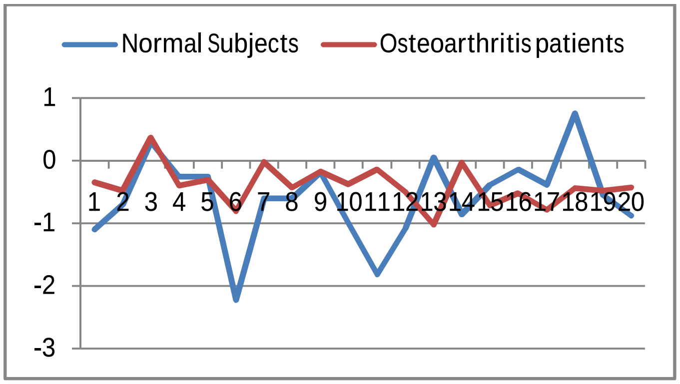


Fig. 5. Skewness of 5th Block

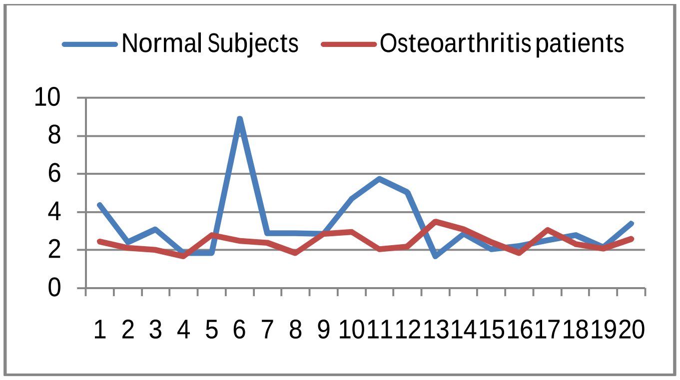


Fig. 6. Kurtosis of 5th Block

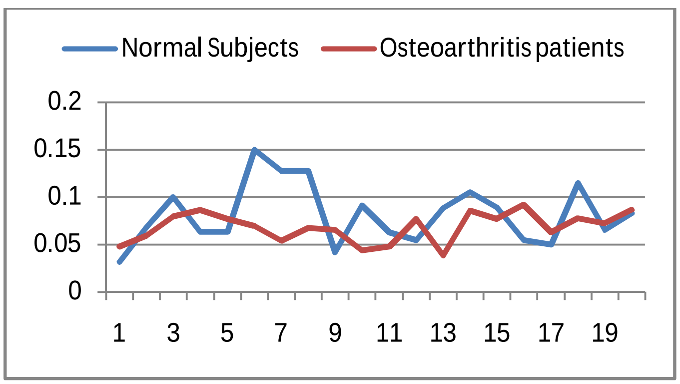


Fig. 7. Standard Deviation of 5th block

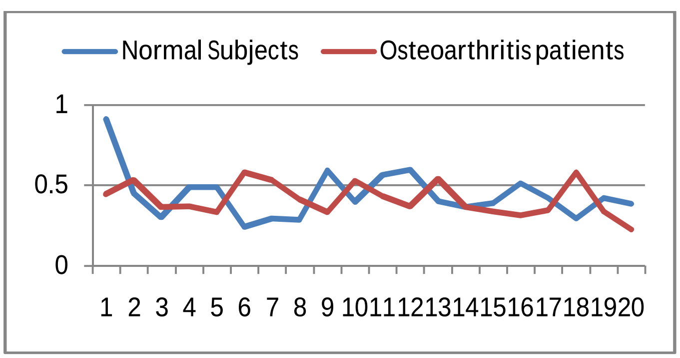


Fig. 8. Energy of 5th Block

More formally, a support vector machine constructs a hyperplane or set of hyperplanes in a high- or infinite-dimensional space, which can be used for classification, regression, or other tasks. Intuitively, a good separation is achieved by the hyperplane that has the largest distance to the nearest training data point of any class (so-called functional margin), since in general the larger the margin the lower the generalization error of the classifier [16]. Whereas the original problem may be stated in a finite dimensional space, it often happens that the sets to discriminate are not linearly separable in that space. For this reason, it was proposed that the original finite-dimensional space be mapped into a much higher-dimensional space, presumably making the separation easier in that space. To keep the computational load reasonable, the mappings used by SVM schemes are designed to ensure that dot products may be computed easily in terms of the variables in the original space, by defining them in terms of a kernel function K(x,y) selected to suit the problem. The hyperplanes in the higher-dimensional space are defined as the set of points whose inner product with a vector in that space is constant. The vectors defining the hyperplanes can be chosen to be linear combinations with parameters of images of feature vectors that occur in the data base. With this choice of a hyperplane, the points X in the feature space that are mapped into the hyperplane are defined by the relation:

$$\sum i \alpha i \ K\ (xi,\ x) = \text{Constant-------Equation No. (5)}$$

Note that if K(x, y) becomes small as Y grows further away from X, each element in the sum measures the degree of closeness of the test point X to the corresponding data base point Xi. In this way, the sum of kernels above can be used to measure the relative nearness of each test point to the data points originating in one or the other of the sets to be discriminated. Note the fact that the set of points X mapped into any hyperplane can be quite convoluted as a result, allowing much more complex discrimination between sets which are not convex at all in the original space [17].

IV. RESULTS AND DISCUSSIONS

The work is implemented on Matlab and Simulink Platform gives prominent results and high accuracy as shown in Figure 8, 9 and Table 1 show the accuracy of algorithm for database of 40 samples.

For processing, the x-ray images were collected from different hospitals of orthopedics and with details of Normal and affected Osteoarthritis patients.

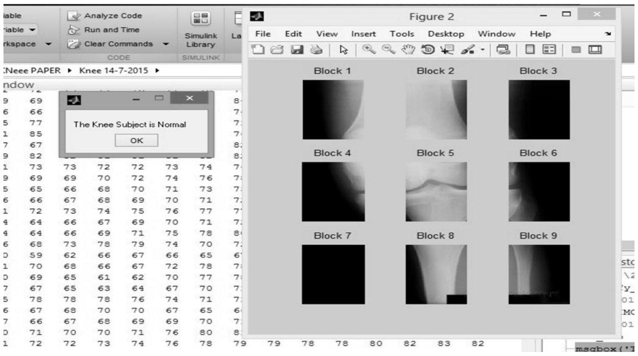


Fig. 8. Results

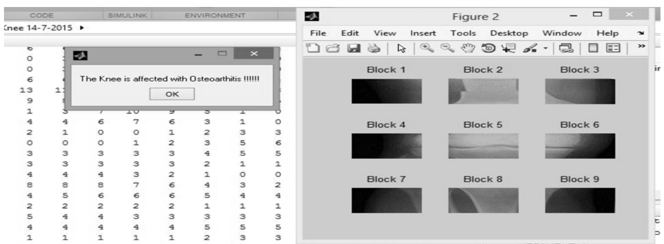


Fig. 9. Osteoarthritis affected knee results

The Accuracy of algorithm with SVM Classifier is as shown in Table 1

Type	No. of Image	No. of correctly Identified	No. of not Correctly identified
Normal	20	17	03
Affected	20	18	02

V. CONCLUSION

In this paper x-ray Image processing based methodology is presented to assist accurate and reliable identification of the presence and grade of disease Osteoarthritis in human knee. The results presented in Section 4 are verified with orthopaedic concert and focused is given on the repeatability of results. The technique is being applied identifying early stage Osteoarthritis patients undergoing clinical trial.

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