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## Local Binary Pattern Approach to the Classification of Osteoarthritis in Knee X-ray Images

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### ABSTRACT

The most common joint disorder, due to aging, wear and tear on a joint is Osteoarthritis (OA). Computer-aided diagnosis system is able to detect the osteoarthritis so that proper treatment options can be considered. In this study, a novel classification system for the classification of OA in knee X-ray images based on Local Binary Pattern (LBP) is presented. The classification is achieved by extracting the histograms of LBP of the knee x-ray image. The performance of the proposed system is analyzed by nearest neighbor classifier using 50 knee X-ray images. The proposed method predicts normal or abnormal knee X-ray image with 95.24% maximum accuracy and medium or worst cases with 97.37% maximum accuracy. Experimental results show that the proposed system could assist radiologists to detect OA earlier and faster.

**Key words:** Osteoarthritis, knee X-ray images, local binary pattern, classification

### INTRODUCTION

The most common type is Osteoarthritis (OA) among 100 different types of arthritis conditions. It occurs more frequently in females after 55 years of age and before the age of 45 in males. To obtain accurate measurements of body temperature in joints of twelve human normal subjects (control group) and for thirteen patients an infra red imaging camera (thermograph) is used in (Frize *et al.*, 2009).

Novel patient specific gait modifications to diagnose OA without changing the foot path are predicted by Fregly *et al.* (2007). Ground Reaction Force (GRF) measurements in 3D are used to detect OA knee gait patterns (Mezghani *et al.*, 2008). The two different GRF features, the coefficients of both polynomial expansion and wavelet decomposition are extracted and classified. WND-CHARM algorithm based features that predict OA is developed by Shamir *et al.* (2009, 2010). They used 2633 image feature descriptors to diagnose OA.

Image processing techniques are used to segment the articular cartilage from the knee Magnetic Resonance Image (MRI) (Swamy and Holi, 2010). Cartilage thickness parameter is used to diagnose OA.

For osteoarthritis (OA) assessment machine vision systems are introduced by Mengko *et al.* (2005). In order to help doctors in determining the region of interest of visual characteristics found in knee OA the system is designed and also to provide accurate measurement of unimpaired joint space width.

A novel edge detection algorithm analogous to region growing is used to predict OA by Bandyopadhyay (2011). In case of noisy and blurs images the algorithm is very effective. An

important step to diagnose OA in knee MRI is the segmentation of femur, patella and tibia compartments. The segmentation of these compartments based on iterative local Branch and Mincut algorithm is proposed by Park *et al.* (2009). With numerous techniques to improve the extensive amount of computation arising from the immense amount of data in high resolution 3-dimensional knee MRI was equipped.

For the visualization and mapping of articular cartilage in Magnetic Resonance (MR) images of the osteoarthritis knee, an automated technique is used and also described by Cashman *et al.* (2002). To develop and certify the software for automated segmentation and thickness mapping of articular cartilage from three-dimensional (3-D) gradient-echo MR images of the knee which is explained as a major goal. In this paper, classification of osteoarthritis in knee X-ray images based on LBP and Classifier is presented.

## MATERIALS AND METHODS

The proposed system for the classification of osteoarthritis in knee X-ray images is built based on Local Binary Pattern (LBP) and by applying  $k$ -nearest neighbor (KNN) for building the classifiers. In this following section the theoretical background of all the approaches are introduced.

**Local binary pattern:** Local Binary Patterns (LBPs) are introduced by Ojala *et al.* (1996) as a means of summarizing local gray-level structure. Around each pixel a binary valued local image pattern is formed. The original LBP operator works in a  $3 \times 3$  window over an image. The pixels in this window are thresholded by its center pixel value, multiplied by powers of two in clockwise or counter clockwise direction and then summed to obtain a pattern for the center pixel. Formally, the LBP operator takes the form:

$$\text{LBP}(x_c, y_c) = \sum_{n=0}^7 2^n s(i_n - i_c) \quad (1)$$

This process is applied for the whole image to obtain LBP of the given image. A  $3 \times 3$  window size consists of 8-pixels, so that a total of  $28 = 256$  different patterns can be obtained. Figure 1 shows the illustration of basic LBP operator.

**KNN classifier:** The  $k$ -nearest neighbor algorithm (KNN) is a method for classifying objects based on closest training examples in the feature space. KNN is a type of instance-based learning where the function is only approximated locally and all computation is deferred until classification. In KNN, an object is classified by a majority vote of its neighbors, with the object being assigned to the class most common amongst its  $k$  nearest neighbors ( $k$  is a positive integer, typically small). If  $k = 1$ , then the object is simply assigned to the class of its nearest neighbor. The neighbors are taken from a set of objects for which the correct classification is known. This can be thought of as the training set for the algorithm, though no explicit training step is required.

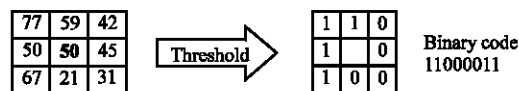


Fig. 1: Illustration of basic local binary pattern operator

The distance measures used in the proposed system for the classification of osteoarthritis in knee X-ray images are as follows:

**Euclidean distance:** Let us consider  $u = (x_1, y_1)$  and  $v = (x_2, y_2)$  are two points. The Euclidean distance between these two points is given by:

$$\text{Euclidean distance}(u, v) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (2)$$

If the points have n-dimensions such as  $u = (x_1, x_2, x_3, \dots, x_n)$  and  $v = (y_1, y_2, y_3, \dots, y_n)$  then the generalized Euclidean distance formula between these points is:

$$\text{Euclidean distance}(u, v) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \dots + (x_n - y_n)^2} \quad (3)$$

**Manhattan distance:** Let us consider  $u = (x_1, y_1)$  and  $v = (x_2, y_2)$  are two points. The Manhattan distance between these two points is given by:

$$\text{MH}(u, v) = |x_1 - x_2| + |y_1 - y_2| \quad (4)$$

If the points have n-dimensions such as  $u = (x_1, x_2, x_3, \dots, x_n)$  and  $v = (y_1, y_2, y_3, \dots, y_n)$  then the generalized Manhattan distance formula between these points is:

$$\text{MH}(u, v) = |x_1 - y_1| + |x_2 - y_2| + \dots + |x_n - y_n| = \sum_{i=1}^n |x_i - y_i| \quad (5)$$

**Cosine:** Let us consider  $x$  and  $y$  where  $x = (x_1, x_2, x_3, \dots, x_n)$  and  $y = (y_1, y_2, y_3, \dots, y_n)$  then  $\cos\phi$  may be consider as the cosine of the vector angle between  $x$  and  $y$  in  $n$  dimension. The cosine of the vector angle between  $x$  and  $y$  is given by:

$$\text{Cosine}(X, Y) = \frac{\sum_i x_i y_i}{\sqrt{\sum_i x_i^2} \sqrt{\sum_i y_i^2}} \quad (6)$$

One important property of cosine angle is that it gives a metric of similarity between two vectors unlike Manhattan distance and Euclidean distance, both of which give metrics of dissimilarities. Also  $\text{Cosine}(X, Y) \in [0, 1]$ , this makes it easy to combine distance between two images using multiple features.

**Correlation:** A correlation is a single number that describes the degree of relationship between two variables  $x$  and  $y$ , where  $x = (x_1, x_2, x_3, \dots, x_n)$  and  $Y = (y_1, y_2, y_3, \dots, y_n)$ . The correlation  $r$  between  $x$  and  $y$  is defined by:

$$r = \frac{N \sum xy - (\sum x)(\sum y)}{\sqrt{[N \sum x^2 - (\sum x)^2]} \sqrt{[N \sum y^2 - (\sum y)^2]}} \quad (7)$$

## PROPOSED METHOD

The proposed system for the classification of osteoarthritis in knee X-ray images mainly consists of two different stages which include the feature extraction stage and classification stage. All the stages are explained in detail in the following sub sections.

**Feature extraction stage:** Feature extraction involves simplifying the amount of resources required to describe a large set of data accurately. Analysis with a large number of variables generally requires a large amount of memory and computation power or a classification algorithm which over fits the training sample and generalizes poorly to new samples. Feature extraction is a general term for methods of constructing combinations of the variables to get around these problems while still describing the data with sufficient accuracy. Figure 2 shows the block diagram of feature extraction stage of the proposed system based on LBP.

The size of original x-ray knee images are over  $1000 \times 1000$  and almost over 60% of whole image comprised of background with a lot of noise as shown in Fig. 3a. Hence, to classify the osteoarthritis in knee X-ray images requires a small region called as Region of Interest (ROI). The ROI region is cropped manually that contain the joint area in the center of the image as shown in Fig. 3b. The

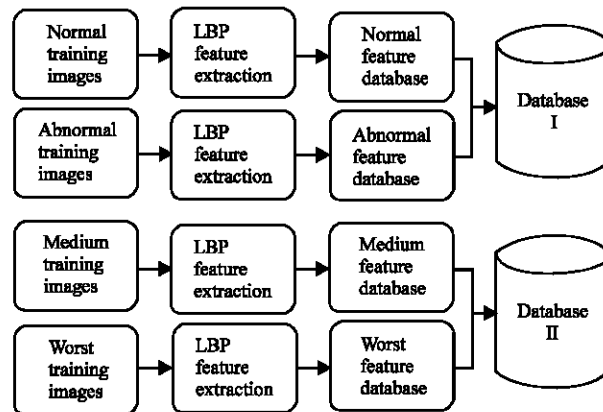


Fig. 2: Block diagram of the feature extraction stage of the proposed system

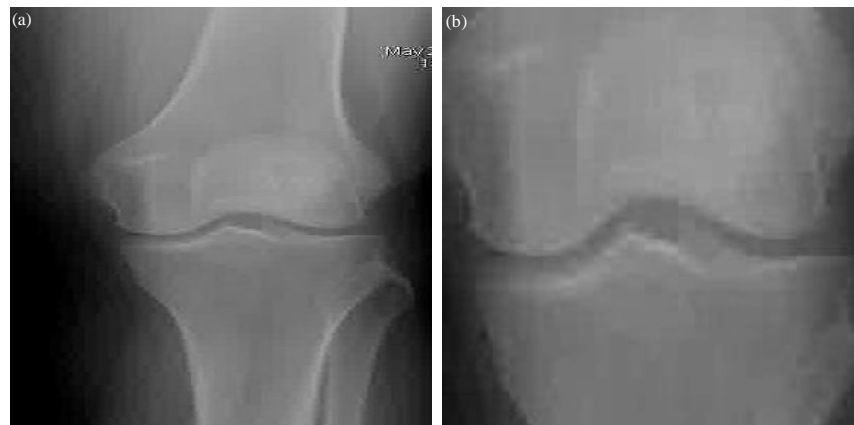


Fig. 3(a-b): Knee X-ray image, (a) Original image and (b) ROI image

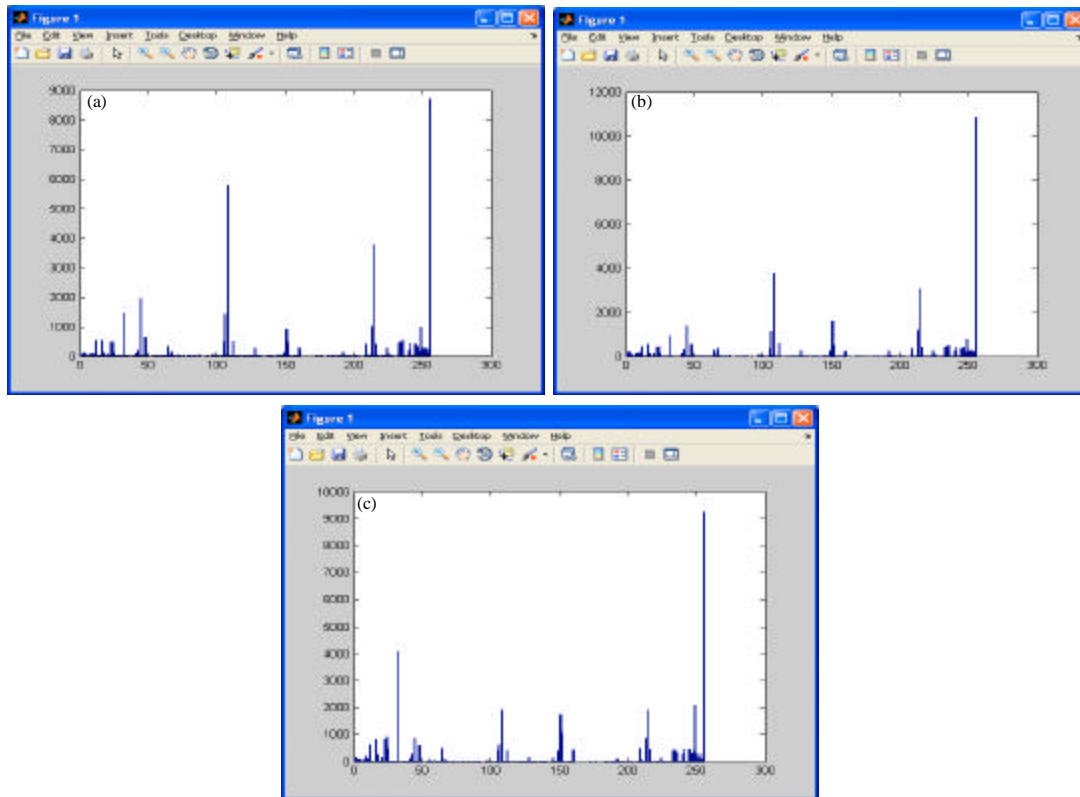


Fig. 4(a-c): Local binary pattern histogram of knee X-ray images (a) Normal case (b) Worst case and (c) Medium case

size of the extracted ROI is  $200 \times 200$ . The proposed histogram of LBP features are extracted for ROI region and stored in the database as feature. Database-I is constructed by using the training images of normal and abnormal X-ray images and used in the initial stage classifier. Database-II is constructed by using the training images of medium and worst case images and used in the final stage classifier. Figure 4 shows the LBP histogram of normal, worst and medium OA knee X-ray images, respectively.

**Classification stage:** Classification phase executes two phases. In the first one, the classifier is applied to classify osteoarthritis knee X-ray images into normal and abnormal cases. Finally, the abnormal case is classified into medium or worst case in the final stage. In this classification stage, classifier in every phase is trained at specific number of training set in each category. The block diagram of the classification stage of the proposed system based on classifier is shown in Fig. 5.

**Initial stage classifier:** In the initial stage classifier, manually extracted ROI from the knee X-ray image is tested for normal or abnormal category. Then the proposed feature, histogram of LBP is initially tested with the trained classifier which uses DATABASE-I. The number of normal and abnormal x-ray images used to create the DATABASE-I and train the classifier is 9 and 21, respectively. To test the classifier 15 normal and 35 abnormal images are used.

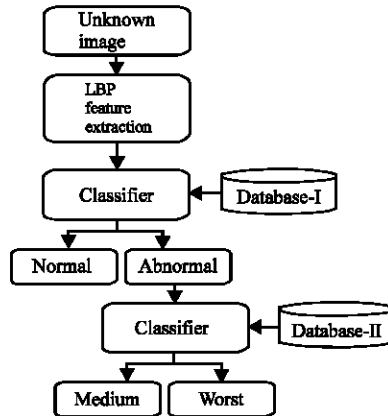


Fig. 5: Block diagram of the classification stages of the proposed system

Table 1: Classification results of proposed method based on local binary pattern using classifier

Distance measure	Normal	Abnormal	Medium	Worst
Euclidean	73.33	94.28	93.75	99.74
Cosine	73.33	97.14	100.00	94.74
Manhattan	80.00	97.14	100.00	94.74
Correlation	93.33	97.14	100.00	94.74

**Final stage classifier:** In the final stage classifier, the abnormal ROI image from the initial stage classifier is further classified into Medium or Worst case. The extracted feature from the unknown ROI image is again tested with the trained classifier which uses database-II. The number of medium and worst case X-ray images used to create database-II and train the classifier is 11 and 13, respectively. To test the classifier 16 medium and 19 worst case images are used.

## EXPERIMENTAL RESULTS

To assess the performance of the proposed system, many computer simulations and experiments with knee x-ray database images were performed. The performance of the proposed system is carried on 15 normal images and 35 abnormal images. Among the 35 abnormal images, there are 16 medium and 19 worst case images available. For training the classifier 60% of total images are used. All the images are considered for the classification test. The distance measures used in the classifier are Euclidean, cosine, Manhattan and correlation measures. The classification rate of proposed system obtained is shown in Table 1. From the table, it is clearly observed that the correlation distance measure used in the proposed system for the classification of OA produces better results than all other distance measures. While using correlation distance measure in initial stage classifier, the overall classification accuracy increases more than 6.6% compare to all other distance measures. In the final stage, the classification accuracy of cosine, Manhattan and correlation distance measure is 97.37% while the Euclidean distance measure produces 96.75%.

## CONCLUSION

A novel classification system for the classification of OA in knee X-ray images based on Local Binary Pattern (LBP) is proposed. The extracted histogram of LBP of the knee X-ray image is used

as features for the proposed system. The robust classifier is used for the classification of knee X-ray images into normal or abnormal, as well as medium or worst cases. The proposed system is evaluated by using 50 images and the classification rate of the system based on all distance measures used in classifier is tabulated. From the experimental results, it is clearly found that the correlation distance measure produces over 93% classification rate for all the cases.

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