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A NOVEL METHOD FOR EARLY DIAGNOSIS OF ARTHRITS FROM RADIOGRAPHS USING FUZZY-C-MEANS CLUSTERING ALGORITHM

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ABSTRACT

Arthritis is a type of disorders that takes place in bone joints. This disease results in mild pain in the early stage to joint immobility in the later stage of the disease. The curse of this kind of disorder is that it cannot be cured. On the other hand, there are more possibility to control the further severity of this disease through proper diagnosis and treatment. Even though many diagnostic tools are available, only a few methods are available to diagnose this disorder at the early stage. This paper discusses a simplistic diagnostic tool developed to diagnose arthritis at its early stage.

Keywords: arthritis, early diagnosis of arthritis, fuzzy-C-Means clustering.

1. INTRODUCTION

Engineering when applied in medical applications can make wonders. Many diagnostic and life support tools stands as the live example for the above statement. This paper describes the application of Fuzzy-C Means (FCM) clustering algorithm for diagnosis of Arthritis. In order to know the effects of arthritis the knowledge about the structure of the bone joint is necessary. The schematic diagram of the bone joint structure is shown in Figure-1.

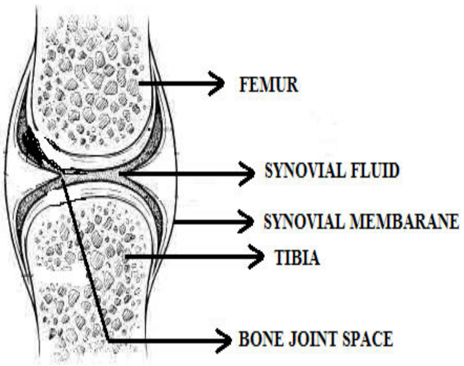


Figure-1. Structure of the Bone Joint.

The part of the bone above the Articular Space (AS) or Joint Space Width (JSW) is called Femur and below the AS is called as Tibia. The lunar shaped fibro elastic cartilage is present at the end of femur and tibia. It serves as a cushion between the joints. The femur, tibia and the cartilage are integrated by a membrane named synovial membrane. The synovial membrane segregates a viscous fluid called as synovial fluid. This fluid acts as a lubricant in preventing the friction between the bone joints during its mobility.

The initial stage of the disease starts with the erosion of synovial membrane followed by the gradual reduction in the synovial fluid. The reduction in the synovial fluid leads to the reduction in the JSW which finally ends up with the reduction in the cartilage volume. The duration for the disease to make the drift to the next stages differs varies with individual. The disease is mostly localized and occurs in bone joint which is subjected to stress. On diagnosis, the disease can be controlled at any stage through proper medications and muscle relaxation exercises. The information regarding the erosions at the early stages are not furnished through any clinical examinations. However by integrating some methodology or algorithms with these examinations can furnish some fruitful information. Some of those methodologies suggested by the researchers are given below.

Chih Yen Chen *et al*. (2012) proposed a method for the segmentation of Phalanx and Ephiphyseal portions in hand from radiographic images. The noises in those images were removed using Gaussian filtering technique. The edges in radiographs were detected using Ostu's thresholding and edge detection method. The image is then subjected to K-means clustering technique. The Phalanx and Ephiphyseal portions were segmented from the clustered image. This method helps to diagnose the eroded portions of hand.

Girija *et al*. (2013) proposed a method for the early diagnosis of OA from MRI. This method uses micro-texture descriptors to model the texture from local grey level pixel intensity variations. The local texture was represented using a 3 x 3 local neighborhood matrix. The extracted features were classified using K-Means clustering technique. The accuracy achieved by this algorithm was 86 %.

Joselene Marques *et al*. (2012) proposed an algorithm for automatic analysis of Trabecular bone structure from MRI. Low field MRI was used for obtaining the image of the joints. The generic texture features were extracted and classification was done. The work was carried out using six different classifiers. The performance of the classifier was evaluated using cross validation algorithms. This method produced a classification rate of 82 %.

Mohamed Ahmed *et al*. (2002) used FCM clustering technique for the segmentation of imperfection image areas from MRI data. These imperfections were caused due to the radio frequency coils or due to the error in the image acquition sequences. The algorithm concluded that FCM is much effective with the segmentation of noise signals from MRI data.

Selvati *et al.* (2013) used FCM algorithm for the segmentation of tissues from MRI. The MRI were subjected to wrapping based curve let transform before the application of FCM algorithm. Tissues such as white matter, grey matter, cerebrospinal fluid from MRI of brain were segmented by this algorithm. The specificity produced by this algorithm was 87.2

Sanjeeva Kumar *et al.* (2013) proposed a method for the measurement of cartilage tissues in knee joints from MRI. This uses adaptive histogram equalization technique to enhance the image. The noises in those images were removed using Gaussian filtering technique. The edges of cartilage were detected using canny edge detection method. The data obtained from the edges were mapped against the prestored data. With a zero crossing detector the dimensions of the edges were estimated. This method can be extended for the early diagnosis of arthritis.

Sapthagirivasan and Anburajan (2013) developed an automated method to estimate the low bone mineral density areas in hip bone joints caused by OA from MRI. The features from the ROI were extracted using Wilicoxon ranking method. The extracted features were classified using kernel based SVM classifier. The algorithm was evaluated using 50 radiographic images. 5-fold cross validation was used to evaluate the performance of the algorithm. The sensitivity, accuracy and positive predictive value produced by the algorithm were 90 %, 90 % and 89 % respectively.

Sreeparna Banerjee *et al.* (2011) proposed a method to diagnose OA from radiographs. The image in this system was analyzed by cellular neural network computers. Various operations such as XOR, NAND, addition, multiplication etc., were done on the images to extract the features. The extracted features were mapped against the pre-stored data using template matching technique. This method helps to diagnose bony spurs and OA from radiographic images. The classification rate produced by the algorithm was 86 %.

The automated method to segment the portions affected by arthritis in radiographic images of knee joints was proposed by Lillik Anifah *et al.* (2011). The algorithm uses contrast limited adaptive histogram equalization technique and template matching for the diagnosis. It is used to segment the AS in knee joints. The overall classification rate produced by the algorithm was 84.38 %. Yeong-Seng Yuh *et al.* (2012) developed an algorithm for the assessment of later stage of arthritis from radiographic images. This uses the texture features for analysis of the image. Wavelet and fusion methods were used for the extraction of texture features. Wavelets were used to obtain the details of sub-bands in the ROI. The extracted features were classified using SVM classifier. This algorithm produced an accuracy of 90 %.

Most of the above research works are carried out to diagnose arthritis at its mid and later stages. This work focuses on diagnosing arthritis at its early stage from radiographic images. The proposed system is described in section 2.

2. PROPOSED SYSTEM

The algorithm developed to diagnose arthritis at the very early stage in the knee joints is discussed in this section. It's the synovial membrane which integrates the femur, tibia and the joint space width. Early stage of the disease starts with the erosion of synovial membrane and these erosions are neither detected with radiographic images nor with any other imaging techniques. However by applying some image processing techniques these erosions can be diagnosed from radiographic images. The disease can be diagnosed at its early stage based on the property and the nature of the disease. The disease affects any one joint initially and slowly progresses towards the other joints at the later stages. The property of the X-rays as well as the nature of the disease at the early stage helps to diagnose at the early stage.

The persons who were reported to have early morning stiffness were the primary subjects taken for analysis. Ten normal subjects were also taken for study to differentiate these subjects from the controlled subjects. The imaging in the knee joints for the normal subjects was done on two different conditions.

Initially these cases are made to relax for an hour. This is done to make their muscles and bones free from strain. The imaging is done after an hour.

The second condition of imaging is done by artificially inducing the strain on the muscles. These subjects are made to do physical exercise in gym for an hour. Five out of the ten cases experienced much strain and the imaging is done on the knee joints for these cases. The data used for the development of this algorithm is consolidated as below.

- Images of knee joints from the person who were reported early morning stiffness
- Images of knee joints in which physical strain is artificially induced.
- Images of knee joints without any symptoms of pain, stiffness etc.

The above images are then subjected to Fuzzy-C-Means clustering technique

2.1 Fuzzy C-means (FCM) algorithm

The property of X-rays and the change in pixels during the formation of image is used for the development of this algorithm. To verify the change of pixels with the change in abnormality, an image in which the Aurticular Space (AS) is normal and the other in which the AS is abnormal are chosen. The Fuzzy C-Means (FCM) clustering techniques were applied on those images. Fuzzy C-means clustering is an unsupervised clustering algorithm which clusters image based on the Euclidean distance between the pixels. The most prominent fuzzy clustering algorithm is the Fuzzy C Means algorithm.

The FCM algorithm receives the data or the sample space, an n x m matrix where n is the number of data and m is the number of parameters. The number of clusters c, the assumption partition matrix U and the convergence value ε must be given to the algorithm. The assumption partition matrix has c number of rows and n number of columns and contains values from 0 to 1. The sum of every column has to be 1. The first step is to calculate the cluster centers. This is a matrix v of dimension c rows with m columns.

The second step is to calculate the distance matrix D. The distance matrix constitutes the Euclidean distance between every pixel and every cluster center. This is a matrix with c rows and n columns. From the distance matrix the partition matrix U is calculated. If the difference between the initial partition matrix and the calculated partition matrix is greater than the convergence value then the entire process is repeated from calculating the cluster centers to the final partition matrix. The final partition matrix is taken and is used for reconstructing the image.

The objective function of FCM is given by,

$$J(U,y)=\sum_{j=1}^{c}\sum_{k=1}^{n}u_{jk}{}^{m}E_j(x_k) \tag{1}$$

The constraint is $\sum U_{jk}=1$
where,

X = $\{x_k \mid k \in [1,n]\}$ is the training set containing n unlabeled samples

Y = $\{y_j \mid j \in [1,c]\}$ is the set of centers of clusters

$E_j(x_k)$ is a dissimilarity measure (distance or cost) between the sample x_k and the center y_j of a specific cluster.

U = $[u_{jk}]$ is the c x n fuzzy c-partition matrix, containing the membership values of all samples in all clusters.

The algorithm seeks optimum combination of (U*,y*) that produces minimum vale for the J function.

$$J(U^*,y^*)=\min_{U\varepsilon M_c} J(U,y) \tag{2}$$

where, $M_c = c^n$

The Fuzzy C-Means (FCM) algorithm consists of the iteration of the following formulae.

$$y_j=\frac{\sum_{k=1}^{n}(u_{jk})^{m}x_k}{\sum_{k=1}^{n}(u_{jk})^{m}} \quad \text{for all j} \tag{3}$$

$$u_{jk}=\begin{cases}\left(\sum_{l=1}^{c}\left(\frac{E_j(x_k)}{E_l(x_k)}\right)^{2/m-1}\right)^{-1} & if\, E_j(x_k)\rangle 0\ \forall j,k\\ 1\ \ if\ \ E_j(x_k)=0\ \ and\ \ u_{jk}=0\ \ \forall l\neq jk\end{cases} \tag{4}$$

Where, in the case of the Euclidean space,

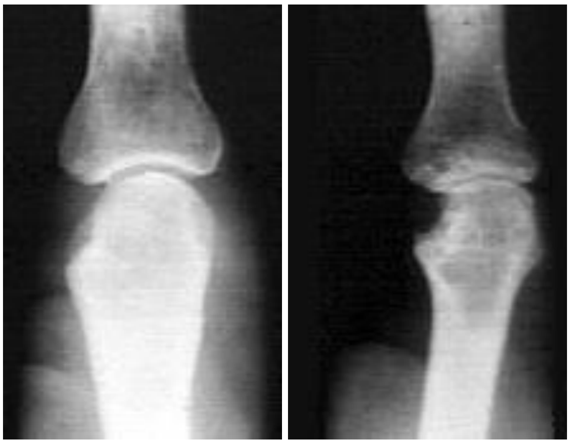
$$E_j=\left\|x_k-y_j\right\|^2 \tag{5}$$

The final partition matrix is taken and is used for reconstructing the image.

3. RESULTS AND DISCUSSIONS

In this work FCM has been used to identify the change in the pixel formation caused due to abnormality from radiographic images. As arthritis erodes the synovial membrane and reduces the synovial fluid in bones, the pixels during image formation also get varied. This results in the variation of clusters.

Hence with the application of FCM to a digital X-ray image of a knee joint which has normal AS, the image is clustered to three and with abnormal AS it is clustered to two. The actual image and the clustered image are shown in Figures 2 and 3 respectively.



(a) Normal AS Joint (b) Abnormal AS Joint

Figure-2. X-Ray Images of normal AS and abnormal AS joint.

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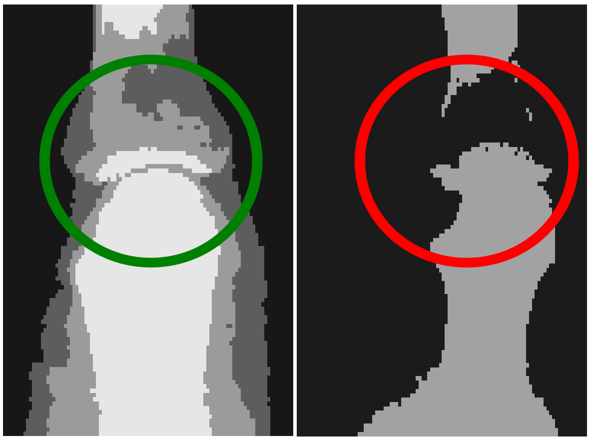

(a) Normal AS Joint (Clustered to three) (b) Abnormal AS Joint (Clustered to two)

Figure-3. Clustered image of normal and abnormal AS joint.

The image of a normal AS has the pixels from three regions of the bone namely synovial membrane, synovial fluid and from the bone joints. The X-rays emerging out from regions of bone joint causes a difference in the pixels during image formation. On the other hand the image with abnormal AS has its pixels from two regions of a bone joints named bones and the muscles surrounding the bone. The differences in the clusters are due the difference in the pixels emerging out from the different portions of the bone joint. Hence an image with normal AS is clustered to three and the image with abnormal AS is clustered to two. From the results it can be concluded that the pixel formation in the images of bone joints will vary with the abnormality.

4. VALIDATION

Among these ten cases, five cases were prescribed to take the medication for arthritis and the other five cases were advised to consume usual medications. Observations are made on the patients after three months. No further erosions are detected in four of five for the first case. On the other hand, the subjects prescribed with normal medications, experienced more stiffness than before. In addition, a noticeable increase in the erosion level in the membrane has been observed during evaluation with the image analysis for the later case.

5. CONCLUSIONS

Since this method of diagnosis produced useful results, this algorithm helps in the diagnosis of arthritis at an early stage from radiographic images. On comparing with the existing work CSM algorithm has the following advantages.

- The algorithm is simple in procedure for the early diagnosis of arthritis.
- The algorithm diagnoses early stage of arthritis from the radiographic images.
- The algorithm is applicable for all the bone joints for early diagnosis.

With the above advantages, no doubt this algorithm will aids the physicians in better diagnosis and proper treatment of arthritis.

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