Image processing based classification of Rheumatoid arthritis

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Abstract. In this paper, we propose the image processing technique applied for diagnosis of Arthritis. Rheumatoid Arthritis is a disease with no cure. Early care, diagnosis is needed for the aggressive treatment of the disease. Thus RA management options include medical treatment, exercise and physiotherapy. At early stage of disease, joints of fingers are mostly affected and then progresses to all joints of the body. The paper is divided in three parts Image preprocessing, phalangeal region extraction, joint location detection. We have examined 4 hand radiograph images affected by RA. Joint location percentage accuracy is 86%. Texture feature extraction method will categorize hand finger joints whether it is normal or affected by RA. The classification accuracy is 80%.

Keywords: Rheumatoid Arthritis, Joint location

1 Introduction

In arthritis two phalangeal bones inter-distance is narrowed as the severity of disease increases. Arthritis is a form of joint disorder that involves joint inflammation of one or more joints. Rheumatoid Arthritis and Osteoarthritis are well known examples of rheumatic diseases that can cause pain and severe damage to the joints in the body. Rheumatoid Arthritis (RA) is continual, systematic disease that mainly affects the joints in the body. Often the first sign of this disease are noted in joints of hand. RA causes bone erosion and disability. 0.5% to 1% of the adult population is affected by RA worldwide. Conventional radiographs have been considered to be a commonly used method for evaluating the progression of bone and joint damage in RA.

At early stage of the disease the symptoms are seen in joints of hand and wrist. Manual method of hand X-ray analysis in RA is time consuming task for radiologists. Therefore precise and accurate analysis of hand radiographs is very much essential.

In each finger there are three joints except thumb. Thumb has two joints. The metacarpophalangeal (MCP) joint is the joint between metacarpal bones and proximal phalanges. Joint between proximal and intermediate phalanx is called as proximalinterphalangeal (PIP) joint

and the joint between intermediate and distal phalanx is called as distal interphalangeal (DIP) joint. In Rheumatoid Arthritis joint space gets narrowed in MCP and PIP joints exclusively. To provide diagnosis it is essential to take into account narrowed metacarpophalangeal, interphalangeal and distalphalangeal hand joints. Among all the joints MCP joint space width is highest.

A more precise estimation of joint space width measurement can be achieved by accurate segmentation in hand radiograph. In these cases general purpose localization and contour detection methods such as Active Contour Model (ACM) can be used to initially approximate bone shape. This shape approximation can be improved by continuing the segmentation process using the Active Shape Model (ASM) algorithm. It is necessary to evaluate joint degeneration or erosion in early diagnosis. Classification of normal and abnormal arthritis is a major challenge.2 Literature Survey

Van't Klooster developed semi-automated method to measure all joint margin of digital hand radiograph, JSW measurement was applied to both hands. Joints of thumb are not considered for analysis [1]. Andrzej Bielecki et al. mentioned the technique where data relating to the subject of investigation was collected and segmentation is carried out first and then the joint locations and minimal JSW are measured using a special algorithm. This method included binarization then thinning, and then branch analysis. After the branch analysis they identified the edges of the upper and lower bone to measure JSW [2]. Syaiful Anam et al. in their paper, to give RA diagnosis, the first step is contour detection of bones. The Level Set Method has been widely used in boundary detection [3]. YingheHuo et al. focuses on both joint location and joint margin detection. For the evaluation of RA patients hand X-ray images, in which the joints have been manually segmented are used [4]. In 2009 G. Langs et al. described automatic localization of joint position and accurate delineation of bone contour. It evaluates result for automatic joint location detection, joint space measurement. It uses local linear mapping and active shape model algorithm. The local linear mapping uses texture features to locate the joint position on hand radiograph. Active shape model (ASM) identifies the individual bone contour with statistical shape and texture model [5].

2.1 Block Diagram

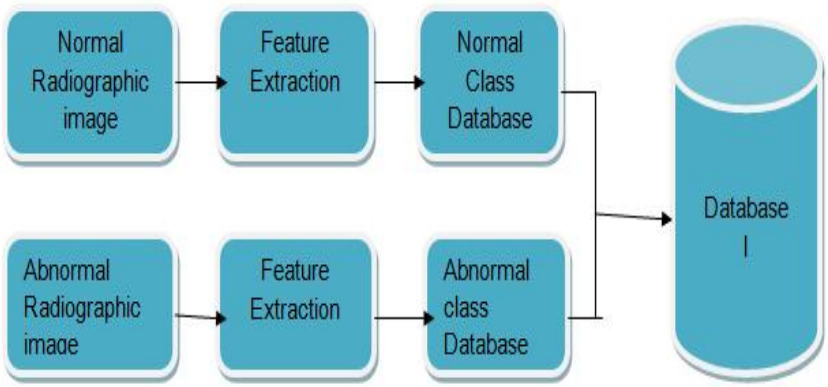

Fig 1. Training Image database

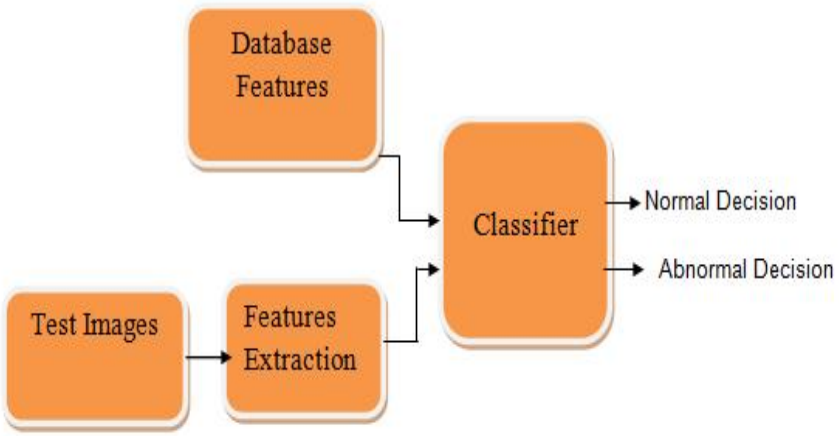

Fig 2. Classification of Arthritis

2.2 Texture feature extraction Method

Texture term indicates set of intensity values. In hand bone region and joint span has different intensity levels so the key points can be extracted. Fig. 2 shows the block diagram for classifying RA, Database contains image features of normal as well as RA affected person. These features are compared with test image texture features and thus depending on the degree of matching, classification is carried out. Segmentation uses Haar wavelet. To differentiate bone and non-bone regions binarization operation is performed. Binarization is done by Otsu's algorithm. Then the skelatonization results in mid line detection it uses thinning process. Then the peak and valley points of fingers are detected along the skeleton. The key points that is the exact joint location is traced by local linear mapping (LLM) algorithm [5]. It uses texture features to locate joints in hand radiograph image.

2.2.1 Preprocessing

Hand X-ray images are collected from hospital and the resolution of digital image is 2000pixels×2000pixels. Image pre-processing is required for contrast improvement; also we have omitted top and bottom 5 rows labels and markers.

2.2.2 Image Binarization

Considering intensity variation in the radiographs, bone and non-bone regions are separated by using Otsu's thresholding algorithm.

Let f(x,y), g(x,y) be the value of pixel in input image and thresholded image respectively.

$$g(x,y) = 1,\ f(x,y) \geq T$$
$$g(x,y) = 0,\ f(x,y) \leq T \qquad (1)$$

This method to obtain binary image will not provide accurate segmentation. Thus the global thresholding method by Otsu [6] is applied to separate foreground and background regions. Otsu method assume that image contains optimum threshold separating foreground and background pixels so that their combined spread is minimal.

2.2.3 Joint location detection

MCP joint has a fixed position relative to the centre of metacarpus. Centroid is to be identified for the image. The centroid is near to the MCP joint so the MCP joint is identified first. The centerline is passed through every figure bone using skeletanization. These branches are used to locate the joint precisely. Each branch passing through middle of finger is divided into three ROIs for analysis, as there are three joints in every finger. Gabor filter [7] is used to locate the joint position. As a result of three regions are analyzed to determine locations of the joints.

For 2D image signals such as images σ is the standard deviation. Φ is the orientation. (x,y) is the position of filter relative to the input signal. Gabor filter can be viewed in following equation

$$g(x,y, \theta,\Phi)=\exp(-x^2+y^2)/\sigma^2.\exp(2\pi\theta.\mathrm{sqrt}(-1).(x\cos\theta +y\sin\Phi))$$

Local linear mapping are used to detect 12 joint positions. The position of the joints is estimated based on peak and valley point of fingers.

2.2.4 Joint feature extraction

In order to localize joint location key points, it is accomplished by local linear mapping applied to local texture features extracted by Gabor filter.

2.2.5 Classification

Minimum distance classifier is a supervised classifier. This method calculates feature vector for each class and measures Euclidian (statistical) distance from each pixel to class mean vector. Depending on the closest distance it provides result whether the image is normal or abnormal.

3 Result

Joint location success rate is calculated as the ratio of number of joints successfully detected divided by the total number of joints. Fig. 3 shows Joint location detection success rate JLDSR in various joints of finger bone. MCP joints are detected accurately.

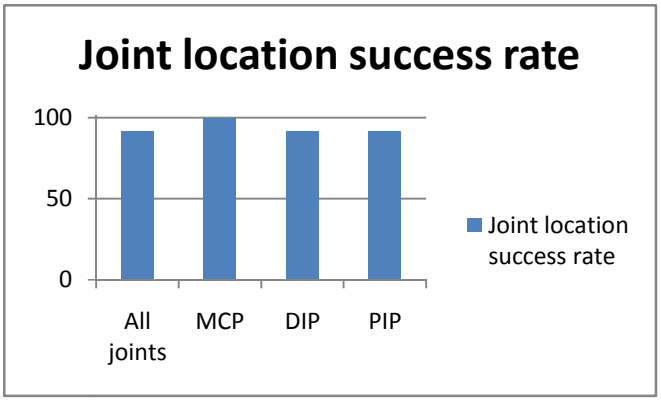

Fig.3 Joint location detection success rate

In summary, to classify Arthritis in grades (0-1), 0 indicates normal and 1 indicates abnormal stage. The classification accuracy is 80%.

Table 1. Classification of disease severity

Image	Actual stage	Detected Stage
A	Normal	Normal
B	Abnormal	Abnormal
C	Abnormal	Abnormal
D	Normal	Unable to predict

Conclusion

All images are tested and calculated mean joint location accuracy is 86 %. Reproducibility is tested by analyzing same test image at different time instants, results are same. Computation time required is 90 Sec. There are problems in JSW measurement of small finger so it cannot be assessed reliably. Minimum distance classifier is used to classify disease severity level.

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