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An Algorithm to Detect Arthritis from Human's Elbow Joint X-Ray Images Using Hybrid Edge Detection Approach

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Abstract: ***Arthritis is bone disease which affects the primary peripheral joints like fingers, wrists, shoulders and feet. This disease results in joint pain, stiffness, swelling of the joints, sometime leads to deformity of joints. Osteoarthritis is a common disease in human under various joints such as knee, hips, hand and wrist. Osteoarthritis is the most common form of arthritis. Rheumatoid arthritis affects about one-tenth as many people as osteoarthritis. The main difference between osteoarthritis and rheumatoid arthritis is the cause behind the joint symptoms. Osteoarthritis is caused by mechanical wear and tear on joints. Rheumatoid arthritis is an autoimmune disease in which the body's own immune system attacks the body's joints. In this research paper, I have presented an algorithm in the general terminology to detect osteoarthritis from human's elbow x-ray images based on hybrid edge detection approach means combination of Sobel and Canny edge detection techniques. This algorithm can be utilized by other researchers to devise an efficient technique/method for human's elbow X-Ray image to detect osteoarthritis.***

Keywords: Arthritis, Osteoarthritis, Rheumatoid, X-Ray, Sobel Edge Detection, Canny Edge Detection

1. Introduction

Bones are the solid organs in the human body protecting many important organs such as hand, leg, brain, heart, lungs and other internal organs. The human body has 206 bones with various shapes, size and structures. The bone injury is a common problem in human beings. It occurs due to high pressure is applied on bone, simple accident, osteoporosis, bone cancer, heredity etc. Therefore, the truthful diagnosis of bone injury is important aspect in medical field. In this case, mainly X-Ray images are used by orthopaedics doctors for better diagnoses/analysis of bone related injuries [1], [2], [3].

Arthritis is bone disease which affects the primary peripheral joints like elbow, fingers, wrists, shoulders and feet. This disease results in joint pain, stiffness, swelling of the joints, sometime leads to deformity of joints. Osteoarthritis is a common disease in human under various joints such as knee, hips, hand and wrist. It is the stage of human bone in which the joints of human body become damaged and stop moving freely which causes pain. As the cartilage become thin and gap between the bones become narrows. The main causes of osteoarthritis are greater than age of 40 years, overweight, previous joint injury and by genetic hereditary. Knee osteoarthritis can make sitting and walking extremely painful. Knee osteoarthritis also varies between male & female genders as per the survey shown by Arthritis Research UK Primary care Centre, Keele University, some of those results are shown in table1.The survey shows that female has higher ratio to get osteoarthritis [4], [5].

In the modern medical science various types of medical imaging tools are available for detecting diseases and abnormalities such as Radiography (X-Ray image), Tomography, Echocardiography, Magnetic Resonance Imaging (MRI), Thermography, Sonography, Mamogram etc. An X-Ray is a type of medical imaging which is used to capture internal bone structure of the body. In X-Ray image electronic wave are transferred into human body to capture internal parts of the bone. It is an easy, simple, cheaper and healthy way of imaging human bones to detect bone related issues. Doctors usually use X-Ray images to detect cavity, swallowed objects, lungs, blood vessels, fracture & location of fractures, bone tumour, arthritis, osteoporosis, bone malignancy, visualization of inner pats of breast of female beings (mammography) etc. According to paper [2] imaging with X-rays involves exposing a part of the body to a small dose of ionizing radiation to produce images of the interior part of the body. In the human body, each and every bone plays an important role for example arm, leg, scalp etc. Figure 1 Courtesy: https://images.google.com/ shows X-Ray image of human being's arm.

Figure 1: Arm of human being

Orthopaedics or physician doctors are always advised patients to take an X-Ray image of injured body parts for accurate diagnoses and further treatment. Such X-Ray image may contain osteoarthritis in the elbow of human hand. In this research paper, I have presented a suggestive algorithm to detect an osteoarthritis from human being's elbow joint X-Ray images. The next sections discuss on related work, followed by edge detection techniques, an algorithm with its pseudocode, result and discussion and finally, conclusion of the paper.

2. Related Work

Many researchers have shown their interest towards the development of algorithm for human X-Ray image analysis to detect arthritis and other diseases. Following paragraphs highlights some important existing research work.

Afzal et al. [1] have worked on a method to detect elbow arthritis from human's hand X-Ray image. They have tested the developed method in MURA (Musculoskeletal Radiographs) dataset and found 86.20% accuracy.

Ahmed et al. [4] have worked on optimized techniques based on a genetic algorithm for the brain tumor detection from MR images. The performance of the proposed genetic algorithm-based cost minimization technique is compared to the classical edge detection techniques, fractional-order edge detection filters, and threshold-optimized fractional-order filters. The proposed method brought its efficiency with an accuracy of 99.09%, FOM of 85.59%.

Connolly et al. [6] have devised a wireless smart glove to facilitate the accurate measurement of finger movement through the integration of multiple IMU sensors, with bespoke controlling algorithms. The developed glove is fitted with sensors to overcome these issues. According to authors this glove helps to quantify joint stiffness and monitor patient progression during the arthritis rehabilitation process.

Gharehbaghi et al. [7] have developed a technique to detect knee arthritis based on the acoustic emissions. They have used many classifiers techniques to analyse the accuracy of the developed mechanism. The classifiers achieved a peak cycle-wise accuracy of 84% and a subject-wise accuracy of 92%.

Hielscher et al. [8] have worked on how to capture proper images of the arthritic finger joints. Authors have found that data obtained at 600 MHz leads to better classification results than data obtained at 0 or 300 MHz.

Huo et al. [9] have developed a method to detect wrist joint space width of patients from radiographic images with rheumatoid arthritis based on image processing techniques. It was found that 90% of the joints had a JSW deviating less than 20% from the mean JSW of manual indications, with the mean JSW error less than 10%.

Jichao and Kun [10] have developed an edge detection algorithm based on machine learning and image depth information. They have obtained 1014 images from different datasets to form a training set. The result was almost more than 90% as per their discussion.

Leung et al. [11] have represented two different methods to quantify bone width changes in MR images. The first method uses segmentation propagation to delineate a bone from the serial MR images giving a global measure of temporal changes in bone volume. The second method uses rigid body registration to determine intensity change within a bone, and then maps these into a reference coordinate system using nonrigid registration. This gives a local measure of temporal changes in bone lesion volume.

Schwaighofe et al. [12] have described a classification system for a novel imaging method for arthritic finger joints. The basis of this system is a laser imaging technique which is sensitive to the optical characteristics of finger joint tissue. The paper concluded that the laser-based imaging permits a reliable classification of pathological finger joints, making it a sensitive method for detecting arthritic changes.

Somkantha et al. [13] have compared the proposed segmentation technique based on the Intensity Gradient and Texture Gradient Features, it was also compared with other segmentation techniques such as active contour models (ACM), geodesic active contour models, active contours without edges, gradient vector flow snake models, and ACMs based on vector field convolution, by using the skilled doctors' opinions as the ground truths. The result shown was quite promising and effective as compared to other above listed techniques.

Yang et al. [14] have used machine learning techniques to detect Rheumatoid Arthritis from Ultrasound images. The SVM (support vector machine) based on GLCM (gray-level co-occurrence matrix) + LBP (local binary patterns) descriptor shows better accuracy (86.55%) than either SVM + LBP (85.43%) or SVM+GLCM (82.51%) for discriminating among four grade RA ultrasonic images.

It is cleared from the above presented extensive literature review that no technique/method/algorithm is perfect and achieved accuracy exactly 100%. Each and every method achieves different accuracy and precision. It gives me relentlessly motivation to work in the field of arthritis detection from human's elbow join X-Ray images to increase the accuracy of clinical diagnostic by applying combination of sobel and canny edge detection techniques and here, in this paper I have presented an algorithm to detect arthritis from human's elbow joint X-Ray images using hybrid edge detection techniques means this approach is combination of two edge detection techniques such as Sobel and Canny.

3. Edge Detection Approach

In this paper, I have not considered any particular edge detection technique, but, I have considered combination of Sobel and Canny edge detector.

The Sobel operator performs a 2-D spatial gradient measurement on images. Transferring a 2-D pixel array into statistically uncorrelated data set enhances the removal of redundant data, as a result, reduction of the amount of data is required to represent a digital image. The Sobel edge detector uses a pair of 3 x 3 convolution masks, one estimating gradient in the x-direction and the other estimating gradient in y–direction. The Sobel detector is incredibly sensitive to noise in pictures, it effectively highlights them as edges [15]. The Sobel operator is an example of the gradient method. The Sobel operator is a discrete differentiation operator,

computing an approximation of the gradient of the image intensity function [16].

The Canny Edge Detection is named after its creator "John F. Canny" in 1968. As per paper Canny [17], it was first created by John Canny for his Master's thesis at MIT in 1983. Papers Canny [17], [18] and Vijayarani et al. [19] discussed on the algorithmic steps as: (1) Convolve image f (r, c) with a Gaussian function to get smooth image f^(r, c). f^(r, c)=f(r,c)*G(r,c,6). (2) Apply first difference gradient operator to compute edge strength then edge magnitude and direction are obtained as before. (3) Apply non-maximal or critical suppression to the gradient magnitude. (4) Apply threshold to the non-maximal suppression image. The canny method is quite effective and provides promising results in terms of edge detection and analysis.

4. Algorithm to detect Osteoarthritis

In this section, I have presented the detailed steps of algorithm to detect osteoarthritis from human being's elbow X-Ray images. I have also given pseudocode for this algorithm to convert into efficient program for the implementation purpose.

Algorithm: Elbow osteoarthritis detection from X-Ray Images

Step-1	**:**	Input an X-Ray image of human elbow.
Step-2	**:**	Median Filter (Image enhancement to remove salt and pepper noise).
Step-3	**:**	Contrast Stretching and Contrast Limited Adaptive Histogram Equalization (CLAHE) [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 elbow].
Step-4	**:**	Edge Detection based on Sobel edge detector.
Step-5	**:**	Edge Detection based on Canny edge detector.
Step-6	**:**	Convert edged image into Binary.
Step-7	**:**	ROI Detection.
Step-8	**:**	Joint Space Measurement *(1 Pixel = 0.264583333 mm).*
Step-9	**:**	Classification (Space of normal Joint and Abnormal Joint).
Step-10	**:**	Display ROI and result of step –8 as an output.

Pseudocode: Elbow osteoarthritis detection from X-Ray Images

```
READ an X-Ray image of human elbow
APPLY Median Filter
DO CLAHE for X-Ray image preprocessing
PERFORM Edge Detection based on Sobel edge detector
PERFORM Edge Detection based on Canny edge detector
CONVERT edged image into binary image
DETECT ROI
MEASURE JSW (Joint Space Width) (1 Pixel = 0.264583333 mm)
CLASSIFICATION of JSW as Normal Joint or Abnormal Joint
Display ROI of elbow and result of Classification
```

5. Experimental Result and Discussion

I have experimented above presented algorithm given in the section – IV in Scilab on 89 X-Ray images of human elbow. These images were randomly selected from online available MURA (Musculoskeletal Radiographs) dataset. Table – 1 shows computer system environment on which proposed method has been experimented.

Table 1: Environment of Machine.

Environment of Machine	
Operating System	Windows 7 SP 1 (64 bit)
Image Processing S/W.	Scilab 5.5.2
X-Ray Image Detail	512 * 512, 8 bit grayscale, .jpg
Processor	Intel Core i5 1.70 GHz
RAM	4 GB
HDD Capacity	500 GB

Images given in the following figure shows the experimental results of Original Human's Elbow Joint X-Ray Images with Arthritis Detection. These are some selected original X-Ray images with their resultant arthritis images.

Following figure – 2 shows 2 rows, row 1 represents original Human's Elbow Joint X-Ray Images with Arthritis, while row 2 depicts bone arthritis detection from corresponding X-Ray images of row 1. It means the resultant arthritis images are shown in the row 2 of the figure 2. The accuracy of this algorithm almost greater than 91% to detect arthritis from human being's elbow X-Ray images provided images are captured in high resolution and good quality.

Figure 2: Experimental Results.

6. Conclusion and Future Attempts

X-Ray image is an important medical imaging component to detect bone related issues and diseases. The edge detection is the foremost requirement for any type of image processing and hence it should be performed in the sensitive manner to analyze the medical image efficiently and effectively. In this research paper, I have presented an algorithm in the general terminology to detect osteoarthritis from human's elbow x-ray images based on hybrid edge detection approach means it is combination of sobel edge detection technique and canny edge detection technique. The proposed algorithm has been experimented on online available MURA dataset using computer machine environment as specified in the table-1. This algorithm can be utilized by other researchers to devise an efficient medical aided tool for human's elbow X-Ray image to detect osteoarthritis. Researchers have scope to work in the direction of other types of images such as MRI image, CT Scan image, Mamogram Image, Sonography etc. Further, Research can also work in the field of the X-Ray image analysis to detect other bone related diseases such as fracture, bone tumor, rheumarthritis etc.

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