

Implementation of Lower Leg Bone Fracture Detection from X-Ray Images

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Computer vision system can help to screen X-ray images for suspicious cases and alarm the doctors. Depending on the experts alone for such a critical matter has caused intolerable errors and hence, the idea of automatic diagnosis procedure has always been an appealing one.

There are many techniques to detect the bone fracture, such as Computed Tomography (CT), Magnetic resonance imaging (MRI), Ultrasound and X-ray which help physicians in detecting different types of abnormalities. Fracture diagnosis and treatment, X-ray images are most frequently used in fracture diagnosis because it is the fastest and easiest way for the doctors to study the injuries of bones and joints. Doctors usually use x-ray images to determine whether a fracture exists. In the recovery process, doctors also use x-ray images to determine whether the injured bones and joints have recovered [06Din]. Although CT and MRI images gives better quality images for body organs than X-ray images, X-ray images are faster and cheaper, enjoy wider availability and are easier to use few limitations. Moreover, the levels of quality of X-ray images are enough for the purpose of bone fracture detection [13Mah]. The system proposed in this thesis classifies the existence of fractures in lower leg bones based only on X-ray images. The human body contains 206 bones with various shapes and structures. The largest bones are the femur bones, and the smallest bones are the auditory ossicles. There are basically five types of bone in human body, such as long, short, flat, irregular and seasmoid [13mah]. Fig.1 shows the anatomy and shape of the human body.

ABSTRACT

A methodology and various techniques are presented for development of fracture detection system using digital image processing. This paper presents an implementation of bone fracture detection using medical X-ray image. The goal of this paper is to generate a quick and diagnosis can save time, effort and cost as well as reduce errors. The main objective of this research is to classify the lower leg bone fracture using X-ray image because this type of bone are the most commonly occur in bone. This paper classifies the two types of fracture (Non-fracture and fracture or Transverse fracture) by using SVM classifier. The proposed system has basically five steps, namely, image acquisition, image pre-processing, image segmentation, feature extraction and image classification.

KEYWORDS: X-Ray images, Lower Leg bone, Image processing, Fracture type, SVM Classifier

1. INTRODUCTION

Today, medical image processing is a field of science that is gaining wide acceptance in healthcare industry due to its technological advances and software breakthroughs. It plays a vital role in disease diagnosis and improved patient care and helps medical practitioners during decision making with regard to the type of treatment. Among the various diseases, bone fracture detection and treatment, which affects many people of all ages, is growing important in modern society [12Mah].

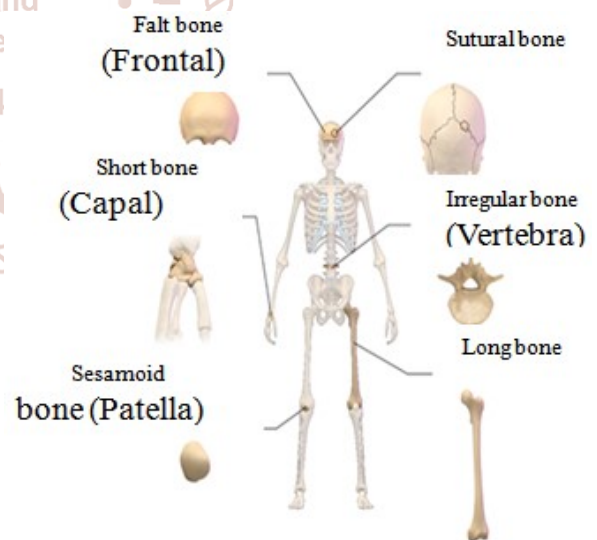


Figure 1.1: Classification of Bone by Shape [16Wik]

2. Overview of proposed system

A. Bone Fracture Detection Using Image Processing in Matlab

The first paper done by Ms. Snehal Deshmukh, et al. [15Sen], they discussed that several digital image processing techniques applied in edge feature extraction for bone fracture detection. In this paper, firstly, linear filtering is used to remove noises from the collected images. Secondly, some edge detection operators such as Sobel, Log edge detection and Canny edge detection are analyzed and then according to the simulation results, the advantages and

disadvantages of these edge detection operators are compared. It is shown that the Canny operator can obtain better edge feature and it can also be produced equally good edge with the smooth continuous pixels and thin edge. Sobel edge detection method cannot produce smooth and thin edge compared to Canny method. But, the same like other method, Sobel and Canny methods are very sensitive to the noise pixels. Sometimes, all of the noisy image cannot be filtered perfectly.

B. Algorithm and Technique on Various Edge Detection

The next paper, Rashmi, Mukesh Kumar, and Rohini Saxena [13Ras] proposed a survey of various edge detection techniques as Prewitt, Robert, Sobel, Marr Hildrith and Canny operators. In this paper, the authors have studied and evaluate different edge detection techniques. They describe that Canny edge detector gives better result as compared to other edge detectors on various aspects such as it is adaptive in nature, performs better for noisy image, give sharp edges, low probability of detecting false edges, etc. The authors stated that Canny method is optimal edge detection technique hence lot of work and improvement on this algorithm has been done and it can detect edges in color image without converting in gray image.

C. Edge Detection of Femur Bone in X-Ray Images – A Comparative Study of Edge Detectors

Shubhangi D.C, et al. [12Shu] analyzed the performance of Laplace operator in comparison with other edge detection methods, namely, Roberts, Sobel, Prewitt, and Canny's operators, which are applied to the X-ray images of femur bones. They observed that Robert cross gradient operator is very quick to compute. The resultant image is very similar to the one obtained by Sobel operator but quality of edge pixels are found to be degraded due to lot of jerky effect on edges. The Sobel operator is slower than the Roberts operator and its performance is poor than the Prewitt operator. From the experimental results, they observed that the Laplace operator gives better edge detection results than the other methods in the investigation of X-ray images of femur bones, which has significance to medical and forensic experts.

D. Determining the Type of Long Bone Fractures in X-Ray Images

Mahmoud Al-Ayyoub and Duha Al-Zghool [13Mah] considered the problem of determining the fracture type from X-ray images. This paper started with the preprocessing and noise removal by using histogram equalization process. After enhancing the x-ray images and removing noise, it then discussed various tools to extract useful and distinguishing features based on: edge detection, corner detection, parallel & fracture lines, texture features and peak detection. The next step is image classification based on the extracted features to predict fracture types. In this stage, Support Vector Machine (SVM), Decision Tree (DT), Navie Bayesian (NB) and Neural Network (NN) were tested to classify fracture types. According to the experimental results, SVM classifier was found to be the most accurate with more than 85% accuracy under the 10-fold cross validation technique.

3. System flow

The procedures needed for this system are image acquisition, image pre-processing, image segmentation,

feature extraction and image classification. The first step, the input image is obtained from different places and the image is filtered out by the Gaussian filter. Then, edge detection method is used to detect the bone structure. And then the Harris algorithm also used for extracting point features from the image. For the classification step, support vector machine (SVM) is used to classify fracture types.

A. Image Acquisition

Image acquisition in image processing can be broadly defined as the action of retrieving an image from some source, usually a hardware-based source, so it can be passed through whatever processes need to occur afterward. Performing image acquisition in image processing is always the first step in the workflow sequence because, without an image, no processing is possible. In this step, medical images are given as input and all types of medical images can be acquired.



Figure 3.1: Samples of Normal Lower Leg Bone X-Ray Images



Figure 3.2: Samples of Fractured Lower Leg Bone X-Ray Images

B. Image Pre-processing

Image pre-processing is the term for operations on images at the lowest level of abstraction. These operations do not increase image information content but they decrease it if entropy is an information measure. Image pre-processing uses the redundancy in images. Neighbouring pixels corresponding to one real object have the same or similar brightness value. If a distorted pixel can be picked out from the image, it can be reported as an average value of neighbouring pixels. Image pre-processing methods can be classified into categories according to the size of the pixel neighbourhood that is used for the calculation of new pixel brightness. The aim of pre-processing is an improvement of the image data that suppresses undesired distortions or enhances some image features relevant for further processing and analysis task [06Olgl].

In pre-processing step, noise suppression is the most important task. Noise reduction is an important and basic part in remote sense image processing. Not only spatial noise but also spectral noise may exist in the image because of the influence of natural light, surface topography, mixed pixel, etc. [08Chi]. Noise is the result of errors in the image acquisition process that results in pixel values that do not reflect the true intensities of the real scene. Most commonly used de-noising techniques are described as follows:

- Median filter
- Average filter
- Gaussian filter
- Winner filter
- Histogram equalization

Among these filters, Gaussian filter is used for noise reduction in this thesis.

C. Image Segmentation

Image segmentation is a very important step in image analysis and performance evaluation of processed image data. The goal of image segmentation is to make simple or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in image. Image segmentation is the process of partitioning an image into non-intersecting regions such that each region is homogeneous and the union of no two adjacent regions is homogeneous. Segmentation is typically associated with pattern recognition problems. It is considered the first phase of a pattern recognition process and in sometimes also referred to as object isolation. According to the expression of Ashutosh Kumar Chaubey [16Ash], segmentation algorithms have been used for a variety of applications. In this thesis, edge-based segmentation method is used in order to segment region of bone area from background.

Edge-based Method

Edge-based segmentation exploits spatial information by detecting the edges in image. Edges correspond to discontinuities in the homogeneity criterion for segments. Edge-based image segmentation algorithms are sensitive to noise and tend to find edges that are irrelevant to the real boundary of the object. Moreover, the edges extracted by edge-based algorithms are disjointed and cannot completely represent the boundary of an object. Therefore, the edge-linking algorithms are applied to create enclosed boundaries. Edge-based segmentation algorithms use edge detectors (Sobel, Prewitt, Robert, Canny, Laplacian) to find edge in the image. In this research, a comparison of the four types of edge detector is tested. Then, Canny edge detection is used to find discontinuities in bone image. Canny detector produces good view of bone structure and gives many advantages than other edge detectors. A comparative study of the four edge detectors are Sobel, Prewitt, Robert and Canny. These result images are shown in the following figure 3.3. In figure 3.3, (a) and (b) are the results of Sobel and Prewitt edge detectors. Then, figure 3.3(c) and (d) are the results of Robert edge detector and Canny edge detector.

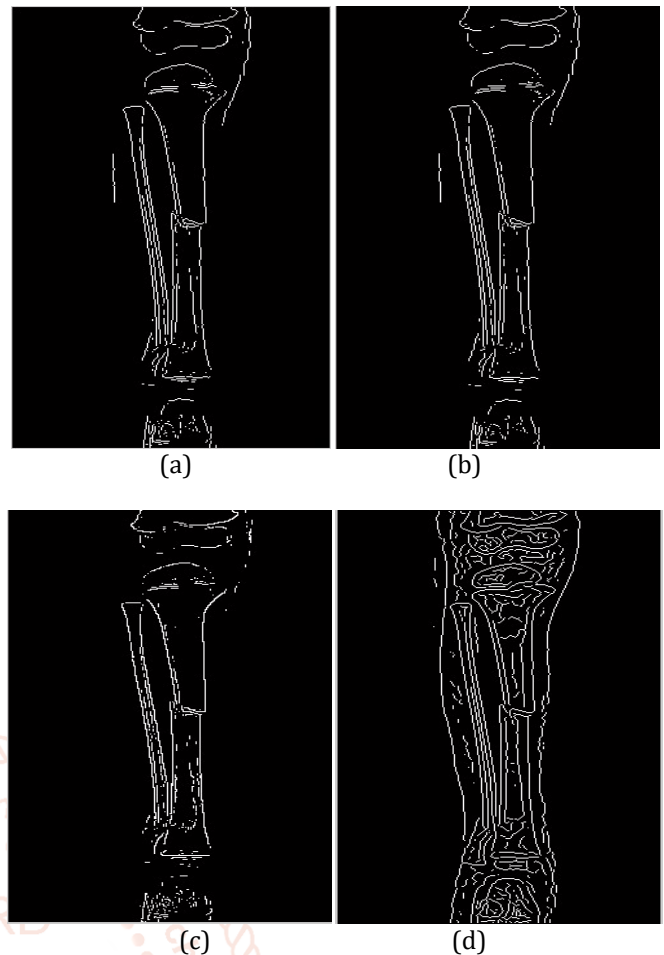


Figure 3.3: Result Images for Edge Detectors

D. Feature Extraction

Feature extraction is the main step in various image processing applications. A feature is a significant piece of information extracted from an image which provides more detail understanding of the image. The commonly used of feature extraction methods are Gray Level Co-occurrence Matrix (GLCM), Wavelet transform, Curvelet transform, Hough transform and Harris corner detection. Harris corner detection techniques is used in this paper.

Harris Algorithm

Harris algorithm detects all corners (in general, intersection point) or most true interest points based on the brightness of images. In this thesis, Harris corner detection is used to detect feature points. Harris features are shape and vector of the bone image. These features are used for fracture classification using SVM classifier which is a representation of the example as points in a feature space. The point which is the direction of the boundary of object changes abruptly. The Harris detector uses the correlation matrix as the basis of its corner decisions. Classification of image points using eigenvalues of matrix (M). The correlation matrix or second moment matrix can be represented as follows:

$$M = \sum_{x,y} w(x,y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$$

Harris defines the response function (R) which decide the point is corner or not with the following equation

$$R = \det M - k \text{trace}^2 M = \lambda_1 \lambda_2 - k(\lambda_1 + \lambda_2)^2 M,$$

R depends only on eigenvalues ($\lambda_1\lambda_2$) of matrix (M). If λ_1 and λ_2 are large or λ_1 is similar λ_2 , Harris can be defined as Corner. If eigenvalues (λ_1 and λ_2) are small, it is almost constant in all direction (flat region) and if λ_1 very much greater than λ_2 or λ_2 very much greater than λ_1 , this can be defined as edge [13Hua] [03Mar].

E. Image Classification

Classification is a step of data analysis to study a set of data and categorize them into a number of categories. It takes a feature vector as an input and responds category to which the object belongs. It employs two phase of processing, training and testing: in training, characteristic properties of typical image features are isolated and in testing, these feature-space partitions are used to classify image feature.

The most commonly used of classifiers are Bayesian, Neural Network, K Nearest Neighbour, and Support Vector Machine that are used to classify the sets of data. Bayesian has always the minimum error rate but it requires exact knowledge of class. Bayesian classifier is applied with Gabor Orientation (GO), Markov Random Field (MRF), and Intensity Gradient Direction (IGD) features [14Jar].

Neural Network classification is fast but its training can be very slow and which requires high processing time for large neural network.

K Nearest Neighbour can have excellent performance for arbitrary class conditional, can be slow for real-time prediction and a large number of training examples, it is not robust to noisy data.

Support Vector Machine (SVM), it can affect in high dimensional spaces. It can avoid under-fitting and over-fitting. SVM also produces very accurate classifier. If the number of features is very much greater than the number of samples, it will give poor performance. In this thesis, support vector machine (SVM) is used to classify fracture types.

Support Vector Machines

Support Vector Machines (SVM) recently became one of the most popular classification methods. They have been used in a wide variety of applications such as text classification, facial expression recognition, gene analysis and many others. Support vector machine (SVM) is supervised learning models with associated learning algorithm that analyzes data and recognizes patterns. SVM classifies unseen data based on a set of labeled training data set. The goal of SVM is to find the optimal separating hyperplane which maximizes the margin of the training data. The maximum margin hyperplane is the one that gives the greatest separation between the classes. Among all hyperplanes that separate the classes, the maximum margin hyperplane is the one that is as far away as possible from the two convex hulls, each of which is formed by connecting the instances of a class. The instances that are closest to the maximum hyperplane are called **support vectors**. There is at least one support vector for each class, and often there are more.

SVM training data builds the hyper plane or decision boundary whether a new example falls into one category or the other. A hyperplane is a generalization of a plane in one dimension; a hyperplane is called a point. In two dimensions, it is a line and a plane in three dimensions. It can call a

hyperplane in more dimensions. A good separation is achieved by the hyperplane. There can be a lot of separating hyperplanes and selects as far as possible from data points of both classes. The optimal hyper plane is correctly classify the training data.

4. Experimental Results

The original X-ray scan of bone fracture image is taken from 'Mandalay Orthopaedic Hospital' in Myanmar. The X-ray scan of bone image is given as input for this system.

The input X-ray image contains noises which is unwanted pixels that affect the quality of the image. Therefore, the image pre-processing stage is needed to remove these noises. For this system, each X-ray image has a resolution of 200 x 200 pixels in size by resizing. In this thesis, 52 of bone images are used where 40 images for training and 12 images for testing. Among the training images, 10 images are normal or non-fracture image and 30 images are fracture image. The next step is image pre-processing. The purpose of pre-processing is to provide image quality for later process and to obtain the best result. After image segmentation is performed, the segmented bone image is used for feature extraction. The extracted feature points are shown in figure 4.1(a) non-fracture image and (b) fracture image. These figures show the feature points from the image by Harris algorithm.

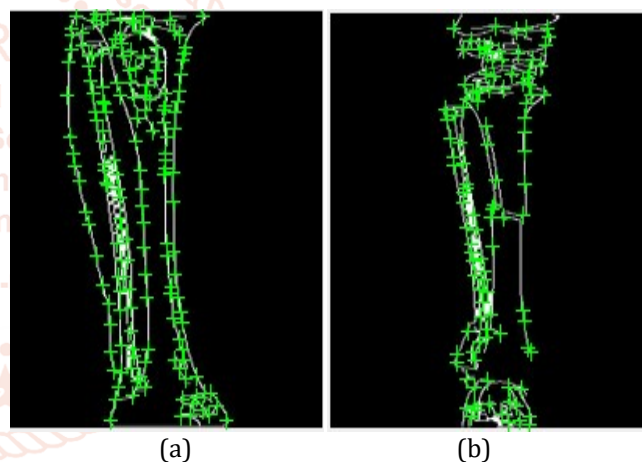


Figure 4.1: Result Images for Harris Corner Detection

Harris detects all Corners or intersection points based on the brightness of images. It uses the second moment matrix or correlation matrix as the basis of its corner decisions. These extracted shape and point feature are used as the input to classify which type of fracture by SVM algorithm.

The SVM algorithm classifies the positive and negative features by training a classifier that uses a linear kernel function to map data into a higher dimensional space. In this system, linear kernel detects the features point to point horizontally. Despite several erroneous matches between the two images, SVM find the optimal point from the feature space. This algorithm produces the classification result of match fracture detected for fracture image and no match fracture detected for non-fracture image. The output classes have the two types in this thesis. The classification results of SVM algorithm are shown in figure 4.2(a) and (b). In which, (a) is non-fracture and (b) is fracture image.

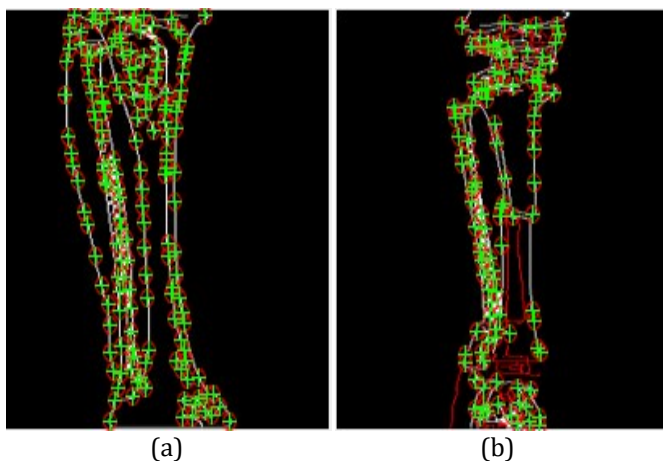


Figure 4.2: Results of SVM classifier for Match Data Images

Finally, the algorithm produces the output image as the bone fracture detection result. Therefore, the final results of this thesis are illustrated in figure 4.3(a) and (b) respectively.

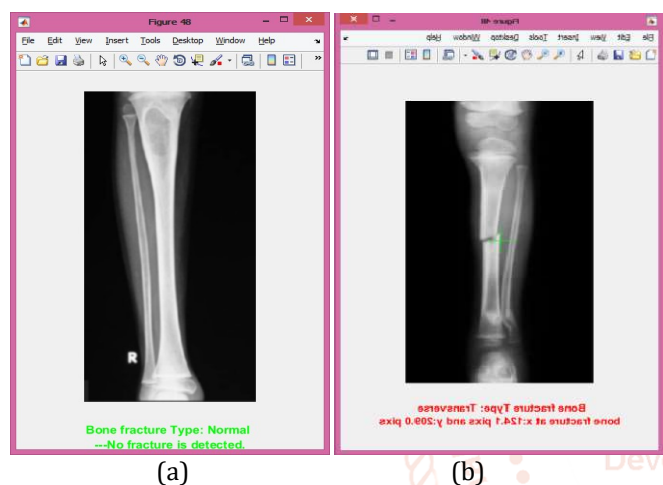


Figure 4.3.Fracture Detection Results

5. Conclusion

In this experiment, many X-ray images are collected from Mandalay Orthopaedic Hospital and various Internet websites. In this paper, 52 of bone images are used where 40 images for training and 12 images for testing. Among the training images, 10 images are normal or non-fracture image and 30 images are fracture image. The algorithm cannot detect correctly in 4 fracture images. According to the test results, the performance of the detection method affect by the quality of the image. After that all, this system determined whether a fracture exists or not in the image. A software algorithm capable of providing some theory after bone fracture detection has been specified, and implemented. The proposed system is developed by using MATLAB programming language. The input X-ray bone

fracture images to this proposed system have various shapes and sizes, so it is hard to get the standard features of these fracture images. Therefore, this proposed system cannot be generated the good performance. According to the experimental results, a combining algorithm can be produced a good result for fracture detection system.

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