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A Study of Various Bone Fracture Detection Techniques

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Abstract: ***The bone fracture is common problem in human beings due to accident or other causes like bone cancer etc. The fracture can occur in any bone of our body like wrist, heel, ankle, hip, rib, leg, chest etc. It is not possible to view fractures by naked eyes, so X-ray/CT images are used to detect it. But sometimes these images lack sufficient details needed to diagnose. Now a days image processing is playing an important role in bone fracture detection. Image processing is important in modern data storage and data transmission especially in progressive transmission of images, video coding (teleconferencing), digital libraries, image database, and remote sensing. This paper presents a study of image processing techniques for bone fracture detection. This paper will help user to study different methods for bone fracture detection using image processing and to design new techniques to improve accuracy of fracture detection. This paper also presents technologies used to implement image processing based system for fracture detection with pros and cons.***

Keywords: x-ray, segmentation, bone fracture, image processing.

1. Introduction

The human body has 206 bones with various shapes, size and structures. Bone fracture is a common problem in human beings. Fractures are classified in various ways. One way is the mechanism by which fracture s classified as

- Traumatic fracture – This is a fracture due to sustained trauma. e.g., fractures caused by a fall, road traffic accident, fight, etc.
- Pathologic fracture – A fracture through a bone that has been made weak by some underlying disease is called pathological fracture. e.g., a fracture through a bone weakened by metastasis. Osteoporosis is the most common cause of pathological fracture.
- Periprosthetic fracture – This is a fracture at the point of mechanical weakness at the end of an implant

Fracture can also be classified based on soft tissue involvement as

- Closed fracture: are those in which the overlying skin is intact
- Open fracture/Compound fracture: involve wounds that communicate with the fracture, or where fracture hematoma is exposed, and may thus expose bone to contamination. Open injuries carry a higher risk of infection.

Other than these fractures can also be classified using many other categories like displacement, fracture pattern, fragments etc.

There are different types of medical imaging tools are available to detecting different types of abnormalities such as X-ray, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), ultrasound etc. X-rays and CT 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 uses x-ray images to determine whether a fracture exists, and the location of the fracture. Sometimes fracture is not clear in x-rays, Image processing helps in such cases to detect fracture.
The tools available today have made it possible to innovatively extract information about human body in a convenient and economical fashion. The continuing advances made available through both hardware and software demands new techniques and enhancement of existing techniques to be developed. It is a well-known fact that there is no common method that can be applied to analyze or process all parts of a human body and the techniques are dedicated to each part separately.

This study describes different methods for fracture detection based on X-ray and CT images only as these are most frequently used methods 28 papers have been studied for the study.

2. Method

In this section different method applied to x-ray/CT images are listed and corresponding papers were discussed. This will help the reader in understanding the potential and amount of research that have been carried in that field. An attempt has been made in providing short technical details of each paper, for the benefit of researchers in this field.

This paper also presents some common and new tools used for image processing in the study of bone fracture detection.

Normally Classification based and transformed base are two types of fracture detection technique. This paper discusses both the techniques.

Vijaykumar V at al.[1] presented a filtering algorithm for Gaussian noise removal. First estimating the amount of noise from the noisy image, then replace the center pixel by the mean of the sum of the surrounding pixels based on a threshold value. Compared to other filtering algorithms such as mean, alpha-trimmed mean, Wiener, K-means, bilateral and trilateral, this algorithm gives lower Mean Absolute Error (MAE) and higher Peak Signal-to-Noise Ratio (PSNR).

Generally the DICOM images are corrupted by the salt and pepper noise. Al-Khaffaf H at al [2] proposed an extension of the K-fill algorithm to remove salt and pepper noise based on the number of black or white pixels in a 3 × 3 window. Assuming that the images are corrupted by the noise modeled as a sum of two random processes: a Poisson and a Gaussian, this approach allows them to jointly estimate the scale parameter of the Poisson component and the mean and variance of the Gaussian one.

2.1 Active contour model (ACM and GACM)

R. Aishwariya et al. [3] proposed the technique that detect the boundaries of objects in noisy images using the information the fracture detection on the x-ray images is founded. The proposed technique for the canny edge detector in the x-ray image locates the edges and using the boundary detection, the system which detects the fracture automatically. The boundary detection techniques also implemented in the models are Active Contour Model, Geodesic Active Contour Model and compare the accuracy of detecting is analyzed and tested Using Matlab.

2.2 Wavelet and Curvelet, Haar

Chan, K.-P.at al [4] proposed a method of feature selection by using three different methods such as wavelet and curvelets transform. Haar method gives the highest accuracy value compared with other two methods.

2.3 Support Vector Machine(SVM) classifier

Lim, S. E at al [6], Yap, D. at al [7] and Lum, V. L. F at al [8] proposed to use Gabor, Markov Random Field, and gradient intensity features extracted from the x-ray images and fed into Support Vector Machines (SVM) classifiers. They observe that the combination of three SVM classifiers improves the overall accuracy and sensitivity compared to using individual classifiers.

2.4 X-Ray/CT auto classification of fracture(GLCM)

Anu T C, Mallikarjunaswamy M.S Rajesh Raman[11] proposed computer based analysis techniques for the detection of bone fracture using X-ray/CT images. It starts from the preprocessing to remove the noise and edge detected by using sobel edge detector. After the segmentation the area of the fracture is calculated. The method has been tested on a set of images and results have been evaluated based on GLCM features. Analysis shown that results obtained are satisfactory and accuracy of this method was 85%.The limitation of this method is ,in CT and some cases of X-ray images very difficult to find the area of fracture

Gray-Level Co-occurrence Matrix(GLCM) is used for feature extraction and selection. GLCM was defined by Haralick et al. in 1973.GLCM is main tool used in image texture analysis. Textures of an image are complex visual patterns that are composed of entities or regions with sub-patterns with the characteristics of brightness, color, shape, size, etc. GLCM is a statistical way to indicate image texture structure by statistically sampling the pattern of the grey-levels occurs in relation to other grey levels.

In this method, different types of classifier are used such as decision tree (DT) and neural network (NN) and meta-classifier. Based on the GLCM textural features, classifiers classify the given image into fractured and non-fractured image.

The performance of the proposed system is evaluated in terms of accuracy, precision, sensitivity and specificity.

Accuracy= (TP+TN)/(TP+TN+FN+FP).
Precision= TP/(TP+FP)
Sensitivity= TP/(TP+FN)
Specificity= TN/(TN+FP)

2.5 Novel morphological gradient based edge detection technique

Swathika.B, Anandhanarayanan.K, Baskaran.B, and Govindaraj.R [12] proposed Novel morphological gradient based edge detection technique in which canny edge detection is applied after finding morphology gradient. The morphological gradient technique removes noise, enhances image details and highlights the fracture region. The fracture edges are more prominently revealed due to the combined effect of morphological gradient technique and canny edge detection algorithm. The processed image output show that the proposed technique provides efficient fracture detection when compared with other edge detection methods.

Using GLCM and fcm

SP. Chokkalingam and K. Komathy [13] implemented a new scheme to diagnose the presence of rheumatoid arthritis by a series of image processing techniques. The system can be enhanced by the improvement of the edge detection and find better segmentation technique. The Gray level co-occurrence matrix (GLCM) features are Mean, Median, Energy, Correlation, Bone Mineral Density (BMD) etc.. After finding all the features, it can be stored in the database. The dataset is trained with inflamed and non-inflamed values and with the help of classifier i.e. neural network.

2.6 Daubechies Wavelet and Fuzzy C-Means (FCM) Clustering

Hs Rathode and Wahid Ali [14] proposed an algorithm for Automatic tumor detection that is based on segmentation using Daubechies Wavelet and Fuzzy C-Means (FCM) Clustering. The segmented portion showing the tumor area in pixels and the time elapsed to detect and calculate the area in seconds. The algorithm developed is accurate and fast to detect and quantify the tumor.

Tanudeep Kaur , Anupam Garg [15] proposed wavelet approach used to detect Fracture detection region on the X-Ray images. Multilevel wavelet is used to find the fracture from the x-ray bone images after applying FCM and Gabor filter. It finds fracture only in horizontal images. It uses Hough transform to find long bones and wavelet decomposition. It finds the fracture only the horizontal images.

Hand

2.7 Using Classifiers DT, BN, NB, NN and mixed

Mahmoud Al-Ayyoub, Ismail Hmeidi, Haya Rababah [16] proposed a system to automatically detect fractures in hand bone. They have collected set of labeled x-ray hand images that contain normal as well as fractured hands and enhanced them by applying some filtering algorithms(e.g. median filter) to remove the noise from them. Then have detected the edges in each image using edge detection methods(sobel). After that, they converted each image into a set of features using tools such the Wavelet and the Curvelet transforms and GLCM. Finally applied classification algorithms based on the extracted features. Four most commonly used base classifiers DT, BN, NB, NN were applied. Further meta classifiers like Voting, Bagging, Boosting, Boosting and Voting and Bagging and Boosting were applied to improve the performance.

2.8 Fusion Classification technique:

S.K.Mahendranα , S.Santhosh Baboo [17] proposes a fusion-classification technique for automatic fracture detection from long bones, in particular the leg bones (Tibia bones). The proposed system has four steps, namely, preprocessing, segmentation, feature extraction and bone detect ion, which uses an amalgamation of image processing techniques for successful detection of fractures. Three classifiers, Feed Forward Back Propagation Neural Networks (BPNN), Support Vector Machine Classifiers (SVM) and Naïve Bayes Classifiers (NB) are used during fusion classification. The results from various experiments prove that the proposed system is shows significant improvement in terms of detection rate and speed of classification boosting and then bagging on the Bayesian Network classifiers with feature using Wavelets, Curvelets and

2.9 Wavelet and Haar

Sachin R., Mahajan, P. H.Zope, S.R.Suralkar [18] proposed automatic segmentation of x-ray image. They applied contrast enhancement and hmomorphic filtering followed by wavelet , Haar transform for feature extraction The Haar transform results in four sub-bands, namely Low-Low, High-High, High-Low and Low-High. The Low-Low region has most of the energy, while High-High has the least energy. The High-Low and Low-High sub bands contain the edge details. The composition operators-occurrence matrix features, energy and contrast, is calculated for each sub-band using Equation (1) and (2)

$$\text{Energy} = \sum_{i,j=1}^{N} C_{i,j}^{21} \quad (1)$$

$$\text{Contrast} = \sum_{i,j=1}^{N} (i-j)^2 C_{i,j} \quad (2)$$

General segmentation algorithms are categorized into six classes, namely thresholding, region-based, edge-based, graph-based, classification-based and deformable models

2.10 Combined snake and GVF

Tian Tai Peng[20] proposed a method to compute neck-shaft angle. The method comprises two algorithms. The first algorithm extracts the femur contour accurately from x-Ray images and the second algorithm computes neck-shaft angle based on the contour of the femur. Initially author applied Modified canny edge detection, snakes and active contours and gradient vector flow then used combined snake and GVF.

2.11 Novel approach using binary tree and cuttoff

Cephas Paul Edward V , Hilda Hepzibah S. [21] proposed robust approach for detection of type of fracture. After applying conrat stretching and homomorphic filtering to X-ray images as a novel idea, the image is binarized and the intensity values are inverted, i.e. black pixels are made white and white pixels are made black. The binary image is exposed to hole filling and all small insignificant blobs are removed with mean thresholding. Now the image is scaled to an arbitrary standard size chosen as 256 x 256. The image is scanned over for the largest blob. The width of this blob is measured. A rectangular window of height and width same as the width of the measured blob is scanned over the image. If there occurs any white space within the black space inside the window, then fracture is detected. To make the process more accurate, different such sample windows are taken and trained using a neural network. Thus this can be used to predict future inputs. Edge detection features can also be used. Instead of Canny, a novel edge detection algorithm is used The image is represented as a binary tree with each node its pixel value. The tree is traversed from bottom to up and the cascade-cut algorithm is applied to it. The nodes are cutoff at the point where there is a sharp change in intensity, which are candidate edge points. From these cut-off portions the edges are formed tree with each node its pixel value. The tree is traversed from bottom to up and the cascade-cut algorithm is applied to it. The nodes are cutoff at the point where there is a sharp change in intensity, which are candidate edge points. From these cut-off portions the edges are formed.

2.12 Using Discrete Wavelet Transform and ring

Rebecca Smith et al. [24] present a fracture detection method for the pelvic ring based on Discrete Wavelet Transform. DWT is applied to windows extracted from the extracted from the ring as defined by prior automated region segmentation. The chosen wavelet coefficient is used to reconstruct an image that highlights the bone boundary. This is followed by morphological operations on its binary image. If single boundary is returned then there is no fracture else there will be multiple boundaries depending on facture type and numbers.

2.13 Using Bi Plane Slicing

M.Mohammed Sathik et. al [26] proposed an idea that X-Ray images can be enhanced by adding the color map. To add the RGB color to the Destination image, the reference image 'mood' color is taken. Although adding color to the gray scale has no much impact, but the human labor is much reduced. After adding color to the original image, it adds up details to the target image. In the second part of this paper, Bit-Plane slicing method is used to extract the details of a Colored X-Ray Image. This method produces different bit level images. In this paper Bit Level 6 is evaluated for RGB colors of the Original image and it is evaluated with the Bit level 6 of the original image. The result shows that the colored X-Ray image Bit level6 yield more details than the Bit level6 of gray scale X-Ray image.

2.14 Supervised learning based classification

MAHMOUD AL-AYYOUB, DUHA AL-ZGHOOL.[27] Proposed long bone fracture detection on x-ray images. Several image processing tools were used to remove different types of noise and to extract useful and distinguishing features. In the classification and testing phase, SVM classifier was found to be the most accurate with more than 85% accuracy under the 10-fold cross validation technique.

Two sets of experiments are discussed by authors. In the first set, the binary classification problem of detecting whether a fracture exists or not is considered, Whereas, in the second set, the 5-class classification problem of determining the type of fracture is considered. The five classes are: normal (i.e., no fracture is detected), Greenstick fracture, Spiral fracture, Comminuted fracture and Transverse fracture.

Specifically it uses Supervised learning in which the system classifies new instances based on a model built from a set of labeled examples (in this work, these are simply the x-ray images each with a normal/abnormal label) along with their distinguishing features (computed via image processing techniques).

3. Technologies

Normally most of researchers are using MATLAB due to the large number (and diversity) of the image processing tools developed under MATLAB for loading image, image processing and user interface development for fracture detection.
OpenCV has the advantage of being a multi-platform framework; it supports both Windows and Linux, and more recently, Mac OS X. OpenCV has so many capabilities it can seem overwhelming at first. A good understanding of how these methods work is the key to getting good results when using OpenCV.

3.1 Advantages of OpenCV over MATLAB

- Speed: Matlab is built on Java, and Java is built upon C. So when you run a Matlab program, your computer is busy trying to interpret all that Matlab code. Then it turns it into Java, and then finally executes the code. OpenCV, on the other hand, is basically a library of functions written in C/C++. You are closer to directly provide machine language code to the computer to get executed. So ultimately you get more image processing done for your computers processing cycles, and not more interpreting. As a result of this, programs written in OpenCV run much faster than similar programs written in Matlab. So, conclusion? OpenCV is damn fast when it comes to speed of execution. For example, we might write a small program to detect peoples smiles in a sequence of video frames. In Matlab, we would typically get 3-4 frames analysed per second. In OpenCV, we would get at least 30 frames per second, resulting in real-time detection.
- Resources needed: Due to the high level nature of Matlab, it uses a lot of your systems resources. And I mean A LOT! Matlab code requires over a gig of RAM to run through video. In comparison, typical OpenCV programs only require ~70mb of RAM to run in real-time. The difference as you can easily see is HUGE!
- Cost: List price for the base (no toolboxes) MATLAB (commercial, single user License) is around USD 2150. OpenCV (BSD license) is free! Now, how do you beat that? Huh? huh? huh?
- Portability: MATLAB and OpenCV run equally well on Windows, Linux and MacOS. However, when it comes to OpenCV, any device that can run C, can, in all probability, run OpenCV.

3.2 Dis-Advantages of OpenCV over MATLAB

- Ease of use: Matlab is a relatively easy language to get to grips with. Matlab is a pretty high-level scripting language, meaning that you don't have to worry about libraries, declaring variables, memory management or other lower-level programming issues. As such, it can be very easy to throw together some code to prototype your image processing idea
- Memory Management: OpenCV is based on C. As such, every time you allocate a chunk of memory you will have to release it again. If you have a loop in your code where you allocate a chunk of memory in that loop and forget release it afterwards, you will get what is called a "leak". This is where the program will use a growing amount of memory until it crashes from no remaining memory. Due to the high-level nature of Matlab, it is "smart" enough to automatically allocate and release memory in the background.
- Development Environment: Matlab comes with its own development environment. For OpenCV, there is no particular IDE that you have to use. Instead, you have a choice of any C programming IDE depending on whether you are using Windows, Linux, or OS X. For Windows, Microsoft Visual Studio or NetBeans is the typical IDE used for OpenCV. In Linux, its Eclipse or NetBeans, and in OSX, we use Apple's Xcode.

3.3 OpenCV using Pyhthon

OpenCV using python is good option. It is an excellent choice for learning Computer Vision, and is good enough for a wide variety of real world applications

- **Ease of use :** If you are a python programmer, using OpenCV (Python) would be very easy. Python is an easy language to learn (especially compared to C++). It is also an excellent first language to learn.

- **Python has become the language of scientific computing :** A few years back MATLAB was called the language of scientific computing. But now, with OpenCV, numpy, scipy, scikit-learn, and matplotlib Python provides a powerful environment for learning and experimenting with Computer Vision and Machine Learning.

- **Visualization and debugging :** When using OpenCV (Python) you have access to a huge number of libraries written for Python. Visualization using matplotlib is about as good as MATLAB. I find debugging code in Python easier than in C++, but it does not quite match the super-easiness of MATLAB.

- **Building web backend :** Python is also a popular language for building websites. Frameworks like Django, Web2py, and Flask allow you to quickly put together web apps. It is very easy to use OpenCV (Python) along with these web frameworks. E.g. read this tutorial that explains how to turn your OpenCV code into a web api in under 10 minutes.

4. Conclusion

The fracture detection techniques discussed above can be applied to different bones in the human body. This is illustrated in Fig 1 below.

Fig.1 Different Bones in Human Body Where Image procesing can applied for fracture detection[24]

X-ray diagnosis is commonly used for fracture detection unless the fracture is complicated (E.g. stress fractures) in which case a CT, MRI or ultrasound may be needed for further diagnosis and operation.

Among the fracture detection techniques discussed, fracture detection using classifiers in X-ray/CT images appears promising. However there is a need to accurately detect fractures using minimum and computationally less expensive features and should be classified accurately using less expensive classifiers. Features that complement each other should be used. This can be achieved by performing relevance and redundancy analysis of classifiers, where optimal features can be selected from the original high dimensional feature set. This will help in achieving higher accuracy and better computational complexity.

Based on the study conducted, a major challenge in fracture detection systems is designing auto detection systems that can be applied to all bones. A detailed study should be performed on large dataset including all bones.

Python Using OpenCV is good option to design application for fracture detection using image processing. For doing research Matlab is good as it is faster (if it is available). If you already had a result of your research, and want to make an application with it, OpenCV, is best, it will take longer to program, but it can make more time and memory optimizations.

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