Bone Fracture Detection Algorithms Based on Image Processing- A Survey

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ABSTRACT
Fracture in bone occurs when an external force exercised upon the bone is more than what the bone can tolerate or bear. As, its consequence structure and muscular power of the bone is disturbed and bone becomes frail, which causes tormenting pain on the bone and ends up in the loss of functioning of bone. Accurate bone structure and fracture detection is achieved using various algorithms which removes noise, enhances image details and highlights the fracture region. Automatic detection of fractures from x-ray images is considered as an important process in medical image analysis by both orthopaedic and radiologic aspect. Manual examination of x-rays has multitude drawbacks. The process is time consuming and subjective. In this paper we discuss several digital image processing techniques applied in fracture detection of bone. This led us to study techniques that have been applied to images obtained from different modalities like x-ray, CT, MRI and ultrasound.

Keywords— Fracture detection, Medical Imaging, Morphology, Tibia, X-ray image

I. INTRODUCTION

Medical image processing is the expanding discipline of science that is tremendously growing in healthcare industry due to its technological advances and software breakthroughs. It plays an indispensable role in diagnosis of disease and improved patient care and helps medical practitioners with regards to the type of treatment. Detection, observation and proper treatment of fractures are considered important, as a wrong diagnosis often lead to ineffective patient management, increased dissatisfaction and expensive litigation. The significance of fracture detection comes from that in clinical practice, an exhausted radiologist has been found to miss fracture cases after looking through many images containing healthy bones. The field of medical imaging has been witnessing advances not only in acquisition of medical images but also in its techniques and expertise of interpretation. The most common ailment of human bone is fracture. Bone fractures are nothing but the ruptures which occur due to accidents. There are many types of bone fractures such as normal, transverse, comminute, oblique, spiral, segmented, avulsed, impacted, torus and greenstick. Computer aided diagnosis is exceedingly active field of research in which computer systems are developed to provide a quick and accurate diagnosis. A bone fracture is a medical condition in which there is a break in the continuity of the bones. Computer detection of fractures can assist the doctors by flagging suspicious cases for closer examinations and thus improve the timeliness and accuracy of the diagnosis. The main focus of this work is to automatically detect fractures in bones.

II. TYPES OF BONE FRACTURE

Bone fracture in human are of several types. Depending on the impact of the force, some of the fractures are more terrible and dreadful than others. Sometimes the specific bone involved, and the age of the person and general health conditions also determine the severity of the fracture. Commonly bone fractures include the hip, wrist, knee and ankle. Hip fractures mostly occur in aged people. The various types of fracture that occur in human body are:

Simple fracture: This fracture is often called as closed fracture. In this fracture the bone breaks out and there is no open wound. This is caused when a broken bone does not penetrate the skin.

Open fracture: the bone breaks such that bone fragments project through the skin. In cases, the wound may penetrate down to the broken bone, so it is not visible through the skin. This type of fracture is also called as compound fracture. Contagion and external bleeding are common to arise in this type of fracture.

Hairline fracture: this type of fracture occurs when is stress is exerted in the foot of lower leg. This can generally be caused by activities such as jogging or running.
Greenstick fracture: these are cracks in bones along only one side of the bone caused by a force perpendicular to the bone’s long axis. This kind of fracture occurs when the bone bends and cracks. There is no entire breaking of the bone into separate pieces. This type of fracture most commonly occur in children whose developing bones are more flexible than adult bones and therefore tend to bend partially.

Complicated fracture: this type of fracture occurs when supporting bones are highly injured and smashed. This may result in the injuries to the arteries, veins and nerves. There may also be injuries in bone lining. It leads to the critical condition for bone.

Avulsion fracture: muscles are connected to the bones by a formation know as tendons. These are a type of connective ligament. Powerful muscle contractions can cause the tendon to come out free, leading to the pull out pieces of the bone. These fractures involve a small piece of bone being torn off from the main bone due to intense force applied on the tendons. This type fracture is more common in the knee and shoulder joints and is caused by over exertion of muscles.

Comminuted fracture: in this type the bone is shattered into several small pieces and it takes more time to heal.

Compression fracture: this type of fracture happens when two bones are pinned against each other. The bone of the spine has this type of fracture. Aged people with osteoporosis have higher risk of developing this kind of fracture.

Spiral fracture: is the result of an extreme twisting force being exerted on bone.

Oblique fractures: these are slanted fractures that occur when force is applied at any angle other than right angle to bone.

Transverse fracture: form perpendicular to the long axis of the bone and are result of force applied to the right angle of the bone.

Various types of bone fractures are shown in Fig 1(a) and Fig 1(b)

III. SYMPTOMS OF BONE FRACTURE

Signs and symptoms of bone fracture include:

- Swelling or bruising over a bone.
- Deformity of an arm or leg.
- Pain in the injured area that gets worse when the area is moved and pressure is applied.
- Loss of function in the injured area.
- In open fractures, bone poking from the skin.

IV. METHODS FOR DETECTION OF BONE FRACTURE

Various algorithms for detection of bone fractures are:

1. Tibia fracture detection:

   The Tibia fracture detection method consists of following steps:
   Pre-processing: In this stage input x-ray image is enhanced and its feature extraction is done. It improves the fracture detection process. This stage proposes a new technique called SACEN (Simultaneous Automatic Contrast adjustment, Edge enhancement and Noise removal) algorithm that adjust contrast, filters noise and enhances the image.
   Segmentation: It is a two steps algorithm. In first step of algorithm the bone structure is separated from x-ray image and in second step the identification of diaphysis region is done from segmented bone structure. Both the algorithm steps are independent of each other and are used in different stages of fracture detection.
   Fracture detection: In fusion based classifier for fracture detection, all the selected classifiers are modelled to work as a binary classifier that signifies whether a fracture is detected or not. If fracture is detected then position of the fracture is highlighted. Three basic classifiers that are considered are:

      Feed Forward Back Propagation Neural Networks (BPNN), Support Vector Machine (SVM) and Naive Bayes (NB) classifier.
Fracture detection rate of this algorithm is given in Table I.

<table>
<thead>
<tr>
<th>Bone Type</th>
<th>TBPN</th>
<th>TSVM</th>
<th>TNB</th>
<th>FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fractured</td>
<td>83.12</td>
<td>85.71</td>
<td>86.08</td>
<td>91.27</td>
</tr>
<tr>
<td>Non-Fractured</td>
<td>92.96</td>
<td>94.55</td>
<td>95.91</td>
<td>98.43</td>
</tr>
</tbody>
</table>

From the above table it is evident that fusion classifier (FC) that combines TBPN, TSVM, TNB produces better results.

2. Bone alignment fracture detection:

This method was given by Y Jia and Y Jiang. This method spots the fractured bones in an X-ray image within casting material and also unveils the alignment between the fractured bones. A geodesic active contour model with global constraints is applied to segment the bone region [3]. A shape is accumulated before and is used as a global constraint of the model. A maximum likelihood function is derived to provide feedback for each evolving process [3]. Experimental results confirm that the method produces the outlines of the fractured bones on the low contrast X-ray images robustly and accurately.

3. Mathematical Morphology method of bone fracture detection:

This method is used for the fracture detection of tibia bones. The original image is divided into several intervals before segmentation to find out the smallest interval with the target. The small regions are then automatically threshold using Otsu method. The segmentation result is examined using statistical method to avoid over or under segmentation, and to enhance accuracy of segmentation. Segmented image is adjusted based on the test results. After second segmentation, verification and adjustment steps are repeated till the stopping condition is conformed. When the segmentation is computed, the target image will not have tough areas.

This process is followed by mathematical morphology to extract the target border and cover boundary fractures. Then target border image is superposed and extracted skeleton is covered to highlight the location of fracture.

4. Discrete Wavelet Transform (DWT) bone fracture detection:

This method is for the fracture detection in pelvic region. DWT is applied to windows extracted from the ring as defined by prior automated region segmentation [3]. The wavelet coefficient is chosen and is used in the reconstruction of the image that highlights the bone boundary. This is followed by morphological operation on its binary image. The bone boundaries of ring are traced using 8-neighborhood of every pixel of edge. If no fracture is identified then window will have single uninterrupted boundary, else there will be multiple boundaries based upon the type and no. of fractures.

5. Gradient analysis method:

This method is used for fracture detection in long bones. The steps in this method are:

1. Edge extraction of x-ray image is achieved using a non-linear anisotropic diffusion method which smooths the image without any substantial loss of information about boundary location of the image.

2. Hough transform with automatic peak identification feature is then applied to determine parameters for the straight lines that appropriately approximate the edges of the bones.

3. The parameters that are used for the approximation of long edges are then further used for the centreline approximation, diaphysis segmentation and fracture detection in the segmented region.

6. Boundary tracing method:

Fracture identification is done on the basis of results of a prior pelvic bone segmentation algorithm—registered active shape model (RASM). Extracted bone boundaries are utilized to create a series of adaptive windows [3]. Later on to examine the contour discontinuities in each window, stationary wavelet transform (SWT) is applied to every adaptive window, then it is considered as a bone fracture.

Jie Wu and team further enhanced this method by examining the displacement between the fractured bones. This method helps in analysing major and minor fracture in pelvic bones.

7. Vertical internal projection method:

This method is used for fracture detection in femur bones by converting it into bone fracture analysis problem. This method identifies the bone fracture based on the shape of the bone segment. The bone fracture locations are identified as: proximal, middle or distal region of the femur bone. Vertical internal projection of every region of preprocessed x-ray image is conducted and combines with the projection curve. After that, Muller AO coding standing for the fracture injure site is judged based on analysis of subsection variances of curves [3]. If the variance ratio is higher than certain fixed value, program output is returned as numeric code ‘1’, of the variance ratio is below than the fixed value than the output code is returned as ‘3’ else returns ‘2’. The fracture region is automatically identified based on the matching rules.

8. Two stage identification process:

This method is proposed for the automatic fracture identification of pelvis region in volumetric CT images. Coarse to fine strategy is practised for this purpose. While detecting coarse fracture, region of fracture is identified first using average intensity and sum of mean curvatures for valleys. Precisely, in fracture identification phase, the above region is modelled as weighted graph and a fracture is modelled as minimum cut in the graph. An additional localizing algorithm interprets the same fracture as valley, depending on the signs of the mean and Gaussian curvature. Joint decision is fetched from the result of above algorithms and is used to identify fracture voxels.

By using statistical correlation and by exploiting the bilateral symmetry of the human mandible hairline fractures are coarsely identified in the first phase. In the second phase Markov Random Field (MRF) approach id used for identifying the fractures.

9. Weighted Flow Network Technique:

By using prior knowledge about fracture pattern and the geometry of human mandible, flow network is
constructed. Edge weight is computed simply by exercising capacity function. The refinement of Ford Fulkerson algorithm i.e. Edmonds-Karp is used for identifying minimum cut in the 2D flow network the minimum cut properly identifies the fracture in the 2D flow network.

10. Finite Element Analysis:
This method is proposed for analysing skull fractures by using finite element. This method is used for the inspection of stress that is induced by the fracture in skull.

11. Local Phase Bases Technique:
In this method 3D local phase symmetry is constructed that generates strong response at bone surfaces and suppresses elsewhere. The accuracy of this technique is investigated based upon localizing bone surfaces and assessed the techniques ability to analyse displaced bone segments. The study proved that the bone fractures can be accurately localized by making use of local phase features.

12. Gray-Level Co-occurrence Matrix Bone Fracture Detection:
The block diagram of the algorithm is shown in figure 2. The input of the x-ray femur images, in DICOM 3.0 standard format will be interpreted into the developed software [5]. The tested x-ray images were taken at 53 kV and 4 mAs and were digitized at 7 bit/pixel using CCD camera [5]. Based on the tags information from the header metadata, the size of the processed images is in 410*500 resolutions [5].

V. CONCLUSION

The various bone fracture detection technique in human body is discussed in this paper. Among the several techniques discussed. The fracture detection using fusion classifier in Tibia Bone Fracture detection technique proves to be quite promising. Designing the CAD system that can handle fracture is any bone of the body is quite challenging.

REFERENCES