Survey on Features and Techniques used for Bone Fracture Detection and Classification

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Abstract: *Bone fracture is a common problem due to accident, osteoporosis and pressure. Moreover, bone is rigid portion and supports the whole body. Therefore, the bone fracture is taken as an important problem in recent times. Bone fracture detection using computer vision is getting more and more important in Computer Aided Diagnosis system because it can help to reduce workload of the doctor or orthopedist.*

Machine learning and image classifier can be used to efficiently detect bone fracture and can classify them. This paper is a study on the various techniques we can employ for the detection and classification of bone fractures. This paper likewise briefs about the openly accessible bone fracture dataset for testing and investigation.

Keywords: Convolutional Neural Networks, Bone Fracture, Canny Edge, Sobel, Machine Learning

I. INTRODUCTION

Bone fracture is common problem even in most developed countries and the number of bone fractures is increasing rapidly. Bone fracture can occur due to a simple accident or pressure. So, quick and accurate diagnosis can be crucial to the success of any prescribed treatment.

In practice, doctors and radiologists relay on X-ray images to determine whether a fracture has occurred or not and the precise nature of the fracture. Manual inspection of X-rays for fracture detection is a tedious and time consuming process. A tired radiologist may miss a fracture image among healthy ones. CAD 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 system has always been an appealing one.

Image processing and machine learning based studies are being used in several areas such as face recognition, fingerprint recognition, tumor detection and segmentation. Different Machine Learning algorithms are used for the classification tasks in these areas. The commonly used ML algorithms are LDA, SVM, Artificial Neural Networks (ANN), Naive Bayes Classifier, K-Nearest Neighbor (KNN), and Deep learning algorithms. The selection of input feature is very important in any classification task, using ML algorithms.

A. BONE FRACTURE TYPES

The different types of fracture include:

1. Traverse fracture: The break is in a straight line across the bone.
2. Linear fracture: The break that runs parallel to the bone's main axis.
3. Oblique fracture: The break that runs diagonal across the bone.
4. Spiral fracture: It occurs when a long bone is twisted (rotated) with force. It is also known as torsion fracture.
5. Greenstick fracture: An incomplete fracture in which the bone is partially broken and partially bent.
6. Comminuted fracture: In this type the bone is shattered into small pieces and this kind will take more time to heal.

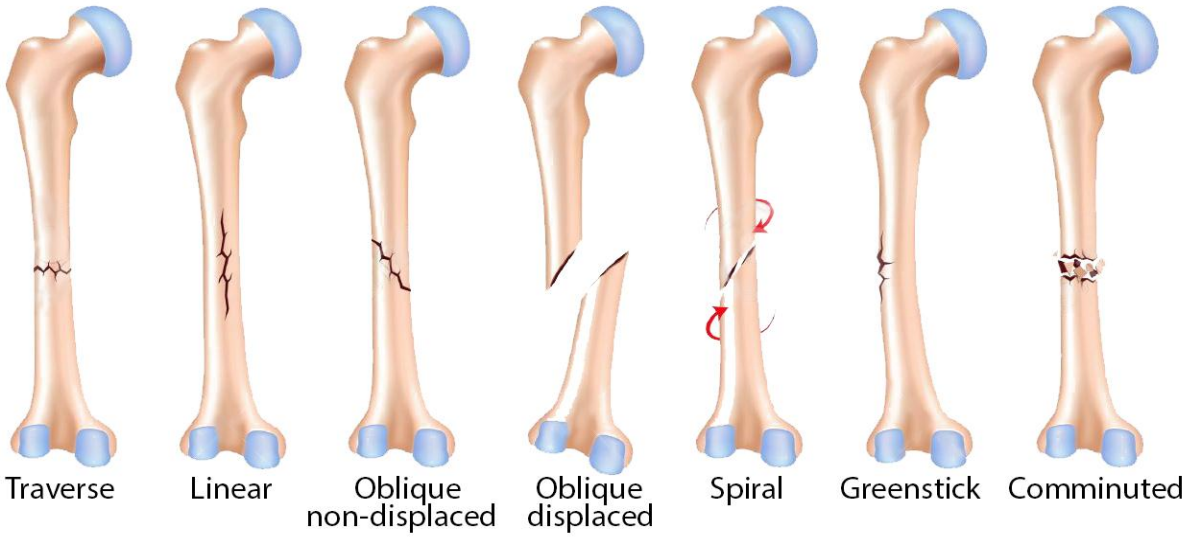

Fig. 1. Types of Bone Fracture

B. Canny Edge Detection

Canny edge operator is considered as superior edge detection operator among the available operators based on the experimental results. It detects faint edges efficiently even in noisy image and show road feature. This method is capable to mark all existing edges in the image and immune to noisy environment. Canny edge detection is a multistage algorithm to detect a wide range of edges in a given image.

1. The original image is smoothed implementing with a Gaussian filter. The result is less blurred image. It obtains the real edges of the image.

2. The edge is detected using Sobel operators for finding horizontal (Gx) and vertical (Gy). Sobel kernel in x and y directions are given below

-1	0	+1
-2	0	+2
-1	0	+1

(a)

+1	+2	+1
0	0	0
-1	-1	-1

(b)

Fig. 2 Sobel Operator (a) Gx (b) Gy

3. After that, the gradient magnitude and direction of the image can be calculated using the following equations

$$G = \sqrt{G^2x + G^2y}$$

$$\theta = \arctan\left(\frac{Gy}{Gx}\right)$$

4. Then, the algorithm tracks along these regions and suppresses any pixel that is not at maximum called non-maximum suppression. It is carried out to preserves all local maxima in the gradient image, deleting everything else will result in thin edges.

5. The last step is binarizing the image pixels by applying two threshold (lower and higher) values. The output of non-maxima suppression may contain the local maxima created by noise. Therefore, double thresholding is used for avoiding this problem. When the edge pixels greater than the higher threshold that are marked as 1and if the edge pixel less than the lower threshold that are marked as 0. If the edge pixel falls in between the two thresholds and is adjacent with higher pixel, then it is marked as 1, otherwise it is marked as 0. Figure 4 show the result images of different edge detectors. [6]

C. Convolutional Neural Networks (CNN)

Convolutional Neural Networks are a type of Artificial Neural Networks that are known to be immensely potent in the field of identification as well as image classification. We take an example to explain the same

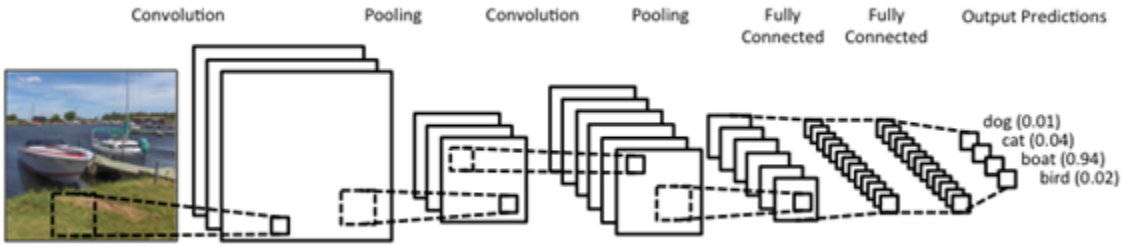

Fig. 3. CNN Architecture

Four main operations in the Convolutional Neural Networks are shown as follows:

(i) Convolution: The main use of the Convolution operation in case of a CNN is to identify appropriate features from the image which acts as an input to the first layer.

(ii) Non-linearity: ReLU or Rectified Linear Unit is a non-linear operation. ReLU acts on an elementary level. In other words, it is an operation which is applied per pixel and supersedes all the non-positive values of each pixel in the feature map by zero.

(iii) Pooling or sub-sampling : Spatial Pooling which is also called subsampling or downsampling helps in reducing the dimensions of each feature map but even while doing so, retains the most consequential information of the map. After pooling is done, eventually our 3D feature map is converted to one dimensional feature vector.

(iv) Classification (Fully Connected layer): The output from the convolution and pooling operations provides prominent features which are extracted from the image. These features are then utilized by Fully Connected layer for relegating the input image into different classes predicated on the training dataset. [15]

II. RELATED WORK

Myint, et al. [1] purpose of this work is to detect fracture or non-fracture and classify type of fracture of the lower leg bone (tibia) in x-ray image. The tibia bone fracture detection system is developed with three main steps. They are preprocessing, feature extraction and classification to classify types of fracture and locate fracture locations. In preprocessing, Unshrap Masking (USM), which is the sharpening technique, is applied to enhance the image and highlight the edges in the image. The sharpened image is then processed by Harris corner detection algorithm to extract corner feature points for feature extraction. And then, two classification approaches are chosen to detect fracture or non-fracture and classify fracture types. For fracture or not classification, simple Decision Tree (DT) is employed and K-Nearest Neighbour (KNN) is used for classifying fracture types. In this work, Normal, Transverse, Oblique and Comminute are defined as the four fracture types. Moreover, fracture locations are pointed out by the produced Harris corner points. Finally, the outputs of the system are evaluated by two performance assessment methods. The first one is performance evaluation for fracture or non-fracture (normal) conditions

using four possible outcomes such as TP, TN, FP and FN. The second one is to analysis for accuracy of each fracture type within error conditions using the Kappa assessment method.

Tripathi, et al. [2] a method is proposed through this paper to visualize and classify deformities for locating fractures in the femur through image processing techniques. The input image is preprocessed to highlight the domain of interest. In the process, the foreground which is the major domain of interest is figured out by suppressing the background details. The mathematical morphological techniques are used for these operations. With the help of basic morphological operations, the foreground is highlighted and edge detection is used to highlight the objects in the foreground. The processed image is classified using the support vector machine (SVM) to distinguish fractured and unfractured sides of the bone.

Johari, et al. [3] purpose of this paper is to find out the accuracy of an X-ray bone fracture detection using Canny Edge Detection method. Edge detection through Canny's algorithm is proven to be an ideal edge identification approach in determining the end of line with impulsive threshold and less error rate.

Dhiraj B, et al. [4] presents a system, which is aimed to provide the orthopedic surgeons with the powerful tool. The traditional machine used to scan the X-ray and MRl reports gives the hazy picture about the bone part, which sometimes leads the surgeons to make wrong assumptions, and may henceforth lead them towards wrong diagnosis of the bone fractures. The software system developed here is equipping the orthopedic surgeons with the tool which is far much better in analyzing the X-rays and MRI scans than the traditional machines and the methods that the doctors have been using till now and can help them detect even multiple fractures with ease. This system works on the methods and algorithms developed to perform various operations on images, but these operations make life easy for the surgeons. The Image Processing is one field which is finding a lot of applications in today's world in the fields like seismology, remote sensing and medical and one example in the field of medical is this software system.

Myint, et al. [5] proposed system has three steps, namely, preprocessing, segmentation, and fracture detection. In feature extraction step, this uses Hough transform technique for line detection in the image. Feature extraction is the main task of the system. The results from various experiments show that the proposed system is very accurate and efficient.

Kurniawan, et al. [6] purpose of this system is to find out the accuration of an X-Ray Bone Fracture Detection using Canny Edge Detection Method. Fractured bone is a bone condition that suffered a breakdown of bone integrity. A disconnected connection between two cartilages also categorized as bone fracture. Normally, bones have elasticity and a great number of strength. This system is built using OpenCV library combined with Canny Edge Detection method to detect the bone fracture. Canny Edge Detection method is an optimal edge detection algorithm on determining the end of a line with changeable threshold and less error rate. The simulation results have shown how canny edge detection can help determine location of fractures in x-ray images.

Anu, T. C, et al. [7] purpose is to develop an image processing based efficient system for a quick and accurate classification of bone fractures based on the information gained from the x-ray / CT images. Images of the fractured bone are obtained from hospital and processing techniques like pre-processing, segmentation, edge detection and feature extraction methods are adopted. The processed images will be further classified into fractured and non fractured bone and compare the accuracy of different methods. Results obtained demonstrate the performance of the bone fracture detection system with some limitations and good accuracy of 85%.

Wu, Zhengyang, et al. [8] this study introduces the convolutional neural network (CNN) algorithm, one of the deep learning algorithms, to distinguish the degree of fracture development while constructing a new model which can automatically identify cracks and determine the category of fractured reservoirs in the meantime. Firstly, the logging curves with strong sensitivity to fractures are selected as the input data of convolution neural network, and the crack category is quantified as the output label of the network. A CNN model which is suitable for the classification of cracks is designed, whose parameters is continuously optimized through a small batch gradient descent method in the training stage. Then the trained convolutional neural network is applied to process the logging data of an oil field. The comparison of the result of crack classification by convolutional neural network with that by the traditional BP neural network indicates that the unique convolutional weight sharing structure of convolutional neural networks can extract the most effective features and greatly improve the accuracy of the fracture classification in dealing with complex nonlinear problems such as the classification of fractured reservoirs.

Cao, Yu, et al [9] present a generalized bone fracture detection method that is applicable to multiple bone fracture types and multiple bone structures throughout the body. The method uses features extracted from candidate patches in X-ray images in a novel discriminative learning framework called the Stacked Random Forests Feature Fusion. This is a multilayer learning

formulation in which the class probability labels, produced by random forests learners at a lower level, are used to derive the refined class distribution labels at the next level. The candidate patches themselves are selected using an efficient subwindow search algorithm. The outcome of the method is a number of fracture bounding-boxes ranked from the most likely to the least likely to contain a fracture. We evaluate the proposed method on a set of 145 X-rays images. When the top ranking seven fracture bounding-boxes are considered, we are able to capture 81.2% of the fracture findings reported by a radiologist. The proposed method outperforms other fracture detection frameworks that use local features, and single layer random forests and support vector machine classification.

Umadevi, N, et al [10] purpose is to automatically detect fractures in long bones and in particular, leg bone (often referred as Tibia), from plain diagnostic X-rays using a multiple classification system. Two types of features (texture and shape) with three types of classifiers (Back Propagation Neural Network, K-Nearest Neighbour, Support Vector Machine) are used during the design of multiple classifiers. A total of 12 ensemble models are proposed. Experiments proved that ensemble models significantly improve the quality of fracture identification.

Raghavendra, U., et al. [11] propose an automated thoracolumbar fracture detection technique using convolutional neural networks (CNNs) without segmenting the vertebra. The proposed method can efficiently classify the normal and fractured subjects with an accuracy of 99.10%, sensitivity of 100% and specificity of 97.61% using our private dataset (Total image 1120). This novel CAD system can assist the orthopedists in their routine screening.

Al-Ayyoub, et al [12] considers the problem of determining the fracture type. To the best of our knowledge, ours is the first work to address this problem. After preprocessing the images, we extract distinguishing features and use them with different classification algorithms to detect the existence of a fracture along with its type. The experiments we conduct show that the proposed system is very accurate and efficient.

Dai, Xiangfeng, et al. [13] propose an on-device Inference App, where the classification model is pre-trained and stored on a mobile device, where it is used to perform classification of new data, which, consequently, does not need to be shared externally. We demonstrate the basic principles of our approach including its evaluation using a case study, which focuses on skin cancer - one of the most common human malignancies.

Patnaik, et al. [14] provides an approach to use various computer vision based techniques (deep learning) to automatically predict the various kinds of skin diseases. The system uses three publicly available image recognition architectures namely InceptionV3, InceptionResnetV2, MobileNet with modifications for skin disease application and successfully predicts the skin disease based on maximum voting from the three networks. These models are pretrained to recognize images upto 1000 classes like panda, parrot etc. The architectures are published by image recognition giants for public usage for various applications. The system consists of three phases- The feature extraction phase, the training phase and the testing / validation phase. The system makes use of deep learning technology to train itself with the various skin images. The main objective of this system is to achieve maximum accuracy of skin disease prediction.

Rathod, et al. [15] propose an automated image based system for recognition of skin diseases using machine learning classification. This system will utilize computational technique to analyze, process, and relegate the image data predicated on various features of the images. Skin images are filtered to remove unwanted noise and also process it for enhancement of the image. Feature extraction using complex techniques such as Convolutional Neural Network, classify the image based on the algorithm of softmax classifier and obtain the diagnosis report as an output. This system will give more accuracy and will generate results faster than the traditional method, making this application an efficient and dependable system for dermatological disease detection. Furthermore, this can also be used as a reliable real time teaching tool for medical students in the dermatology stream.

Gavai, et al. [16] Classification of objects into their specific classes is always been significant tasks of machine learning. Existing recent Google's inception-v3 model comparatively takes more time and space for classification with high accuracy. In this paper, we have shown experimental performance of MobileNets model on TensorFlow platform to retrain the flower category datasets, which can greatly minimize the time and space for flower classification compromising the accuracy slightly.

Cheng Qian, et al. [17] presents an Android application to automatically identify plant species using a single leaf image as input. At the pre-processing phase, we proposed an improved segmentation method to eliminate the noise caused by capturing on non-uniform background so we can obtain the binary image which only contains the leaf shape. Then, several morphological features and Hu moment invariants descriptors were extracted as inputs of a joint classifier which combines the back propagation neural network (BPNN) with a weighted k-nearest-neighbor (KNN) to distinguish 220 species of plants.

The outputs of the joint classifier are the top ten species that best match the query leaf image. At the end, we implemented these algorithms on Android OS and the application we developed has been downloaded about a million times.

Vinayshekhar Bannihatti Kumar, et al [18] provide an approach to detect various kinds of skin diseases. We use a dual stage approach which effectively combines Computer Vision and Machine Learning on clinically evaluated histopathological attributes to accurately identify the disease. In the first stage, the image of the skin disease is subject to various kinds of pre-processing techniques followed by feature extraction. The second stage involves the use of Machine learning algorithms to identify diseases based on the histopathological attributes observed on analysing of the skin. Upon training and testing for the six diseases, the system produced an accuracy of up to 95 percent.

Dhiraj B. Bhakare, et al. [19] presents a system, which is aimed to provide the orthopedic surgeons with the powerful tool. The traditional machine used to scan the X-ray and MRl reports gives the hazy picture about the bone part, which sometimes leads the surgeons to make wrong assumptions, and may henceforth lead them towards wrong diagnosis of the bone fractures. The software system developed here is equipping the orthopedic surgeons with the tool which is far much better in analyzing the X-rays and MRI scans than the traditional machines and the methods that the doctors have been using till now and can help them detect even multiple fractures with ease. This system works on the methods and algorithms developed to perform various operations on images, but these operations make life easy for the surgeons. The Image Processing is one field which is finding a lot of applications in today's world in the fields like seismology, remote sensing and medical and one example in the field of medical is this software system.

Lum, Vineta Lai Fun, et al. [20] presents a study of probabilistic combination methods applied to the detection of bone fractures in X-ray images. Test results show that the effectiveness of a method in improving both accuracy and sensitivity depends on the nature of the method as well as the proportion of positive samples.

Table -1: Different Bone fracture classification methods.

Sl No	Title	Author & Year	Method/Techniques used	Evaluation Measure	Comments/Observations
1	Analysis on Leg Bone Fracture Detection and Classification Using X-ray Images	Myint, et al. [1] 2018	Harris corner detection, Decision Tree (DT) , Kth Nearest Neighbor (KNN)	Accuracy – 85%	Harris corner detection is used to find the broken points. Decision Tree is used to classify image as fractured or non-fractured. KNN is used to classify the fracture type as Transverse, Oblique, and Comminuted fracture types.
2	Automatic detection of fracture in femur bones using image processing	Tripathi, Ankur Mani, et al [2] 2017	Canny edge detection, Sobel operator, Support Vector Machine (SVM).	Accuracy -- 84.7%	Canny edge detects the bone edge accurately and Sobel operator detects the clear fractured edge. SVM is used to classify image as fractured or non-fractured.
3	Bone Fracture Detection Using Edge Detection Technique	Johari, et al. [3] 2018	Canny Edge Detection, Sobel operator	Accuracy – 87.3%	Sobel operator with the parameter sigma 4.75 is used to enhance the efficiency of the system and it diagnoses the hairline fracture more effectively.
4	Novel Approach for Bone Fracture Detection Using Image Processing	Dhiraj B, et al. [4] 2018	Support Vector Machine (SVM), K-Nearest Neighbor (KNN)	Accuracy – 85%	The different classifiers like SVM (Support Vector Machine), K-Nearest Neighbor (KNN) can be

					used for classification.
5	Detecting leg bone fracture in x-ray images	Myint, et al. [5] 2016	Canny Edge Detection	---	Much higher accuracy can be achieved by gaining a better dataset with high-resolution images.
6	Bone Fracture Detection Using OpenCV	Kurniawan, et al. [6] 2014	Canny Edge detection using OpenCV	Accuracy— 66.7%	Performance and accuration of the detection system affected by the quality of the image. The better the image quality, better the results.
7	Detection of Bone Fracture using Image Processing Methods	Anu, T. C, et al. [7] 2015	Sobel Edge Detector using GLCM features.	Accuracy – 85%	Gray Level Co-occurrence Matrix (GLCM) method is used to extract textural features such as entropy, contrast, correlation, homogeneity. Results are evaluated based on GLCM features.
8	Classification of Reservoir Fracture Development Level by Convolution Neural Network Algorithm.	Wu, Zhengyang, et al. [8] 2018	Convolutional Neural Network (CNN) and BP neural networks.	Accuracy– 97.5%	The accuracy of convolution neural network is higher than that of BP neural network, which is basically consistent with the manual interpretation.
9	Fracture Detection in X-Ray Images through Stacked Random Forests Feature Fusion	Cao, Yu, et al [9] 2015	Random forests for feature fusion and Support Vector Machine (SVM)	Accuracy – 81.2%	This system can be used for various types of fractures over different anatomical regions. SVM and single layer random forests increase the effectiveness. Accuracy could be further improved by incorporating more types of local features.
10	Multiple classification system for fracture detection in human bone x-ray images	Umadevi, N, et al [10] 2012	Support Vector Machine (SVM), Back Propagation Neural Network (BPNN), K-Nearest Neighbor (KNN)	SVM Accuracy – 91.89 BPNN Accuracy— 90.46 KNN Accuracy— 89.76	Texture features and shape features were extracted from the x-ray images forming a total of 12 features. Experimental results showed that the ensemble model that combines BPNN + SVM + KNN with both texture and shape features significant improvement in terms of accuracy and precision.
11	Automated system for the detection of thoracolumbar fractures using a CNN architecture.	Raghavendra, U., et al. [11] 2018	Convolutional Neural Network (CNN)	Accuracy – 97.6%	A thoracolumbar fracture needs to be treated at the earliest stages. The system can be implemented in android device using Tensorflow..

12	Determining the type of long bone fractures in x-ray images	Al-Ayyoub, et al [12] 2013	Support Vector Machine (SVM), Decision Tree (DT), Nave Bayes (NB)	Accuracy – 85%	SVM classifier was found to be the most accurate than other classifiers. Integrating the proposed technique into the software of an x-ray machine is very useful for teaching and research purposes.
13	Machine Learning on Mobile: An On-device Inference App for Skin Cancer Detection	Dai, Xiangfeng, et al [13] 2019	Convolutional Neural Network (CNN) using TensorFlow	Accuracy – 75.2%	The system can be modified for fracture detection in android device using Tensorflow lite.
14	Automated Skin Disease Identification using Deep Learning Algorithm	Patnaik, Sourav Kumar, et al [14] 2018	Inception V2 Inception V3 MobileNet	Accuracy – 88%	MobileNet is light weight architecture and fast model, so it is preferred for mobiles and embedded applications for fracture detection.
15	Diagnosis of skin diseases using Convolutional Neural Networks	Rathod, Jainesh, et al. [15] 2018	Convolutional Neural Network (CNN)	Accuracy – 90%	Bone fractures can be diagnosed using CNN technique and also be classified using the same.
16	MobileNets for Flower Classification using TensorFlow	Gavai, Nitin R., et al. [16] 2017	Convolutional Neural Network (CNN) using MobileNets.	Accuracy – 85%	MobileNets can be used for classification of fracture images and to develop android applications.
17	An Android Application for Plant Identification	Cheng Qian, et al. [17] 2018	Joint classifier which combines the back propagation neural network(BPNN) with a weighted k-nearest-neighbor (KNN)	Accuracy – 92.8%	An android application identifies plant species and same can be modified to identify and classify fractures.
18	Dermatological Disease Detection Using Image Processing and Machine Learning	Vinayshekhar Bannihatti Kumar, et al [18] 2016	kth Nearest Neighbor (kNN), Decision Trees (DT), Artificial Neural Networks (ANN)	Accuracy -- 95%	The system has two Stage refinement process and combining the two stages increases the accuracy and efficient of the dermatological disease detection. Same can be used for classification of bone fractures.

III. CONCLUSION

The survey has done on Bone Fracture Detection and Classification. This paper displays the different existing strategies proposed by various creators. Here comparison made between existing techniques on the basis of classification methods used and the accuracy. There are several image processing techniques for the detection of the bone fracture. Canny Edge Detection method with sobel operator is most commonly used for fracture identification. The machine learning is very powerful strategy for the classification of type of fracture. The accuracy of the classification of fracture mainly depends on the size of the dataset, quality of the images and number of epochs used for training the model and the method used for classification. The different techniques can be cascaded for higher classification accuracy. There are future scopes of improvements in present techniques as no model guarantee hundred percent accuracy.

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