Bone Fracture Detection in X-ray Images using Convolutional Neural Network

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3 authors:

Rinisha Bagaria
CMR Institute of Technology

Sulochana Wadhwani
Madhav Institute of Technology & Science Gwalior

Arun Kumar Wadhwani
Madhav Institute of Technology & Science Gwalior

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Rinisha Bagaria, Sulochana Wadhwani, A. K. Wadhwani

Madhav Institute of Technology & Science, Gwalior, India

Corresponding author: Rinisha Bagaria, Email: rinisha.bagaria19@gmail.com

It is critical to design a fracture detection system to offer quick results and reduce diagnosing errors. Using X-ray images in growing artificial intelligence methodologies, especially the deep learning method, has become a practical choice for detecting bone fractures. This research paper suggests a deep learning method using X-ray images for early diagnosis of bone disorders and also detection of different bone fractures. The effectiveness of the convolutional neural network model for classifying bone fractures from normal bones is used. Several significant factors such as no. of epochs, batch size, type of optimizers and learning rate are considered to find the best-suited model. Hence, it is found that the convolutional neural network model has good performance using the specificity of 89.865%, accuracy of 90% approximately, and area under ROC curve of 0.8088.

Keywords: Deep Learning, Medical Image Analysis, X-ray Imaging, Image Processing Techniques, Image Classification.

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1 Introduction

Deep Learning (DL) had a significant impact on the medical field, and it led to significant improvements in the detection of abnormality and early diagnosis of diseases. Medical imaging like X-rays and computed tomography (CT) scanning has significance in identifying bones' fractures. But the visual examination of X-rays by a radiologist at an extensive range is a very lengthy process. There is a chance of a few errors during diagnosis due to a lack of medical practices. Thus, there is a need to model a better DL method to improve the power of X-ray imaging and drop off a radiologist's workload. The convolutional neural network model (CNN) provides more effective results than conventional Artificial Intelligence (AI) techniques in the DL algorithm. DL has been broadly used for analyzing or diagnosing various medical image modalities.

Some studies have been done with deep learning networks for the diagnosis of bone fractures. For example, there are different image segmentation methods available for medical image analysis. Still, wavelet transform is one of the best image processing methods, which help to decompose images into different levels [1-2]. Rinisha Bagaria et al. explain the basic pre-processing methods, segmentation methods and classify the X-ray image dataset with an error backpropagation neural network[3-4]. Justin Ker et al. review the machine learning methods practical to medical image analysis focuses on convolutional neural networks and emphasises clinical aspects in the relevant field [5]. Muhammad Imran Razzak et al. explained state-of-the-art deep learning architecture and its optimization used in image classification and medical image segmentation. They also overview the challenges and future scope in deep learning for medical image processing [6]. ZhiFei Lai & HuiFang Deng plan an efficient model based on neural networks to fuse the distinct feature groups obtained in the first and second stage, also achieved good overall classification accuracy [7]. D. H. Kim & T. MacKinnon worked on Artificial intelligence in the detection of fracture: using transfer learning from deep convolutional neural networks, for fracture detection on radiographs [8]. Bin Guan et al. designed thigh fracture detection with a deep learning technique that depends on a new dilated convolutional feature pyramid network (DCFPN). This method has tough possible applicability in practical clinical environments [9]. Liang Jin et al. suggested a deep learning model named FracNet, which detects and segments rib fractures. They made the approach for rib fractures detection from CT scans [10]. Tomi Nissinen et al. see the pathological features and predict fracture risk from X-ray images using a deep learning approach [11]. Sylvain Guy et al. represent limitations and programming issues in the deep learning method to diagnose proximal femur fractures [12]. Bin Guan et al. proposed a novel deep learning method for fracture detection in arm bone X-rays, and it has potential application in real clinical environments [13].

In this work, a DL empowered fracture detection model using X-ray images is made. Different parameters are taken into consideration for obtaining the most accurate CNN model. The chief contributions of the research work are outlined below:

- The effectiveness of the efficient CNN model has been analyzed comprehensively. The impact of several hyperparameters such as learning rate, no. of epochs, optimization techniques and batch size has been studied.
- The data is taken from Vidhya Imaging Centre, Gwalior, which is unprocessed and limited. To overcome this, some pre-processing is applied, and then data augmentation is used for increasing the number of images in the dataset.

The research work is organized into four sections; now in Section 2 describes the acquisition of data, including pre-processing methods and proposed methodology. In Section 3, the performance analysis and experimental outcomes are explained. At last, the closing notes are given in Section 4.

2 Materials and Method

A detailed description of the suggested method is presented in this section. The data is acquired, and the methodology is designed for fracture detection is the bones and the data used to validate the proposed model.

2.1 Dataset

To validate the proposed work, the X-ray images are collected from three distinct sources. Dataset is prepared from the X-ray images provided by Vidhya Imaging Centre, Gwalior. Few images are also taken from portable digital X-ray machines available at the biomedical laboratory in the Electrical Engineering Department of MITS, Gwalior. A dataset of X-ray images has been collected from the medpix repository, which contains approximately 2000 images approximately [14]. In the experiment, initially, 200 X-ray images were chosen, in which 60 images are fractured images, and 140 images are non-fractured. Sample images from the dataset are represented in Fig. 1. In this experiment, 80% of the data is given for training & the remaining 20% is for testing purposes.

2.2 Proposed Methodology

The proposed method for automated diagnosis of bone fracture detection is prepared. This method aims to classify an X-ray image into fractured or non-fractured cases, which has two processes. The first process is pre-processing (it includes normalization and augmentation). The second process is classification by setting different parameters of the CNN model. The details of pre-processing are explained in the next section. The architecture of the CNN model is represented in Fig. 2. There are a total of seven layers in this CNN model.

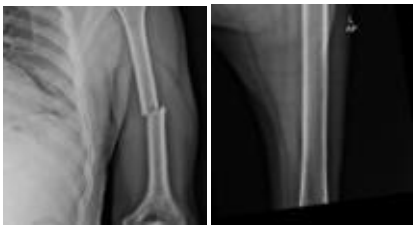


Fig. 1. Samples of X-rays images from dataset (a) Fractured (b) Non-Fractured

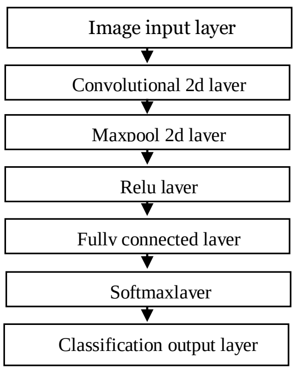


Fig.2. The architecture of the CNN model

2.2.1 Preprocessing

In the pre-processing phase, normalization and data augmentation of a dataset is to be performed.

The first method is the Normalization of data which is used to keep numerical stability in CNN models. The CNN models are used to learn faster and more stable in normalization. The pixel values of the considered images normalize in between the range 0-1. All input images are grayscale images, and rescaling is obtained by multiplying 1/255 with every pixel value.

The second is Data Augmentation, in which CNN models require a massive dataset for practical training. But, the existing training images in the input are significantly less (i.e. 200 X-ray images). It is an essential concern when performing X-rays analysis using a deep learning approach while it is tough to gather medical data. To overcome it, the augmentation approach is used to help in increasing the number of images. This also enhances inconsistency in the images and treats them as a regularizer. The methods used in data augmentation are rotation, flipping, scaling and addition of noise. The considered X-rays images are augmented with the methods of:

(1) Rotating by the angles of 180 degrees clockwise.
(2) Flipping horizontally and vertically.
(3) Scaling by the specific dimension of [600 400].
(4) Adding salt & pepper noise.

At last, a more significant training set of 530 images has been obtained, almost three times that of 200 images.

2.2.2 Fracture detection with CNN models

To get superior outcomes, the CNN model proved a broad range of image processing applications. On the other hand, training the models from scratch would be tough to analyse fractured cases due to the partial accessibility of X-ray datasets. In this research, CNN models are used for the classification of fractured bone from standard bone cases. The architectural representation of the considered model is shown in Table 1. These models have successful outcomes in medical image analysis and computer vision problems, and hence, these are chosen for bone fracture detection.

Table 1. Architectural description of CNN models.

Model Name	No. of Layers	Input Size	Output Size
CNN	7	[224 224 3]	[2,1]

3 Experimental Results

Results obtained from the experiments are shown in this section, and a study for the detection of bone fractures using X-rays is made. The impact of few hyperparameters allied with these CNN models conceded a comparative study amongst them.

3.1 Experimental setup and performance metrics used

The CNN models were evaluated with the help of X-ray images taken from the Vidhya Imaging Centre, and some X-ray images were downloaded from the medpix repository. The information of the dataset splitting used without and with augmentation is represented in Table 2. The augmented X-ray images are fed to training the CNN models. After performing data augmentation on training X-ray images, 530 images are obtained, further split into a training set and validation set in the ratio of 80% and 20%, respectively. In other words, 424 images are provided for training and 106 images for validation, as tabulated in Table 2. The validation set is used to obtain an optimal model and to prevent it from overfitting.

Table 2. Results of data splitting without and with augmentation dataset.

Category	Original images dataset		Augmented images dataset		
	Train	Test	Train	Validation	Test
Fractured	60	15	70	15	15
Non-fractured	140	85	354	91	85
Total	200	100	424	106	100

Initially X-ray images resized according to the input size of the CNN model, i.e. [224 224]. The implementation of all models is done using the Deep Learning toolbox in the Matlab R2019a software environment. Each model is trained for different epochs, batch size, learning rate. Training is performed using Adam optimizer, mainly used for X-ray images, and the process environment is set at auto. Performance analysis of every model has been estimated using various metrics such as accuracy (Acc), specificity (Spe), area under the ROC curve (AUC). These parameters were evaluated by using values obtained using a confusion matrix. These values are True Positive (TP), True Negative (TN), False Negative (FN) and False Positive (FP). The metrics are expressed as below in Eq. (1), Eq. (2), respectively.

$$Acc = \frac{n_{TP}+n_{TN}}{n_{TP}+n_{TN}+n_{FP}+n_{FN}} \quad (1)$$

$$Spe = \frac{n_{TN}}{n_{TN}+n_{FP}} \quad (2)$$

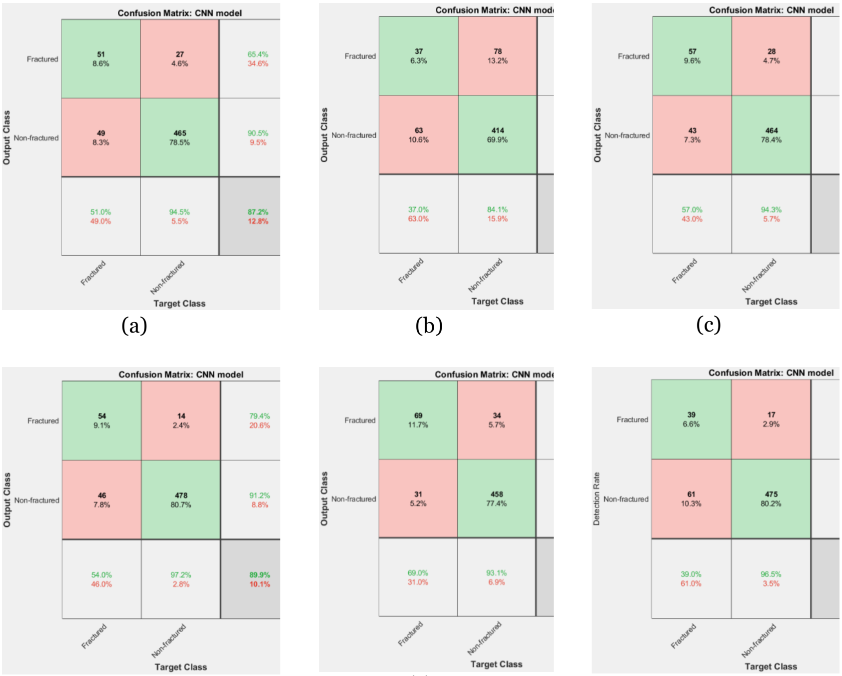
In this research, fractured bone cases are assumed as positive cases, and non-fractured ones are assumed as negative ones. Where, n_{TN} shows predicted non-fractured cases accurately, n_{TP} shows predicted fractured cases accurately, n_{FP} indicates inaccurately predicted fractured cases and n_{FN} indicates inaccurately predicted non-fractured cases.

3.2 Performing results

The performance of training inaccuracy, including fixed optimizer, batch size, and initial learning rate obtained by all considered models at distinct epochs, as shown in Table 3. The confusion matrix has been accepted for all CNN models on the considered dataset, represented in Fig.3. It can be seen that the model, which has 20 epochs, adam optimizer, 32 batch size, 1e-03 learning rate, could be able to classify all bone fracture cases with an accuracy of 90% approximately. Therefore, it can say that this model is best fitted for fracture detection of bone using considered X-ray images.

Table 3. Performance analysis of trained models.

CNN Model	Epoch	Optimizer	Batch size	Initial Learning rate	Accuracy (%)	AUC	Specificity
(a)	10	adam	10	1e-05	87.20%	0.8244	87.20%
(b)	20	adam	32	1e-06	76.20%	0.6589	76.20%
(c)	20	adam	32	1e-05	88.00%	0.8286	88.00%
(d)	**20**	**adam**	**32**	**1e-03**	**89.90%**	**0.8088**	**89.90%**
(e)	20	adam	32	1e-04	89.00%	0.8417	89.00%
(f)	20	adam	32	1e-02	86.82%	0.6819	86.82%

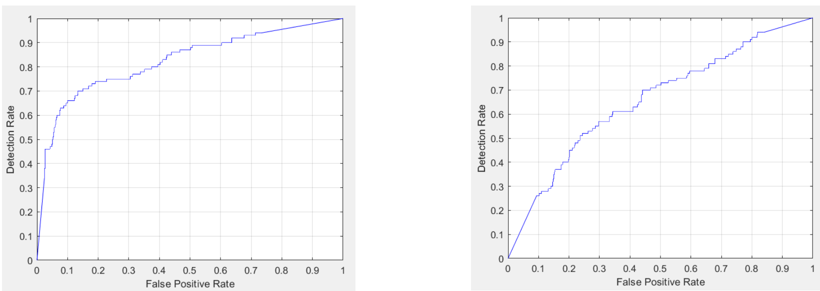


(a) (b) (c)

(d) (e) (f)

Fig.3. Confusion matrix of each CNN model with different parameters

Fig.4 represents the ROC curves for all CNN models. The comprehensive image classification outcomes were obtained for all models. The CNN model with a learning rate of 1e-03 has obtained the greatest performance with a specificity of 89.90%, accuracy of 89.865%, and AUC of 0.8088. CNN model with a learning rate of 1e-04 is the second-best model for bone fracture detection, which obtained a specificity of 89.00%, accuracy of 89.00%, and AUC of 0.8417.



(a) (b)

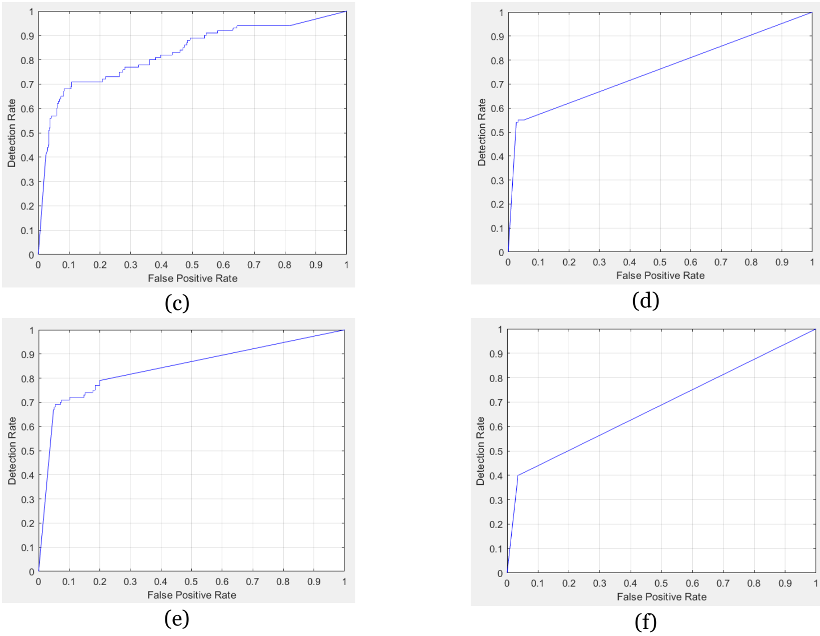


Fig.4. ROC plot of each CNN model with different parameters

3.3 Discussion

This work is based on detecting bone fractures in X-ray images. After, several trials have been made to build up a reliable identification model using deep learning approaches. Six CNN models have been used for this purpose. Most of the previous techniques were estimated using a minimal number of data. So a comprehensive study is done in this work to obtain the efficiency of the six effective CNN networks for detecting fractured bone and non-fractured bone X-ray images. Many experiments are conducted on a relatively large dataset to determine the best performing CNN model for bone fracture detection screening. Bone fractured and non-fractures X-ray images are considered from two sources in this research.

To overcome the data imbalance problem, normalization and data augmentation are used as pre-processing. The detailed comparative analysis and experimental results, along with all models established. This CNN model obtained an accuracy of 90% approximately. It is cost-effective and efficient to help the radiologists in verifying their medical interpretations and taking accurate decisions. The primary purpose of the work is to get faster decisions for the early diagnosis of bone fracture detection and its analysis. The major limitation is that it is validated with a limited number of X-ray images. No large dataset publicly available exists to date. In future, to validate the approach using large datasets can be performed.

4 Conclusions

This research proposes a deep learning-based automated technique for effective medical image classification of fractured bone images from non-fractured images. Six CNN models considered some essential factors and their outcomes over a set of available X-ray images and images obtained from the imaging centre. After performing, the results show that the CNN model with a learning rate of 1e-03 has obtained the most excellent performance with a specificity of 89.90%, accuracy of 89.865%, and AUC of 0.8088. Hence, the efficiency of the suggested model can be established for multi-class image classification difficulties. Additionally, it can explore different optimizers and the various CNN networks used in the proposed work to propose an extra reliable network.

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