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Abnormality Detection from X-Ray Bone Images using DenseNet Convolutional Neural Network

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ABSTRACT

Introduction: According to the survey of the World Health Organization and the International Agency for Research on Cancer; the death rate because of cancer is increasing day by day. It is preferable to detect cancer at its earlier stage or detect any kind of lesion which can cause cancer in the future. This paper shows how Artificial Intelligence especially the Convolutional Neural Network of Deep Learning can be used to detect abnormality from X-Ray bone images.

Objective: To detect the abnormality in bone from X-Ray Images.

Methods: MURA (Musculoskeletal Radiographs) dataset is used which was prepared by the Stanford ML group. Dataset is identified and categorized into training and validation dataset and after that data preprocessing techniques are used. This help in making the dataset convenient for the DenseNet (Densely Connected Convolutional Networks) Model. Tenserflow and Keras libraries are used to build DenseNet model.

Results: Classification Table and Confusion Matrix methods are used to evaluate the performance of DenseNet (Densely Connected Convolutional Networks) Model for the detection of abnormality in bone from X-Ray Images. By using this proposed model more than 85% accuracy achieved.

Conclusion: The result obtains from the proposed model will be helpful to the radiologist to make better decisions. This independent model can further be used to detect cancer of bone from X-Ray Images.

Key Words: Bone Abnormality, Bone, Convolutional Neural Network, Deep Learning, DenseNet, X-Ray Images

INTRODUCTION

Deep Learning had a remarkable impact on the various field like agriculture, medical, education, weather, entertainment and many more in recent years. Deep Learning is the extension of machine learning methods. These methods are based on artificial neural network.[1]

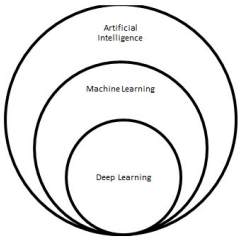

Figure 1: Figure shows that Deep Learning is the subset of Machine Learning, which come under the umbrella of the Artificial Intelligence domain[2].

The main benefit of deep learning over machine learning is that deep learning automatically detects features, which may be 1000 times more than what human can think of. Deep Learning techniques used to train computers to learn through a huge amount of data. A computer program can be developed which can gain knowledge and analyze any data like a human does, through deep learning methods. Research in this field has broad-spectrum in the applications like Chatbots to improve Customer experience, Spelling and grammar correction for errorless text writing, detect objects from the satellite which help to aerospace and military, auto-generation of music as per human mood, service which senses the unusual things in industrial plant, cancer cell detection in medical research, self-driving car and many others. In many of the fields, we have to deal with images rather than data or information. In computer vision, this process is well known as image processing.[3] This image processing can be done

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more effectively and efficiently with the help of Convolution Neural Network, which is modelled, based on the concept of deep learning. Convolution Neural Network has three layers called input, hidden and output. Various operations like convolution, activation, padding, pooling, normalization and Softmax performed to obtain the desired output in the hidden layer of CNN.CNN become a newly emerging field in deep learning through which image can be read and analyze to produce a significant result.[4]

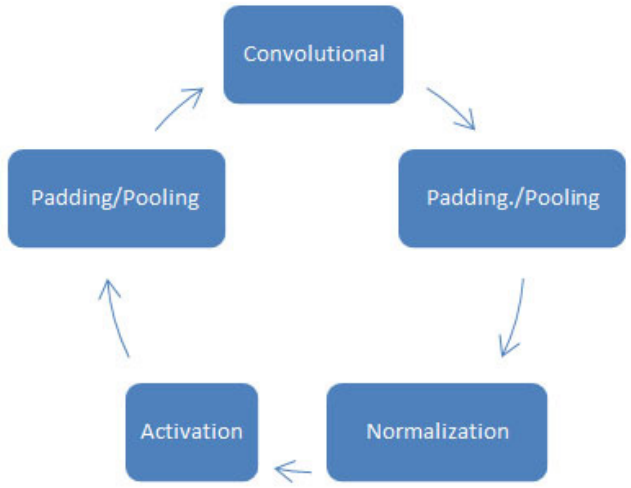

Figure 2: Operation perform in the hidden layer of CNN Model.[5]

Cancer, which considers as an abnormal growth of the cell, which harasses and spread into any human body organ. As per the record of ICMR-NICPR (Indian Council of Medical Research – National Institute of Cancer Prevention and Research), More than 2.5 million people live with this disease in India. On average 7 lakhs of new patients with cancer registered and around 6 lakhs of people lose their life because of cancer. According to World Health Organization (WHO), Worldwide 9.6 million people were estimated to have died from cancer in 2018.[6] As per the survey of the International Agency for Research on Cancer (IARC), there will be 21.7 million cases and 13 million deaths in 2030 predicted because of cancer. In India, over 80% of cancer cases are detected late and patiently advised to go for advanced-stage treatment.[7]

Table 1: Year wise death toll worldwide according to ACS and IARC[6,7]

Year	New cancer cases	Death	Area	Survey Agency
2016	1,688,780	600,920	USA	American Cancer Society
2015	1,685,210	595,690	USA	American Cancer Society
2014	1,658,370	589,430	USA	American Cancer Society
2013	1,665,540	585,720	USA	American Cancer Society
2012	1,660,290	580,350	USA	American Cancer Society
2012	14.1 million	8.2 million	World wide	International Agency for Research on Cancer (IARC)
2030 (expected)	21.7 million	13 million	World wide	International Agency for Research on Cancer (IARC)

This death rate can be reduced if cancer detected in its early stage or by finding any abnormality and rectify it before it converted into a tumour. A total of 75 types of cancer exists from which one type is bone cancer. In bone cancer, also there are 19 types of bone cancer. Osteosarcoma and Ewing are the most commonly seen bone cancer. The research objective is to detect any kind of abnormality or lesion on the bone from x-Ray images at its early stage so that patient gets the treatment at the earliest and can be saving from cancer.

The number and the table suggest the diversity and adversity in the disease like cancer. So, at the preliminary stage of the research, it has been found some thrust in the research of such disease prevention and prediction. Medical science is completely dependent upon the various images, which is generated or prepared because of some report testing. It is diagnosed only after the body is completely affected by that particular disease. The changes in the body when the body host the decease initially, the decease can be prevented or cured if the reports are tested and examined in early stage.

With this initial perception and state of mind, the research title was proposed where such decease prevention can be done in a much more efficient and effective manner where the chance of decease can be predicted in advance. The corrective steps can be taken to avoid it too completely. Moreover, Artificial Intelligence with Computer Vision and Image Processing was found most suitable to research the domain.[3]

LITERATURE SURVEY

Substantial and remarkable work in the field found which is targeting disease detection and prevention with aids of Information Technology. Algorithm to calculate the mean inten-

sity and tumour size from MRI images found useful in the prediction of various stages of cancers and bone cancer.[8] It has been found that Region Growing Algorithm is the best-suited method to detect tumour size and bone cancer stage.[9] Various other methods like texture-based region growing, cellular automata edge detection, K-Mean clustering algorithm and algorithm to calculate the sum of pixel intensities also gives the better result to detect cancer. Image segmentation is one of the important processes in image processing to detect bone cancer from radiography image.[10-17] Especially biomedical image segmentation based on Entropy, Fuzzy Entropy and the Least Square Method used for it.[18] Neuro-Fuzzy Classifier found useful to detect different types of brain cancer. In this various image processing techniques are used and the grey level Co-occurrence Matrix method used to extract texture features.[19]

The Computer Vision and Image Processing Feature Extraction and Pattern Classification (CVIP-FEPC) software found useful to detect bone cancer from thermography images. Thermography image gives better result than X-Ray, CT scans and MRI images in terms of diagnostic time and reduces the exposure of radiation.[20] There are some advantage and disadvantage of using computer-aided diagnosis and it was found that it gives more accurate result.[21] Osteosarcoma and Ewing's sarcoma having similar early symptoms like fever and pain.[22] Radiologist also remain in dilemma in the detection of these two types of bone cancer and this type of case, computer vision technology with artificial intelligence will be useful to the radiologist to draw a decision. Looking at the era and the current trends with futuristic technologies, the tasks related to image processing can be dominated by the use of Artificial intelligence especially Convolutional Neural Network techniques of Deep Learning.[23-29]

RESEARCH RATIONALE AND METHODOLOGIES

Dataset

Dataset is one of the most crucial and important components for any deep learning algorithm. This dataset is divide into three categories called training dataset, validation and test dataset. The training dataset is the backbone for any deep learning project. The training dataset is used to train the neural network and it comprehends and memorizes such data, which help the network to predict the information in future. More amount of data in the training dataset result in accurate prediction. After having a dataset, the next important task is to label the data properly so that the neural network can be trained to answer Yes/No or can able to categories the data. Validation data set are used to identify the overfitting and under the fitting issue of neural network.

To trained the proposed CNN model, MURA (Musculoskeletal Radiographs) dataset is used which was prepared by the Stanford ML group and it also opens access. MURA is one of the largest datasets of bone X-Ray images. MURA contains around 60,000 images from 14,656 studies. All images are labelled as either normal or abnormal by the radiologist. To obtain a better result these images are classified into seven different classes Elbow, Finger, Forearm, hand, homers, shoulder and wrist.

Table 2: Different categories wise Training and Validation Dataset[30]

Category	Training Dataset		Validation Dataset		Total Studies
	Normal	Abnormal	Normal	Abnormal	
Elbow	1094	660	66	92	1912
Finger	1280	655	92	83	2110
Forearm	590	287	64	69	1010
Hand	1497	521	101	66	2185
Humerus	321	271	68	67	727
Shoulder	1364	1457	99	95	3015
Wrist	2134	1326	140	97	3697
Total Studies	8280	5177	630	569	14656

Data Preprocessing and Augmentation

Data preprocessing is the important step by which data can be frame into proper input for the proposed model. In data preprocessing, we did the following three things. Data augmentation is the method in deep learning to increase the training dataset so that it results proposed model to provide an accurate result. Normally, Data Augmentation can be done by rotating image and flipping the images horizontally and/or vertically. For the research, we had to increase the dataset for training and validation. To achieve this, we had rotated the images to 30 degrees and flipped them horizontally. Because of this, we had 2 times more dataset than we started initially.

Image Normalization

Normalization of images is required so that the proposed neural network don't face the issue of over or underfitting. To normalize all images, the mean and standard deviation are calculated. This mean value subtracted from each image mean intensity value and then subtracts the result value by standard deviation.

Resizing Images

All CNN model required a fixed size of images as input. The model, which we proposed, required all image in 224 x224 sizes.

Proposed Model

DenseNet Model used to detect any kind of lesion from bone X-Ray images. DenseNet is architecture is based on ResNet Architecture. The major difference between ResNet and DenseNet is that in ResNet each layer received a piece of knowledge from its immediate previous layer while in

DenseNet each layer received collective knowledge from all its previous layer. Batch normalization, ReLU and 1x1 Convolution operations to reduce the model complexity and size. This layer considers a bottleneck layer in DenseNet.

Advantage of DenseNet

- Better Gradient Flow
- Efficiency gained in parameter and computation
- Diversified feature identified instead of co-related feature

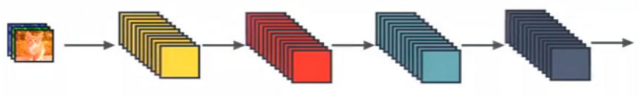

Figure 3: Architecture of standard Convolution Neural Network[31]

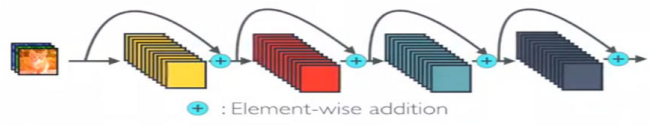

Figure 4: Architecture of ResNet[31]

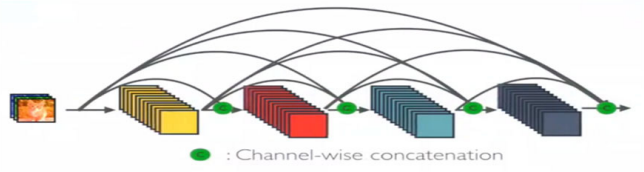

Figure 5: Architecture of DenseNet[31]

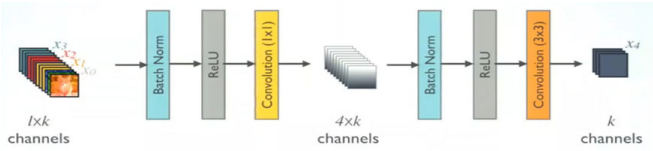

Figure 6: Operation Perform inDenseNet[31]

The architecture of DenseNet with various no of layer seem like below.

Layers	Output Size	DenseNet-121($k = 32$)	DenseNet-169($k = 32$)	DenseNet-201($k = 32$)	DenseNet-161($k = 48$)
Convolution	112 × 112	7 × 7 conv, stride 2			
Pooling	56 × 56	3 × 3 max pool, stride 2			
Dense Block (1)	56 × 56	[1 × 1 conv, 3 × 3 conv] × 6	[1 × 1 conv, 3 × 3 conv] × 6	[1 × 1 conv, 3 × 3 conv] × 6	[1 × 1 conv, 3 × 3 conv] × 6
Transition Layer (1)	56 × 56	1 × 1 conv			
	28 × 28	2 × 2 average pool, stride 2			
Dense Block (2)	28 × 28	[1 × 1 conv, 3 × 3 conv] × 12	[1 × 1 conv, 3 × 3 conv] × 12	[1 × 1 conv, 3 × 3 conv] × 12	[1 × 1 conv, 3 × 3 conv] × 12
Transition Layer (2)	28 × 28	1 × 1 conv			
	14 × 14	2 × 2 average pool, stride 2			
Dense Block (3)	14 × 14	[1 × 1 conv, 3 × 3 conv] × 24	[1 × 1 conv, 3 × 3 conv] × 32	[1 × 1 conv, 3 × 3 conv] × 48	[1 × 1 conv, 3 × 3 conv] × 36
Transition Layer (3)	14 × 14	1 × 1 conv			
	7 × 7	2 × 2 average pool, stride 2			
Dense Block (4)	7 × 7	[1 × 1 conv, 3 × 3 conv] × 16	[1 × 1 conv, 3 × 3 conv] × 32	[1 × 1 conv, 3 × 3 conv] × 32	[1 × 1 conv, 3 × 3 conv] × 24
Classification Layer	1 × 1	7 × 7 global average pool			
		1000D fully-connected, softmax			

Figure 7: Architecture of DenseNet with various no of layers.[31]

With the help of TensorFlow and Keras library, DenseNet with 169 layer and Sigmoid activation function can build such that in each epoch model loss is decrease and accuracy increase.[32]

RESULTS

Confusion Matrix and classification table methods are used to evaluate the model for lesion detection of X-Ray bone images.

Table 3: Confusion Matrix

Total Study = 400	Model : Positive	Model: Negative
Radiologist: Positive	200 (True Positive)	31 (False Negative)
Radiologist: Negative	29 (False Positive)	190 (True Negative)

Table 4: Classification Table

Performance Measure	Formula	Percentage
Accuracy	Accuracy=(TP+TN)/ (TP+FN+FP+TN)	86.67%
Precision (Positive) Precision (Negative)	Precision P = TP/ TP+FP Precision N = TN/ (FN+TN)	87.34% 85.97%
Recall (Positive) Recall (Negative)	Recall P = TP/TP+FN Recall N = TN/FP+TN	86.58% 86.76%
F1 Score (Positive) F1 Score (Negative)	F1 Score P = 2*(Recall P * Precision P) / (Recall P + Precision P) F1 Score N = 2*(Recall N * Precision N) / (Recall N + Precision N)	86.95% 86.26%

CONCLUSIONS

From the result, it can be concluding that the DenseNet Model can be used to detect abnormality from Bone X-Ray images. The same model can be used for cancer detection which can be detected from x-Ray images. These results will be helpful to the radiologist for the prediction of abnormality and presence of cancer in the X-Ray and MRI images.

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Authors' contribution

Mr. Abhilash Shukla: Study Design, Literature Review, Dataset, Implementation

Dr. Atul Patel: Data and Statistical analysis, Manuscript Review

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