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Lung Cancer Detection Using Region Based Convolutional Neural Network (R-CNN)

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Abstract: Lung Cancer is a risky disease that causes human to death at primary age and it is an unrestrained cell growth in tissues on the lung. The effective identification of the lung nodule importantly leads to the chance of lung cancer risk assessment. Finding the precise locations of lung nodules are a dangerous and complicated task. Nowadays, Image processing methods are commonly used in several medical areas for improvement of image for former detection and treatment stages. Medical image segmentation is a critical step in evolving Computer-Aided Diagnosis (CAD), which supports the physician to admit an suitable procedure about the clinical case. The goal of segmentation is to alter interpretation of the image and do it easy to examine. Precise lung segmentation from Computed Tomography (CT) is a hard task due to the uneven shape and countless ambiguity in lung edges with the background. Here, we proposed a new identification model for Lung Cancer Nodule using Region based semantic segmentation algorithm: R-CNN (Regions with CNN feature). Our proposed approach follows effective image processing methods as step by step procedure as Pre-processing, Gray-scale conversion, Image Enhancement, Image Segmentation, Feature extraction and Cancer Nodule detection. For this research, LUNA16 dataset is used, which has 3D image of lungs which is deposited in around 180 2D image slices according to their image number. The dataset is composed from Kaggle repository. Our proposed method produced enhanced result on all the tested images compared with the results of earlier research works.

Keywords: CT Image, Lung Cancer Detection, Convolutional Neural Network (CNN), **Regions with CNN feature** R-CNN.

I. Introduction

In recent time the Lungs Cancer diseases are rises widely, the human body made up of with varied fundamental organs, one of those is Lung, The Lungs are of two section right lung as well as left lung and function of lungs are to trade of gas which we called as breathing or respiration. The present modern lifestyle, ecological contamination is infinitely increasing the Human Lungs problem.In the past few years the Lung Cancer became the main health diseases in human body. It is quite tough to diagnose Lung Cancer in early stage of it, which may leads to raise the risk factor of survival of patients [1]. Consistently the treatment on Lung cancer depends upon the how early this disease can be diagnose so that treatment can control on growing (in stage) and spreading of Lung Cancer in other part of body. It is quite probable to control Lung Cancer disease by giving correct treatment, there are several treatments are obtainable in the field of Medical Science such as Surgery, Chemotherapy and radiography as it is depend on the phase of disease, health of patient, as well as some other factors. The rate of survival is only 14% of patient for five years.

The medical image is one of the exciting research fields in medical problem domains to detect and diagnosis numerous diseases [2]. Medical image analysis is used to analyzing and resolving medical problems by using dissimilar medical image analysis techniques to detect related and unknown information or knowledge from any medical images. There are several medical imaging modalities that used to screening the from our body, those are Computed Tomography (CT scan), Positron Emission Tomography (PET), mammography, X-ray, and Magnetic

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Resonance Image (MRI), ultrasound and so on, that used for early detection as well as diagnosis of disease. But one of the top imaging technique is Computed Tomography (CT scan) imaging are effective for lung cancer detection and diagnosis because it can reveal every suspected and unsuspected lung cancer nodules from CT images.

We propose a method that uses a Convolutional Neural Network to detect cancerous nodules reinforced by Chest Tomography images of the lungs. In the first step, we extract lung regions from the Chest tomography image, and each of the slices in this region is segmented to separate tumors. By inputting the segment in the earlier step, the Convolutional Neural Network architecture is trained. The study's ultimate aim is to determine whether the patient's lung nodule is malignant or benign.

II. Related Work

Akash P Keladi et al., 2021, proposed a method that uses a CNN to identify cancerous nodules supported by Chest Tomography images of the lungs. The reason for using CNN is that it can mine spatial information from data using kernels, which other networks cannot. D-CNN is used in the proposed method to identify lung cancer based on CT images. A Deep CNN consists of several hidden layers such as fully-connected layer, thresholding layer. Towards the end, softmax layer is used to define the result. It is confirmed that CT scans gives more accurate analysis of the lung nodules and detects lung cancer with almost ±95% accuracy rate compared to ±90% X-Ray images [3].

Eali Stephen Neal Joshua et al., 2021, The authors had discovered the lung nodule classification using the improvised 3D AlexNet by the lightweight architecture. They have displayed the binary classification (benign and malignant) on CT images from the LUNA 16 database conglomerate along with database image resource inventiveness. The results achieved are through the 10-fold cross-validation. Investigational outcomes have revealed that the projected lightweight architecture achieved a higher classification accuracy of 97.17% on LUNA 16 dataset when related with usual classification algorithms and low-dose CT scan images as well [4].

Anubha Gupta et al., 2021, proposed a CNN model which targets to growth the accuracy and will also consider the time delay and processing power of the process of detection of cancer for increased effectiveness. It was examined that Manual CNN used for the detection of the nodule shows notable accuracy which makes it a promising method for the diagnosis that can be done timely. Accuracy and loss is hence calculated and it is found that Manual CNN gives the maximum accuracy of about 96.88 val accuracy compared to AlexNet which is about 51.56 only .The greatest model having highest accuracy and minimal loss is further selected for prediction [5].

Chan Zhang et al., 2021, aims to perform segmentation and abstraction of CT images of pulmonary nodules based on CNN. The Mask-RCNN algorithm is an image segmentation model, which performs R-FCN structure for identifying cancer nodule. The experimental outcome shows that the trained Mask-RCNN algorithm model completes the segmentation task of lung CT images more effectively. As the result, speed of R-FCN algorithm for cancer nodule detection is 0.172 seconds/picture and the complete accuracy is 92.85% [6].

Suresh Babu. P et al., 2020, The key objective of this work is to categorize the tumors found in lung as malignant or benign by means of CNN. The accuracy attained by means of CNN is 96%, which is more effective when compared to accuracy attained by the traditional neural network systems. To increase the detection of lung cancer in the CT images there are four main steps involved. Initially, the lung CT image is pre-processed to eradicate any noise that exists in the image. Secondly, the image is segmented to acquire Region of Interest (ROI). Thirdly, feature extraction is applied to abstract features like entropy, energy, and variance. Lastly, dissimilar classification algorithm is applied on the extracted features of the lung CT image [7].

III. Proposed Methodology

In this proposed work, Image Acquisition, Pre-processing, Feature Extraction and finally the Classification process, are the four main processes used in this report.

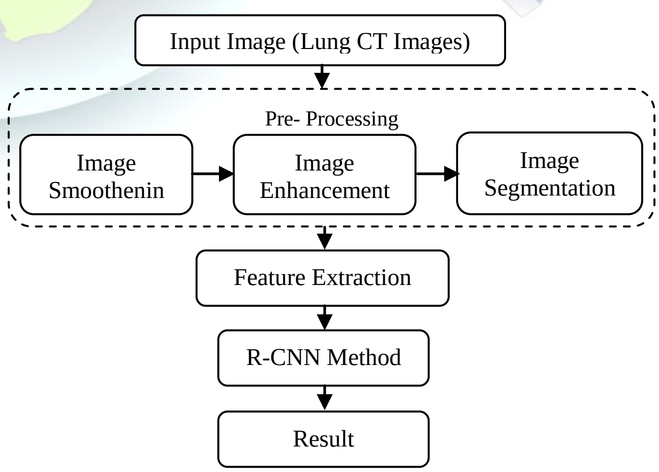

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Figure1. Lung Cancer Detection Process

Figure 1. shows the process involved in lung cancer detection system.

1) Image Acquisition: Compared to MRI scan and X-ray images, CT scan images of lung cancer patient are more helpful, because of low noise and better clarity. Image pre-processing can be handled easily in CT scan due to lesser distortion in the images. LUNA16 dataset is a subset of LIDC-IDRI which is an international image resource for evaluating and identifying lung cancer. CT scan images from LUNA16 dataset are fed as input for our input layer. CT scan images in LUNA16 dataset are in DICOM format (Digital Imaging and Communication in Medicine) which is a standard format for medical imaging. A typical CT scan image used for analysis of lung cancer patient is shown in Figure 8(1) and 9(1). Images acquired from the dataset are in raw form and has lots of noise. In order to separate the noise, improve contrast, clarity of the image, the image is pre-processed. To get the image in required form, various techniques like smoothening, enhancement are applied on the image, in the next step.

2) Image Pre-Processing: Due to movements in the body, medical images are always distorted. To get clarity in the image and remove unwanted noise in the image, pre-processing step is performed. Unwanted noise in image is removed by filtering techniques. Images are also resized in pre-processing as per need of the input system. Smoothening, enhancement and segmentation are the stages performed in image pre-processing. Smoothening is the first stage in image pre-processing. To provide better input image for other automated image processing techniques, image is enhanced. As a final stage, image is subdivided into constituent parts or objects using segmentation.

a) Smoothening: In order to separate the noise, improve contrast, clarity of the image, pre-processing is required. To get the image in required form, techniques like smoothening, enhancement are applied. Noise & other small fluctuations in the image are suppressed by smoothening; similar to that of suppression of high frequencies in frequency domain. Sharp edges that bear important information of the image are blurred by smoothening process. Sobel filter is used to remove noise from the image. In image processing, for extracting edges or to slightly change the pixel intensities, Sobel filter is used. Sobel is one of the digital filters which helps to extract edges on the basis of an angular matrix. Greater the value of grayscale level, lighter the area and lesser the value of grayscale level, darker the area. Color range lies between 0-255. It is used to discover the estimated absolute gradient magnitude at every point in an input grayscale image. Sobel filter is performed on both X and Y dimensions, to find the intensity gradient of the edges in the image. The operator comprises of a pair of 3x3 convolution kernels.

Consider A as an input matrix as shown in Figure 2,

A =

a11	a12	a13	...	
a21	a22	a23	...	
a31	a32	a33	...	
...	...	...	...	

Figure 2. Input matrix A (2D Image)

Gx =

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

Gy =

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

Figure 3. Gradient Kernals Gx and Gy

where A as an input 2D image array or matrix, Gx & Gy are the gradient kernel that will be multiplied with input image array A which is shown in Figure 3. Gx is the horizontal gradient and Gy is the vertical gradient. The Negative gradients are appeared to be darker and the positive gradients are appeared to be brighter. Each pixel value is computed by shifting the row towards right till the end row has been reached. Example below in Figure 4 shows the calculation of values of Gx & Gy:

a11	a12	a13	...	
a21	a22	a23	...	
a31	a32	a33	...	
...	...	...	...	

a) Input Matrix

b11	b12	b13	...	
b21	b22	b23	...	
b31	b32	b33	...	
...	...	...	...	

b) Output Matrix

Figure 4. Input and Output Matrix

Gx value is calculated by using equation (1)

$$b11 = a11*1+a12*0+a13*(-1)+a21*2+a22*0+ a23*(-2) + a31*1+ a32*0+ a33*(-1) \qquad \ldots(1)$$

Gy value is calculated by using equation (2)

$$b11 = a11*1+a21*0+a31*(-1)+a12*2+a22*0+ a32*(-2)+ a13*1+ a23*0+ a33*(-1) \qquad \ldots(2)$$

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At each pixel in the image, the gradient approximations given by Gx and Gy are combined to give the gradient magnitude, using:

$$G = \sqrt{Gx^2 + Gy^2} \ldots(3)$$

Once the Sobel is obtained, then compute its inverse matrix for extracting smoothen data G^{-1}.

Figure 8(2) and 9(2) shows the sobel filtered image of the lungs with and without cancer nodules.

b) Image Enhancement: To develop interpretability and perception of information in images for human eyes, or to offer improved input image for other automated image processing techniques, enhancement technique is used. Spatial domain and frequency domain are the two key categories in Image enhancement. For image enhancement purpose, histogram equalization is used. Output after performing image enhancement from original image is shown in Figure 8(3) and 9(3). Image contrast is developed using histogram equalization by adjusting image intensities namely extending out the intensity range of the image. Global contrast of the image is improved by this method, when its usable data is denoted by close contrast values. Areas of lower local contrast gains greater contrast by this method.

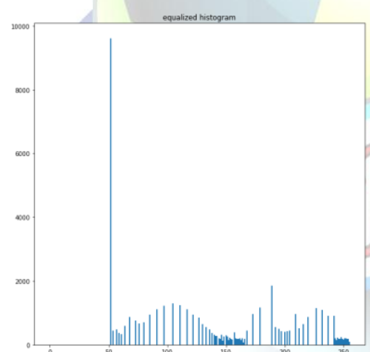

Figure 5. Equalized histogram of Lung with Cancer Nodule

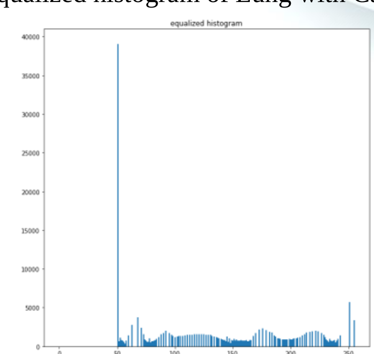

Figure 6. Equalized histogram of Lung without Cancer Nodule

The above Figure 5 and 6 is the equalized histogram graph of Lung with and without Cancer Nodule.

c) Image Segmentation: The process of partitioning a digital image into numerous segments is Image Segmentation. To shorten an image or change the representation of an image into more meaningful and easier to analyze, is the aim of segmentation. Image is separated into its constituent regions or objects by Segmentation. Set of segments that jointly cover the entire image or else a set of contours extracted from the image, is the outcome of image segmentation. In proposed model, Region based Convolutional Neural Network approach is used on based lung segmentation on CT scan images for lung cancer detection. Image segmentation is the next step after smoothening and image enhancement. Lung CT image segmentation using watershed algorithm is to highlight the lung parts and make binary masks for lungs using the approach of semantic segmentation. Main purpose of using Watershed segmentation is to find the 'watershed lines' in an image in order to separate the distinct regions. Unique boundaries from an image are segmented by the marker based on watershed segmentation.

Below are the basic procedure followed by marker-controlled watershed segmentation:

a) Transform the color image to grayscale image.
b) Gradient Magnitude is calculated as segmentation function (This is an image whose dark regions are objects which are being segmented).
c) Foreground objects in the image are marked. (These are connected blobs of pixels within all of the objects)
d) Background markers calculated (These are pixels not part of any object).
e) Alter the segmentation function so that it only has minima at the foreground and background marker locations.
f) Detect watershed transform of the segmented function of the image.
g) Segmented binary image is the outcome result.

The segmented lung is shown in 8(7) and 9(7). The segmentation process has undergone the above steps which are shown in 8(4), 8(5), 8(6) and 9(4), 9(5), 9(6).

3. Feature Extraction: Normality or abnormality of an image is determined in the final result by Feature extraction. This is one of the essential stage. Input data is transformed

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into reduced representation set of features, when the input data to an algorithm is large to be processed and suspected to be redundant. Normality or abnormality in CT scan images are detected by Region based CNN (R-CNN), in this proposed work. R-CNN comprises of two categories in the identification of lung cancer. Pre-processing functionalities suitable to train and process the images in R-CNN, is the first category, this enables feature extraction to be performed. Classification of input CT scan images where it identifies the type of nodule as cancerous or non-cancerous, is the second category.

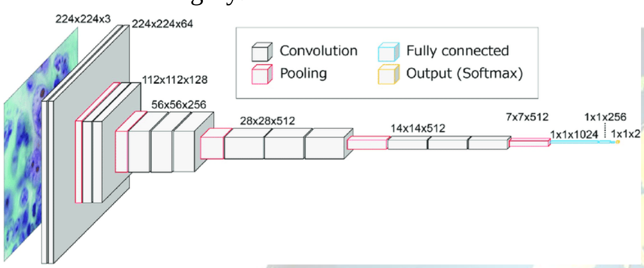

Figure 7. R-CNN Architecture for analyzing an image

The Architecture of CNN as presented in Figure 7. which comprises of 25 layers such as 8 convolution layer, 8 ReLu layers, 7 max-pooling layers and 1 fully connected later with softmax layer. VGG Net is a pre-trained Region based CNN. Objects can be distinguished and unseen objects can be classified by VGG Net to extract features (feature extractor). VGG was designed with the purpose of improving classification accuracy by growing the complexity of the CNNs. Images of suitable network size is fed as input to the first input layer. Second layer is convolution layer, which accepts input images of size 256 x 256 and then input images are converted into feature maps by applying Convolutional kernel of size 3 x 3. For converting image to feature maps, each Convolutional layer is followed by activation Rectified Linear unit (Re-Lu) layers. After Convolutional layer the next later is max pooling layer, the size of filter or kernel used is 2 x 2 and 2 pixels stride. Outputs of previous two layers are finally applied to the fully connected layer to generate 1024 output dimension. Resulting outputs are then applied to another completely connected layer followed by softmax layer. Possibility of benign or malignant cancer type is classified by the completely connected layer along with softmax layer.

Training and Testing Model

Training phase and Testing phase will take place after making successful lung segmented masks. In the training phase, DCNNs are trained using 500 CT scan images for the classification of lung nodule either cancerous or non-cancerous. To train the segmented lungs models with a batch size of 32 for image data generator and using 100 images in each epoch for 30 epochs with exception of 500 images in each epoch for VGG-16. Training images are with shape of (512, 512, 3) for VGG-16. An unknown image is applied as input in the testing phase to classify as cancerous or non-cancerous. In the proposed model, images are trained and tested in DICOM format by modifying the network parameters to take DICOM format images, in order to have minimum loss of features. The proposed designed network accuracy can be achieved by appropriate evaluation.

Performance Measures parameters

Performance evaluation parameters like accuracy & loss can be analyzed to check the performance of a medical image.

a) **Accuracy:** One of the most important performance measure parameter to evaluate the model. The model gives correctly classified number of pixels from the given image.
b) **Loss Function:** This is another important performance measure parameter of the network. Loss predicts the error in neural network. Loss is calculated by Loss function.

IV. EXPERIMENTAL RESULT

LUNA 16 is the source dataset and lung nodule CT scan images are used for the input layer. Dataset of the Lung Image Database Consortium image gathering (LIDC-IDRI) is an international image resource for evaluating and detecting lung cancer. LUNA 16 dataset is a subdivision of LIDC-IDRI dataset. Original image sizes are 512 x 512, but it is hard to train huge sized images in R-CNN, so images size are reduced to a appropriate size for the network by pre-processing the images. Images are categorized into training and testing images for calculating the network and for effective classification of cancerous and non-cancerous images, which supports early stages diagnosis in patients. Region based CNN model is trained by using 90% of training images from the given dataset. The model is calculated by 10% of testing images from the same dataset, post training. Image examples are fed into the network model which gets categorized into cancerous or non-cancerous images.

The Lung Cancer Detection using R-CNN on CT images (with and without cancer nodule) is stated below in following Figure 8(8) and 9(8).

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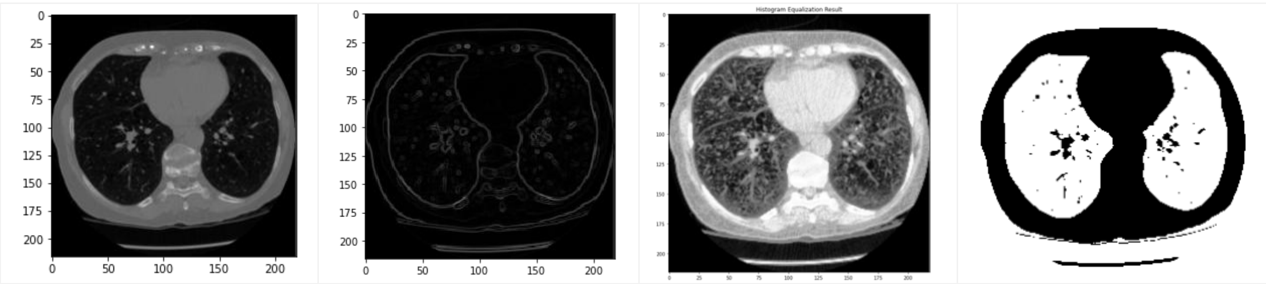
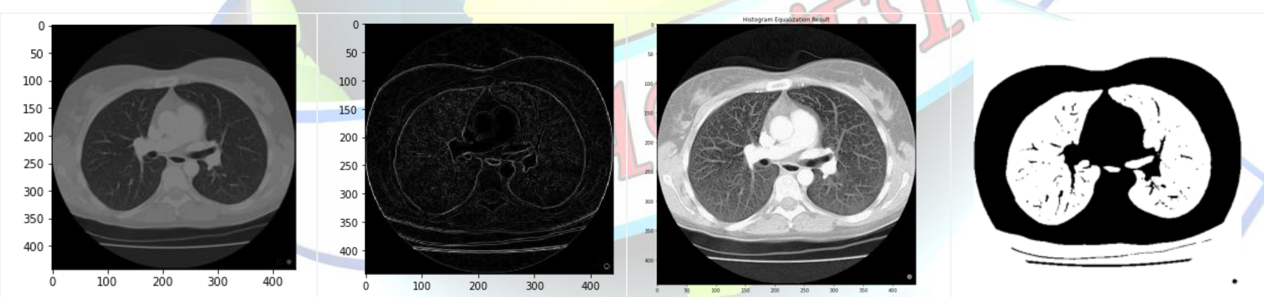


1. Original Image 2. Sobel Filter Result 3. Image Enhancement Result 4. Gradient Magnitudes
5. Internal Marker 6. External Marker 7. Segmented Lung 8. Cancer Detected Image

Figure 8. Cancer Nodule Detection on CT image (with Cancer Nodule)



1. Original Image 2. Sobel Filter Result 3. Image Enhancement Result 4. Gradient Magnitudes
5. Internal Marker 6. External Marker 7. Segmented Lung 8. Cancer Not Detected Image

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Figure 9. Cancer Nodule Detection on CT image (without Cancer Nodule)

The computation of this model is executed by using a Computer with Intel Core i5-2330M CPU, 2.20 GHz, 4 GB RAM, 64-bit Windows 10 OS.

As observed from the outcomes, it is obvious that as the training proceeds, classification accuracy will be improved along with rise in computation time, thereby decreases the percentage of loss as shown in the output graphs Figure 10and Figure 11. As the result, 99.82% of accuracy is attained in the complete process of R-CNN, which is the best level of accuracy attained when compared with earlier research works which is shown in Table 2. The following Table 1. shows the accuracy and loss function obtained in proposed model.

Performance parameters	***Accuracy***
Accuracy	99.82 %
Loss Function	28.2414

Table 1. Simulation Result of Proposed Model

Algorithms	***Accuracy***
Lung cancer detection using R-CNN (proposed)	99.82 %
Lung cancer detection using CNN [3]	±95 %
Lung cancer detection using 3D CNN [4]	97.17 %
Lung cancer detection using CNN [5]	96.88 %
Lung cancer detection using CNN [6]	92.85%
Lung cancer detection using CNN [7]	96 %

Table 2. Result comparison with existing models

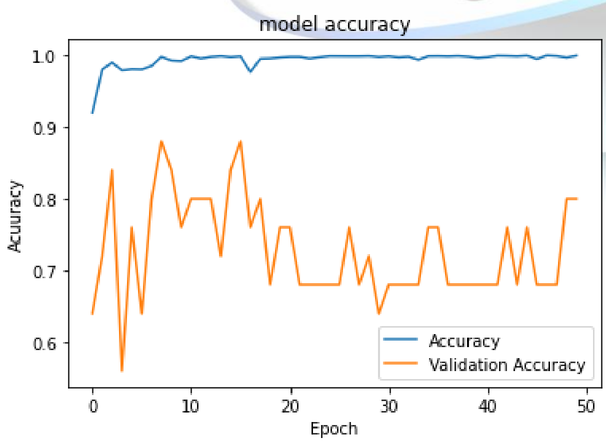

Figure 10. Result in terms of Accuracy

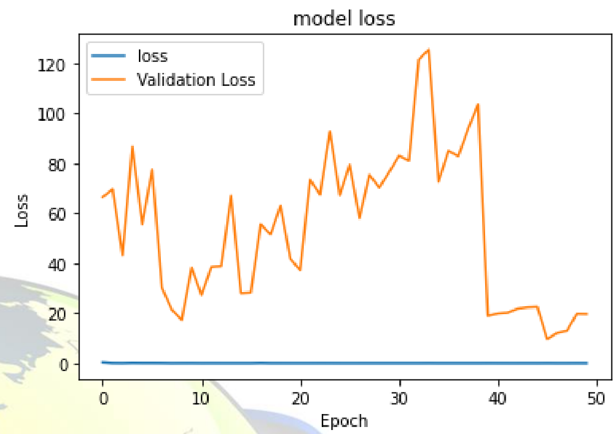

Figure 11. Result in terms of Loss Function

V. CONCLUSION

Lung cancer early signs are lung nodules. Survival rate of patients can be enhanced by early detection of lung cancer which plays an energetic role. Fast scanning speed, high image size and capture small areas are the advantages of Computed Tomography (CT) scan. One of the most active applications of CT scan is for clinical diagnosis. Region based Convolutional Neural Networks (R-CNN) is used in this research work, for identifying lung cancer nodules on CT scan images. LUNA 16 dataset is used in this research work which goes to LIDC dataset. For training the system, lung images with dissimilar shape, size of the cancerous tissues has been fed as the input. In order to make equivalent size and format of the images, pre-processing has been completed before applying input CT images to network model. Presence and absence of cancerous cells with accuracy of 99.82% is attained in the proposed R-CNN method, which is improved result when compared to earlier works. As a future research work, the system can be trained with bigger datasets for identifying the cancer type with its size and shape and Deep CNN architecture could be used to execute the experiments. System can also be developed by including dissimilar dataset types with 3D lung cancer images for classification.

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