Lung Cancer Detection using CT Scans using Deep Learning
Arvind Rajan¹, Ashwin Jayachandran², Ashwin Thomas Abraham³, Pranav Peter⁴, Deepa. P. L⁵
B.Tech. Student¹, ², ³, ⁴, Assistant Professor⁵
Department of Electronics and Communication Engineering
Mar Baselios College of Engineering and Technology, Thiruvananthapuram, Kerala, India

Abstract:
Cancer is one of the most dangerous diseases in the world that affects all people, irrespective of age or gender. Lung cancer is the second most common type of cancer and it has a high mortality rate. This makes the study of lung cancer eminently crucial. Early detection would facilitate in saving a large number of lives. Though CT scans are a powerful imaging technique, it is difficult for radiologists to locate and identify cancerous tumors as it is a very time and attention consuming process. It also requires knowledge and skills of a particular subspecialty of radiology. So, we can say the diagnosis will solely depend on the expertise of the radiologist. The use of computer aided systems provide radiologists with assistance thus accelerating this diagnosis process. By applying powerful deep detection models in computer vision, we can detect the presence of cancerous lung nodules in CT scans. The proposed method comprises a classification network that classifies the input CT scan data into two classes: benign and malignant. Here we have both modified a pre-existing network and built a new network from scratch to classify the CT images. The main focus being the development of a new network that can give better results in classification of the images.

Keywords: AlexNet, CT Scans, Deep Learning, Lungnet, Transfer Learning.

I. INTRODUCTION
Cancer is a disease that occurs due to the uncontrolled growth of cells. Normal healthy cells are born, perform a certain function and later on die and are replaced by other cells. This is not the same case for cancerous cells, for these cells, cell death does not occur and they keep on multiplying to form a large mass of cells. These large masses of cells are known as tumours. Now tumours can be broadly divided into two types: benign and malignant. Benign tumours are not cancerous, i.e. they are harmless. It does not invade other tissues or spread. Malignant tumours and cancerous and invade other tissues as well as spread around the body. Lung cancer is one of the most commonly seen types of cancers and has enormous psychological impacts on the patients who come by the disease due to its high mortality rate. Globally, there were an estimated 2.1 million lung cancer cases and 1.8 million deaths in 2018.[8] It usually begins within the cell lining of the lungs. When cancer starts in the lungs, it is called primary lung cancer. One of the most vital organs not only in our respiratory system but that of the body is our lungs which are present in the chest cavity. The function of the lungs is to help us to breathe, that is to take in air from the atmosphere and provide oxygen to the bloodstream. Now each of the lungs is surrounded by a sac-like substance known as the pleural sac which contains a fluid known as the pleural fluid, the function of this fluid is to allow the outer and inner layers to glide over each other, thus reducing the amount of friction. The lung is also divided into a number of sections with the help of the pleural sac, these sections are known as lobes. As the right lung is larger, it has three lobes while the left lung has two lobes. Now like all cells, the cells present in the lung have a chance to mutate and thus cannot perform the same functions like that of a normal healthy cell. This leads to resultant tumors, now these tumors can be both cancerous and non cancerous. The main two types of cancerous tumors are small cell lung carcinoma (SCLC) and non small cell lung carcinoma (NSCLC). Now the most difference between the two is that in almost all cases the origin of SCLC is the bronchi, which is the passageway for air to enter into the lungs. For lung cancers, grading is done by doctors to find out the rate at which the cancer is growing and if it will in fact spread to other parts of the body. Grading is done on the basis of the appearance of the cells underneath a microscope.

Grade1: These are known as low grade cells and they are similar in appearance to healthy cells they only have a minute chance of spreading.
Grade2: Their appearance is more atypical to the common cell and have a higher chance of spreading to different parts of the body. They are also known as moderate grade cells.
Grade 3: They are known as high grade cells and have a very high chance of spreading to other cells. These cells look and behave nothing like normal cells.

The diagnosis methods usually followed by the hospitals are:
• CT-Scan: It is a medical imaging technique that employs x-rays which are used to produce a cross-sectional image of the affected area. This is done by taking x-ray measurements at different angles. A CT scan would prove more useful than a normal x-ray because it gives an idea about the size, shape and location of the tumor in the lung.
• MRI Scan: It is another medical imaging technique that is used to form images of the organs in the body using powerful magnetic fields and radio waves. However a disadvantage of taking MRI scans is that it does not perform well on moving parts. Thus the expansion and contraction of the lungs during breathing would lead to a problem. As a result it is rarely taken in cases related to the lung but it is used to check if the cancer has spread to other parts of the body.
• Sputum Cytology: Sputum is basically the mucus produced in the respiratory tract. This sputum can be isolated and can be looked at underneath a microscope to detect the presence of cancerous cells.
• Tissue Samples (Biopsy): In this process a small portion of the tissue is removed and is observed under a microscope and
appropriate inferences are made. There are a number of tests available namely bronchoscopy and thoracentesis. Over 2 million people every year are diagnosed with lung cancer. Lung cancer if diagnosed early is curable. When there has been a failure to detect a cancerous lung tumor, the person usually to blame is the radiologist. The most frequent acts of malpractice that result in a delay in diagnosis are: the radiologist misread the chest x-ray and failed to appreciate the x-ray shown; the radiologist on receiving the x-ray failed to read and appreciate the significance of the report; or when a recognized sign or symptom receives inadequate attention. A couple of years ago an article was published in the American Journal of Roentgenology highlighting a failure to diagnose lung cancer by not one but two radiologists. The person in question was a 66 year old woman who after consulting her physician (specialized in internal medicine) about the severe abdominal pain that had been increasing in severity over a three day period was finally admitted in the emergency section of a local public hospital [10]. After examination the physician-on-duty in the emergency department prescribed that a CT scan be taken, on examination of the CT scan the radiologist reported the presence of a 1.8cm long granuloma in the left lung. The very next day a surgeon was called up and the woman was operated on confirming the presence of an abdominal abnormality. After another 3 days a follow-up CT scan was taken and the radiologist had written in his report that there was no change in the lung volume. After two days the woman was discharged with no further radiologic studies being performed at the hospital and no contact between the hospital and the woman. Eighteen months later a malpractice lawsuit was filed against the radiologists and physicians in question due to her 1.8cm carcinoma being incorrectly read as a granuloma. As a result the diagnosis of cancer was further delayed by a period of one year. This is not one isolated incident that has occurred, a number of cases such as this one has happened around the world. Each day a number of people suffer from medical negligence. So, as a remedy adopting an automated computer system would be very useful in diagnosing a patient’s health from the test results. One such way of approach for finding the patient having a lung tumor from a CT scan has been discussed in this paper. Goran et. al. [1], they pitched the idea of using a double convolutional network(CDNN). The procedure of testing the network remains more or less similar to the ones presented in the papers given below. First, a known dataset was used to train CDNN. This CDNN was built by the researchers and used max pooling to increase accuracy for tumor search. After extensive training with 100 epochs, the CDNN obtained an accuracy of 99.6 percent, contrasted to an accuracy of 87.6 percent obtained from regular CDNN as per their findings. The paper also highlights the ability of the CDNN to identify the stage of cancer. The CDNN was acknowledged as being able to satisfactorily detect cancer in T3. The research intends to modify the DNN to show the location of the detected tumor in the CT scan. S. Sasikala et. al. [2], they used a Convolutional Neural Network (CNN) to detect lung tumors and classify them as cancerous and non-cancerous. Segmented CT scan images of lung are fed to train the CNN architecture. The research was able to achieve an accuracy of 96 percent contrasted against multi layer perceptron network back propagation algorithm which gave an accuracy of 93 percent. The accuracy can further be improved by increasing the dataset size, tuning the hidden neurons and using 3D convolutional neural networks. Ignatious et. al. [3], here they used Watershed Segmentation promising better results than existing systems. The research was in collaboration with Regional Cancer Centre, Trivandrum which tested the proposed model on a dataset of 200 slices of CT images, giving an accuracy of 94.4 percent. The proposed model was not able to detect tumors along lung borders. The CT scan images were pre-processed before undergoing segmentation. The segmented image was used for feature extraction which helps identify if there is a tumor within the lung. Extracting more features from the image and increasing size of dataset can improve accuracy. Suren Makaju et. al. [4], this paper primary focus was to assess and evaluate all the current techniques that are used to detect lung cancer. The techniques here refer to experimental computer-aided DL models. These techniques were graded on the basis of detection accuracy and further listed out their shortcomings and proposed improvements to the existing models. The research aimed at achieving a 100 percent accuracy in detection rate. The research concluded that the best model at that time was not able to determine the degree of cancer in the detected nodules and an unsatisfactory 86 percent accuracy rate. The paper further proposed a new model which uses Watershed Segmentation and Support Machine Vector for detection and classification of cancer nodules respectively. This model gave an accuracy of 92 percent but was not able to classify cancer as Stage I, II, III, or IV. Further pre-processing and elimination of false objects can improve accuracy. QingZeng Song et. al. [5] , in this paper they analyzed three different neural networks namely CNN, DNN and SAE . These networks were tested with the dataset obtained from the Lung Image Database Consortium (LIDC) and it was observed that the convoluted neural network proved to be the most accurate in differentiating between benign and malignant nodules. However they also faced difficulties due to dataset limitations.

II. MACHINE LEARNING (ML): “AN APPROACH TO ACHIEVE AI”

Machine learning in simple terms is the practise of using algorithms to interpret data, learn from it and then apply the gained information to make predictions about something. A more technical definition would be, that ML is the study of algorithms that computers can use to complete a particular task without any explicit instruction. Deep Learning(DL): “A technique for implementing machine learning”. DL is a subset of machine learning which can handle a huge amount of data in the most efficient way where machine learning fails. It is a set of algorithms that try to mimic the human neural network using multi-layered neural architecture.

III. DEEP LEARNING

Deep learning is a sub_field of machine learning Which is part of a larger field of Artificial Intelligence (AI). “General AI” is a concept of amazing machines that have senses just like us and can mimic the ability of humans to think, reason and make decisions. This concept has been around in all kinds of novels and movies for a reason, we can’t pull it off yet. The closest yet to AI that humans have managed to develop is the concept of “Narrow AI”. These technologies are applied to achieve specific tasks for example, image classification, face recognition on camera applications etc. To understand how this is done, we look into the concept of Machine Learning.

IV. DEEP NEURAL NETWORK (DNN)

Artificial neural network is a set of advanced machine learning algorithms which forms the basis for several different deep
learning models. Hence, deep learning may sometimes be referred to as deep neural networking. DNN follows a trial and error process and requires a huge amount of data to identify and extract features. All Deep Neural Network consists of three layers: Input layer, hidden layer and output layer. The input layer is where the dataset is given for training/testing. The feature identification and extraction is done in the hidden layers. The final prediction by the network is found in the output layer. Different Types of Deep Learning Networks are available in literature. Some of these are given in the table

<table>
<thead>
<tr>
<th>Model</th>
<th>Category</th>
<th>Learning Model</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto encoder</td>
<td>Generative</td>
<td>Unsupervised</td>
<td>● Suitable for future extraction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● Works with unlabelled data.</td>
</tr>
<tr>
<td>LSTM</td>
<td>Discriminative</td>
<td>Supervised</td>
<td>● Efficient for data with long time lag.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● Gates provides necessary protection to the access of the memory cell.</td>
</tr>
<tr>
<td>CNN</td>
<td>Discriminative</td>
<td>Supervised</td>
<td>● Computations are done by convolutional layers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● Connections are lesser than DNN.</td>
</tr>
<tr>
<td>VAE</td>
<td>Generative</td>
<td>semi-supervised</td>
<td>● A class of AEs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● suitable for scrutiny of labelled data.</td>
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</tbody>
</table>

V. CONVOLUTION NEURAL NETWORK

In deep learning, convoluted neural network is a category of deep neural network that deals with image processing. They are fully connected networks, in such a structure each neuron is connected to all the other neurons in the subsequent layers. It consists of an input layer, a number of hidden layers and an output layer. The hidden layers usually consist of several convolutional layers. It is usually followed by pooling and other convolutional layers. In other words, it is a three dimensional collection of neurons forming several layers that transform a given input through certain processes into an output.

The basic architecture of a CNN is as follows: CONVOLUTIONAL LAYERS:

It is used to extract unique features from the input image. It does so by performing convolutional operations using a kernel that operates on the input which is then passed on to the subsequent layers. There are different kernels corresponding to different applications. These kernels are normally kept small but can be extended if necessary depending on the input. Square kernels are used if the image is a 2D or 3D one.

Figure 1: Convolution operation using kernels

Figure 2: Pooling operation

POOLING LAYERS: It is another block of CNN. The function of this layer is to eventually reduce the spatial size of the representation, i.e. reduce the number of learnt parameters. Pooling layer is used for dimensionality reduction without much loss in information. Pooling means selecting a filter size, making it mask the image area and replace the whole area with a single value in the centre position. Most commonly used pooling functions are max-pooling function, min-pooling function, average-pooling function, etc. In max-pooling, the centre position of the mask area is replaced with the maximum value among the values masked by the filter. In min-pooling, the centre position of the mask area is replaced with the minimum value and in average pooling, it is replaced with the average of all the values masked by the filter mask. Of all, max pooling is the most commonly used as it usually yields satisfactory results.

Figure 3: ReLU function
FULLY CONNECTED LAYERS: These layers are usually present at the end of the network and they have connections to all the neurons of the previous layer. The function of this layer is to take output of the previous convolutional/pooling layers and assign to it a suitable class suiting the features.

Figure 4. CNN architecture with Fully connected layers

WEIGHTS AND BIASES: The neural network is initially set with some weights before the training process. During the training period, these weights are updated until the optimum weights are found. The product of inputs and weights are summed with a constant value called Bias which helps in offsetting the result. The result is thus moved to either the positive or negative side of the activation function by addition of bias.

Figure 5. Weights and bias

LOCAL RECEPTIVE FIELDS: In a neural network the fully connected layers receive input from all the neurons in the previous layer. In the convolutional layer, it only receives input from a small subset of neurons. This corresponds to the receptive layer.

VI. ALEXNET

AlexNet consists of eight layers in which five of them are convolutional and the remaining three are fully connected layers. It uses the non-saturating ReLU activation function. The SoftMax layer uses the output from the fully connected layers to convert the scores (output from the fully connected layer) into probabilities, which then can be divided among thousand classes based on the probabilities.

VII. TRANSFER LEARNING USING ALEXNET

Alexnet is an eight layered convolutional neural network in which five of them are convolutional layers and three of them are fully-connected layers.[6,7] Our objective is to modify an existing network (Alexnet) which can predict whether the image of lung CT-scan is normal or has a tumor. We modified AlexNet by removing the final classification layer which consist of 1000 categories and added a new layer with only two classes benign and malignant.

VIII. DATASET

Dataset used for training the neural networks: AlexNet and Lungnet was taken from CancerImagingArchive.net[11] which consists of CT scan images of both benign and malignant nodules saved in the format of Digital imaging and Communications (DICOM). The dataset consisted of 19089 CT scan images of which 10109 were benign and the rest 8980 malignant.

IX. PROPOSED METHOD

The network is trained using the labelled dataset after preprocessing. Once the network is trained it is then fed with input images. This is again preprocessed before giving to the DL network. The network would then classify the image as normal or tumorous. The preprocessing step is done to format the input image to the size which is standard to the neural network, in this case Alexnet. The block diagram for the proposed model is given below:

Figure 7. Workflow of DL network
The preprocessing step can be pretty much avoided in the proposed architecture allowing to input the raw CT-scan image.

X. IMPLEMENTATION DETAILS

The implementation of the network and following testing was done on MATLAB. MATLAB short for “matrix laboratory” is a computer programming language developed by MathWorks. It allows for operations like matrix manipulation, implementation of algorithms etc. In particular, the Deep Learning Toolbox which allows for easy designing and implementation of Neural networks. Using MatLab we can import a pre-existing network and modify it or simply create a new network according to our requirement. For our project, we have used MATLAB2019b version, which also allows to extract the MATLAB code too.

XI. PROPOSED ARCHITECTURE

The proposed network is named Lungnet It consists of 53 layers which is a mix of 16 convolutional stack layers, 4 fully connected stack, 5 pooling function, 19 ReLU functions, 3 batch Normalization, 3 dropout layers and 1 layer each for input, output and probability(softmax layers). A detailed view of the network is given in figure. The input size is of 512x512 which is the default dimension of a CT image.

XII. TRAINING AND TESTING

For training, 7843 benign and 6965 malignant CT images were used. Testing was done with the remaining 2266 benign and 2015 malignant CT images. AlexNet works only with the images that are of 227 x 227 resolution format. Initially the CT scan images are of 512x512 resolution but they were converted to 227x227 during the preprocessing stage. lungnet on the other hand accepts CT images in their raw format (512x512) as a result the preprocessing stage can be excluded resulting in no data loss.

XIII. RESULTS AND DISCUSSION

AlexNet has the drawback of having a large feature size and requires preprocessing of the input CT images. The results obtained from Lungnet were superior to that of AlexNet by having an accuracy of 93%, sensitivity of 100% and specificity of 86.8%. This is shown in the Confusion Matrix for Lungnet given in the figure. Confusion matrix for AlexNet was also found for comparison purposes. The results obtained from the proposed network i.e. Lungnet and the pre-existing AlexNet is shown in TableII.
IV. CONCLUSION

The proposed model network can successfully identify the presence of malignant nodules in the lung. The advantage of using Lungnet is that no data loss occurs due to resizing of images and due to the large number of layers, the network is more precise and accurate. While conducting testing, some difficulty was faced due to a availability of benign CT images. It is speculated that a more vast and diverse dataset could help further improve the study and work on the current network and hence give better results. Future scopes include segmentation and identification of location of malignant nodules in the lung.

V. REFERENCES


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