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IDENTIFICATION OF LUNG CANCER DETECTION USING 3D CNN

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ABSTRACT

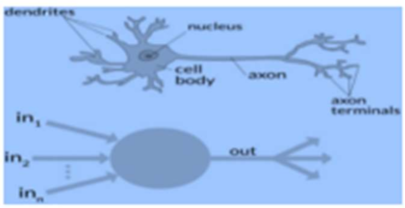
Lung cancer is one of the most prevalent cancer-related diseases with a high mortality rate, and this is largely due to the lateness in detecting the presence of malignancy. Again, the conventional methods used in the diagnosis of lung cancer have had their shortfalls. While the effectiveness of computerized tomography in detecting this malignancy, the large volumes of data that radiologists must process not only present an arduous task but may also slow down the process of detecting lung cancer early enough for treatment to take its course. On a global scale, lung cancer is noted to be one of the most prevalent cancer-related diseases with a high mortality rate. The prognosis of the disease has not been very favorable and this is largely due to the lateness in detecting the presence of malignancy. It is more necessary for care to immediately & correctly examine the lung cancer nodules.The various Machine learning models have been utilized in the medical field for quite a while now, and as it has displayed its many strengths, so could the limitations not be hidden. It is in addressing these limitations and improving on the detection prowess of the convolutional neural network that the 3D model is now fast gaining attraction, it has motivated us. When there several methods used to examine lung cancer ,deriving towards CT scan images as CT Scan images are powerful and it takes images of internal organs, vertebrae, and the spine in 360 degrees which gives a more clear view.

In this paper, we are using 3D Convolutional Neural Network (CNN) for identification of lung cancer from the Computed Tomography (CT) scans of the patient, since CNN makes it easier to obtain the important information from the images. This paper focuses on developing a 3-Dimensional Convolutional Neural Network that Detects whether the CT Scan Image is Cancerous or Non-Cancerous. Therefore, an automated method that can determine whether the patient will be diagnosed with lung cancer is the aim of this paper.

Keywords: Computed Tomography (CT), Convolutional Neural Network (CNN), Lung cancer, Lung cancer, radiologists

1. Introduction

Lung cancer is a virulent lung tumor in which uncontrollable and unbalanced growth of cells ultimately leads to invasion of the neighboring cells resulting in a cancer. Lung cancer[1] can be seen on computed tomography (CT) scans which is created by combining a series of X-ray images taken from different angles around the body. Most of the cancerous deaths in the world are due to lung cancer with 1.8 million deaths annually. Deep Learning falls under machine learning which helps you to abstracts a model from the dataset by implementing deep neural networks. Deep neural networks can be used which would be an effective way for finding the cell growth region from the CT[9] scans using image pattern recognition and image classification. Using deep learning we can investigate various features or dimensions of an image or textual data. Deep learning works better when we perform more and more data. It prevents Overfitting and acquires more dimensions and therefore gives us more accuracy. Deep Learning outshines when there is a lack of understanding for feature introspection. It imitates The working of Human Brain in processing data and create patterns for use in decision making.



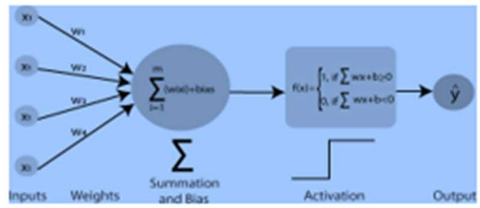


Fig-1. Perceptron **Fig-2 Single Layer Perceptron**

- **Single Layer Perceptron**

A Perceptron is an algorithm used for supervised learning of binary classifiers full stop it was inspired by the actual brain. binary classifiers decide whether an input usually presented by a series of vectors belong to a specific class. a perceptron is a single Layer neural network.

- **Multilayer Perceptron**

A Multilayer perceptron is a combination of many perceptron's. For a single layer perceptron, we can only perform a single class and we cannot take multiple decisions whereas for a multilayer perceptron we have multiple dense layers and for every layer, we can extract multiple features from the input that is provided and therefore we can get better accuracy.

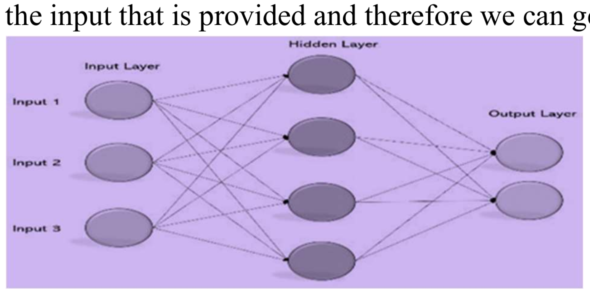


Fig-3 Multilayer Perceptron

- **The disadvantages of the Single Layered Neural Network or the Multilayered Neural Network are**

a) Over Fitting

Refers to a model that models the training data too well. Overfitting happens when a model learns the detail and noise in the training data to the extent that it negatively impacts the performance of the model on new data.

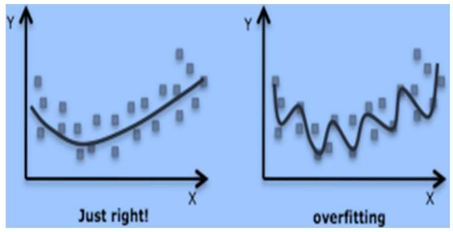


Fig-4 Overfitting

b) Curse of Dimensionality

The difficulties related to training models due to high dimensional data is referred to as 'Curse of Dimensionality'.

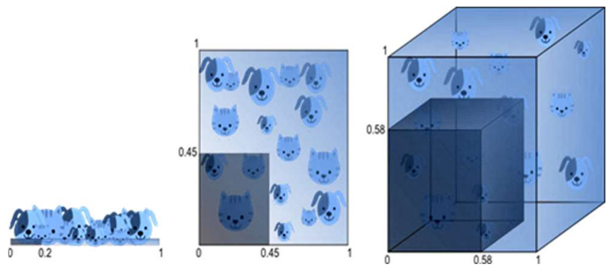


Fig-5 Curse of Dimensionality

c) Variance in object Position

Observing changes of the object position in the training data set.

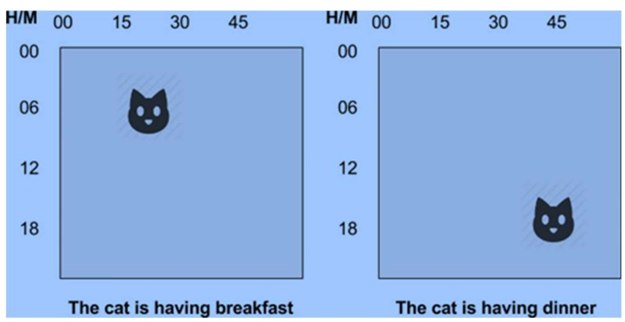


Fig-6 Variance in Object Position

- **CNN**

A Convolutional Neural Network is a Deep Learning Algorithm which can take in an input image, assign importance(weights and biases) to various aspects/objects in the image and be able to differentiate from another.

CNN works on the principle of Template Matching. Template Matching is a technique in digital Image Processing for finding small parts of an image which matches a template image.

- **Components of CNN[7]**

Convolutional Filter

This layer is the first layer that is used to extract the various features from the input images. In this layer, the mathematical operation of convolution is performed between the input image and a filter of a particular size MxM. By sliding the filter over the input image, the dot product is taken between the filter and the parts of the input image with respect to the size of the filter (MxM).

The output is termed as the Feature map which gives us information about the image such as the corners and edges. Later, this feature map is fed to other layers to learn several other features of the input image.

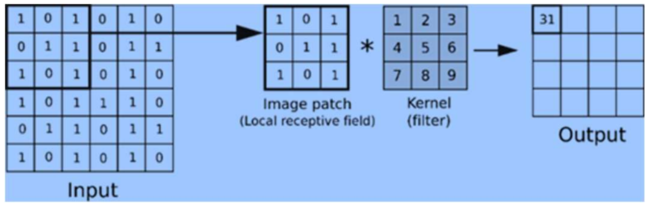


Fig-7 Convolutional Layer

Pooling Layer(To reduce the dimensions of the feature map)

In most cases, a Convolutional Layer is followed by a Pooling Layer. The primary aim of this layer is to decrease the size of the convolved feature map to reduce the computational costs. This is performed by decreasing the connections between layers and independently operates on each feature map. Depending upon method used, there are several types of Pooling operations. In Max Pooling, the largest element is taken from feature map. Average Pooling calculates the average of the elements in a predefined sized Image section. The total sum of the elements in the predefined section is computed in Sum Pooling.

The Pooling Layer usually serves as a bridge between the Convolutional Layer and the FC Layer

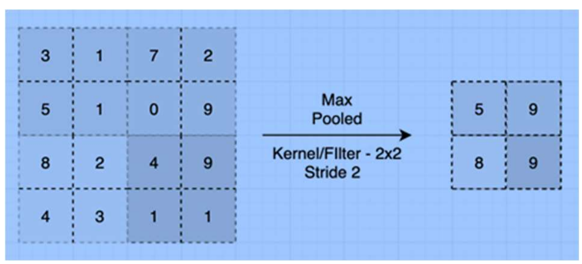


Fig-8 Pooling Laye

Padding Layer(The amount of pixels added to the image when being processed)

In cases where we want to increase the size of the output and save the information presented in the corners, we can use padding layers where padding helps by adding extra rows and columns on the outer dimension of the images. So the size of input data will remain similar to the output data.

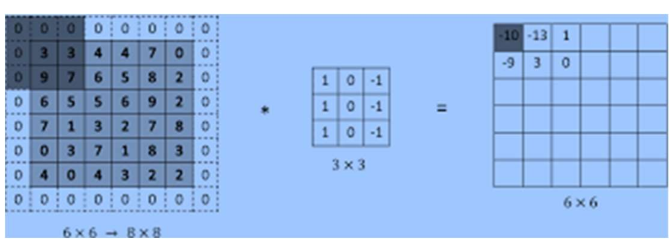


Fig-9 Padding Layer

Padding basically extends the area of an image in which a convolutional neural network processes. The kernel/filter which moves across the image scans each pixel and converts the image into a smaller image. In order to work the kernel with processing in the image, padding is added to the outer frame of the image to allow for more space for the filter to cover in the image. Adding padding to an image processed by a CNN allows for a more accurate analysis of images.

Flattening Operation

Flattening is converting the data into a 1-dimensional array for inputting it to the next layer. We flatten the output of the convolutional layers to create a single long feature vector. And it is connected to the final classification model, which is called a fully connected layer. In other words, we put all the pixel data in one line and make connections with the final layer.

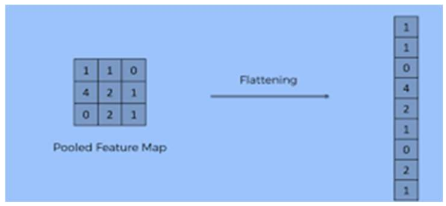


Fig-10 Flattening

2. LITERATURE SURVEY

- **Lung Cancer detection using CNN**

CNNs were applied to detect and classify lung cancer CT scans of the patients collected from hospitals. Convolutional Neural Networks is a sort of deep learning paradigm applied for processing data which has a grid pattern like images , it is all about using Deep Learning with Computer Vision. A good way to gain foreknowledge about this technique is to imagine a Neural Network Architecture. The obtained model gave accuracy of 90.78% while applying on the dataset collected.

Like a Neural Network, a typical Convolutional Neural Network consists of a multiple hidden layers called a Convolutional Layer where the linear function computes the strided convolutions over an image to extract features. It also consists of a pooling layer that computes another function such as Max Pool or Average Pool to reduce the size of the image in the neuron to speed up the computation. It does it by extracting the features of the neuron image and ignoring the rest, this makes the network more robust. There is also fully connected layer which is like a hidden layer in a neural network where the sum of the outputs of each layer are flattened and where each value is an input to the next layer followed by an activation function and an output.

Convolutional Neural networks can identify and classify lung cancer types with greater accuracy in a shorter period, which is crucial for determining patients' right treatment procedure and their survival rate. Benign tissue, Adenocarcinoma, and squamous cell carcinoma are considered in this research work.

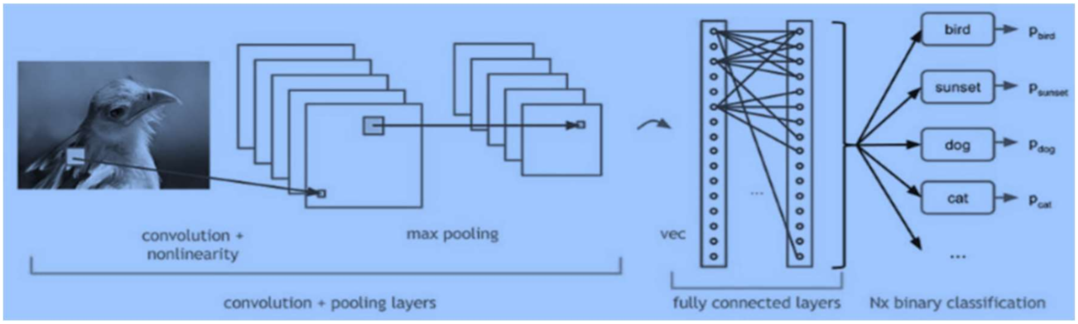


Fig-11 Convolutional Neural Network Example

□ **Lung Cancer detection using CNN[3]**

Lung Cancer Dataset	*Format*	*Merits*	*De Merits*
Data Science Bowl 2017 (Kaggle)	*Format: CT Scan Images*	It automatically detects important features without any human supervision.	High accuracy in image recognition problems

The study can be improved by including regularly enhancing the accuracy of the model by training it on bigger and more extensive datasets.

Performance Analysis

The trained model of nodule detector is tasted on 9744 candidates.

From the confusion matrix, 9233 non-nodules were correctly predicted to be non-nodule out of 9298 nodules. 65 non-nodules were wrongly predicted. 399 nodules were correctly predicted out of a total 446 nodules. 47 nodules were predicted incorrectly to be a non-nodule.

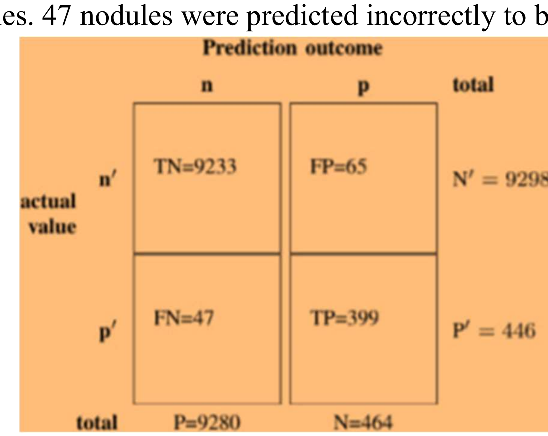


Fig-12 Confusion matrix

Lung Cancer Detection System	**Accuracy**

Image Processing Techniques[8]	**80%**
Image Segmentation Based on Gray Coefficient Mass Estimation with Gabor Filter[2]	**83%**
Proposed Method(3D CNN)	**90.78%**

Fig-13 Accuracy

- **Lung Cancer detection using KNN**

In pattern recognition, the K-Nearest Neighbor algorithm (K-NN) is a non-parametric method used for classification and regression. The effective and important parameters in the performance of KNN algorithm are distance measure ,neighbor number(k) and weighted method. The accuracy obtained for k=5 is 83.33%. K-Nearest Neighbors (KNN) algorithm is the best known, old, simple and effective pattern classification methods proposed by Thomas. M. Cover and Peter. E. Hart, where the sample data point is located and the nearest neighbor is determined by the k value. The effective and important parameters in the performance of KNN algorithm are distance measure, neighbor number (k) and weighting method. In this study, we used KNN with different k values to compare performance of the method. We took k as 2, 3 and 5 for the number of neighbors.

- **Lung Cancer detection using ANN[4]**

The Artificial neural network takes input and computes the weighted sum of the inputs and includes a bias. This computation is represented in the form of a transfer function. This weighted total is passed as an input to the activation function to produce the output. Activation functions choose whether a node should fire or not. In this Study they have used a feed foreword neural network with 10 hidden layers instead of using full sized image they reduced their image dimensions to in the ratio of 1/32. The accuracy obtained was 82.43%. Standard Digital Image Database, Japanese Society of Radiological Technology 247 CT Scan Images, with 154 Cancerous and 93 Non-Cancerous.

COMPARISION OF EXISTING METHODS[10]

Aut hor	Methodology	Result	Dataset
S.Santosh Baboo,E.Iyyapparaj "Analysis of classification methods for diagnosis of pulmonary nodules in CT images",Eng.Sci.Comput.,vol.109 49.20 19	Context ual Clusteri ng [SVM]	Accuracy=76 %	LIDC-IDRI

Sheeraz Akram et al. Comparision of Lung Cancer Detection Algorithms 2019IEEE	Artificial Neural Network(ANN)	Accuracy=82.43 %	Standard Digital Image Database,JSRT
Aparna Kanakatte,Prashant Nareshet al.,Comparision of Lung Cancer Detection Algorithms 2019 IEEE	K-Nearest Neighbour (KNN)	Accuracy=74.32 %	Standard Digital Image Database,JSR T
Radhika P R,Rakhi.A.S.Nair A comparative study of lung cancer detection using machine learning Algorithms 2018 IEEE	Naïve Bayes	Accuracy=87.87 %	Lung Cancer Dataset,Dataworld
ICCCNT 2019 IEEE[5][6]	Vanilla CNN	Accuracy=90.78 %	Data Science Bowl 2017 (Kaggle)

Table 1: Comparison of Existing Methods

RESEARCH CHALLENGES

During our research, there were several techniques that have been implemented to detect lung cancer. The challenges faced were

- **Selection of Medical Imaging Technique**

There have been too many methods developed in recent years to diagnose lung cancer, most of them utilizing Computed Tomography CT scan images , some of them using X-Ray Images and using Magnetic Resonance Imaging (MRI) Images. CT Scan images are too powerful and advanced versions of X-Ray's. Thus selecting the correct type of data has always been a concern as a minute error can cause a huge impact on an individual's life. CT scan takes images of internal organs, vertebrae, and the spine in 360 degrees which gives a more clear view.

- **Data Understanding**

This phase is about collecting the data, gaining familiarity and ultimately understanding the strengths, opportunities and weakness of the data as data does not always fit the problem that is being solved. The analyst must be aware of the structure of the data and be able to describe it and ultimately verify the quality of the data. Some common questions an analyst may ask himself/herself is "Is the data complete?, Is there any missing values, Have I explored the data enough?".

- **Quality of Data**

Data Quality is one of the most common issues that include presence of noise ,missing or redundant data. Thus improving the data will improve the quality of the result. Data plays a significant role in the machine learning process. One of the significant issues that machine learning professionals face is the absence of good quality data.

- **Choosing the Right Dataset**

Choosing the right dataset is also a challenging task to detect cancer at early stages. For most of the machine learning and deep learning algorithms data is large data is important for image classification and processing. There are various datasets like LUNA 16 Data set,LIDC Dataset, Chest CT Scan images datasets Dataset etc. Choosing the right dataset can also minimize the false-negatives.

3. 3D CNN PROPOSED SOLUTION

This summarizes the advancements in machine learning and deep learning applied to CNN for the development of lung cancer detection.3D CNN is used when we need to consider volumetric context. When there several methods used to examine lung cancer ,deriving towards CT scan images as CT Scan images are powerful and it takes images of internal organs, vertebrae, and the spine in 360 degrees which gives a more clear view. In 3D convolutional neural network, everything is similar to a simple convolutional neural network except that in 3D CNN a 3-dimensional filter moves throughout the dataset in 3 directions (x, y and z - axis). In 3D convolution, a 3D kernel is convolved to a cube by adding multiple contiguous frames one after another. The filters extract the features important for more precise prediction from the dataset, and gives output in another 3-dimensional space. The 3D images are given as input and are pre-processed and various layers are set with values, there is no hard and fast rule that values are fixed, hence to test the layers' multiple times with different values and arrive at a set of values that were optimal.

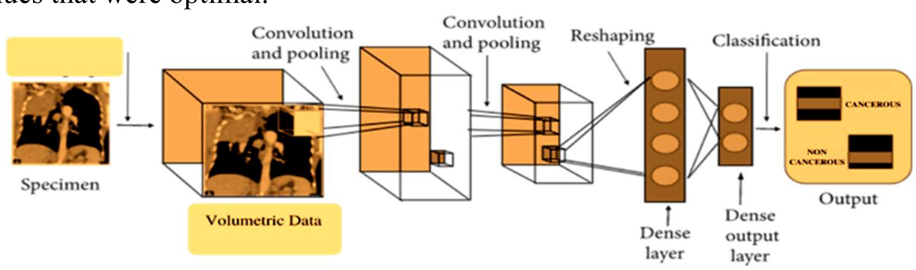


Fig- 17 Proposed 3D Lung Cancer Mechanism

FEATURES OF THE PROPOSED SYSTEM

The completed paper should accomplish the following Objectives:

- **Self Education on Deep Learning**

A large part of this paper contains a lot of self education, initially the author knew very little about deep learning, as part of this paper the author should have a good grasp on deep learning concepts.

- **User Research and Evaluation**

The paper should have a user-centred design aspect. This means that the system should be designed to help certain users. In this paper the user would be medical professionals who work in diagnosing lung cancer.

- **System: Upload CT Scans**

The system should be capable of getting CT Scans from Users that will be utilized by the Deep Learning Model.

- **System: Detection of Lung Cancer**

The system should be able to detect the lung cancer within the CT scan images that users have uploaded.

- **System: Display Results**

The system should be able to give information that our user can appropriately understand and gain insight from it.

DATASET DESCRIPTION

Lung Cancer is one of the leading life taking cancer worldwide. Early detection and treatment are crucial for patient recovery. Medical professionals use histopathological images of biopsied tissue from potentially infected areas of lungs for diagnosis. Most of the time, the diagnosis regarding the types of lung cancer are error-prone and time-consuming. Building deep learning models require a lot of data. For this paper datasets has been researched and identified before any real work has begun. Since there is a heavy emphasis on building models for this paper, a key part of the paper relies on a Dataset.

Kaggle 3D Unlabeled Dataset: Data Science Bowl 2017

This dataset was part of the Kaggle competition Data Science Bowl 2017. The topic of the competition was about lung cancer detection. The dataset was provided by the National Lung Cancer Screening Trial, The Cancer Imaging Archive, Diagnostic Image Analysis Group (Radboud University), Lahey Hospital and Medical Center and Copenhagen University Hospital. The dataset contains full CT scan images of a patients lungs. The dimension for this is (512,512, 200) which is (Height, Width, No. of Images).

This dataset was what the author originally wanted to work with as the data was labeled as desired and useful for the paper. However the largest challenge that hindered the author from continuing using this data is the size of the entire dataset. The entire dataset is about 100GB zipped which could not fit on the authors laptop. Preprocessing the entire dataset would also be too computationally heavy.

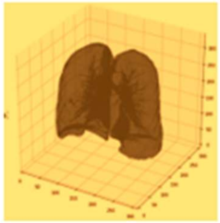


Fig-19 Segmented Lungs

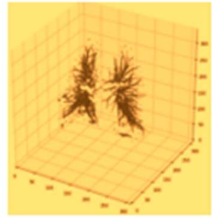


Fig-20 Segmented Nodules

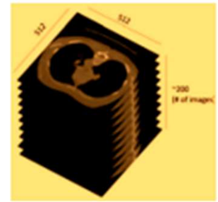


Fig-18 3D Kaggle Dataset

LUNA16 Labeled 3D - Lung Nodule Analysis Dataset 2016

The LUNA16 dataset is also 3D CT scans of lung cancer annotated by radiologists. The dataset contains 3D images and a CSV file containing annotations. This dataset was part of the LUNA16 Grand Challenge in 2016. The dataset is still publicly available for research. Like the Kaggle dataset the format of the 3D Image is a 3 dimensional array (512,512, 200) (height,width,no. of images). The main advantage of this dataset is that the dataset is broken down into 10 subsets which makes it much easier to work with.

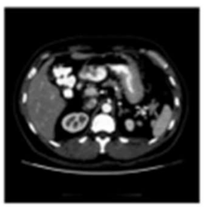


Fig-21: Sample Image Slice

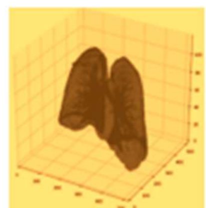


Fig-22: Image Lungs Instance

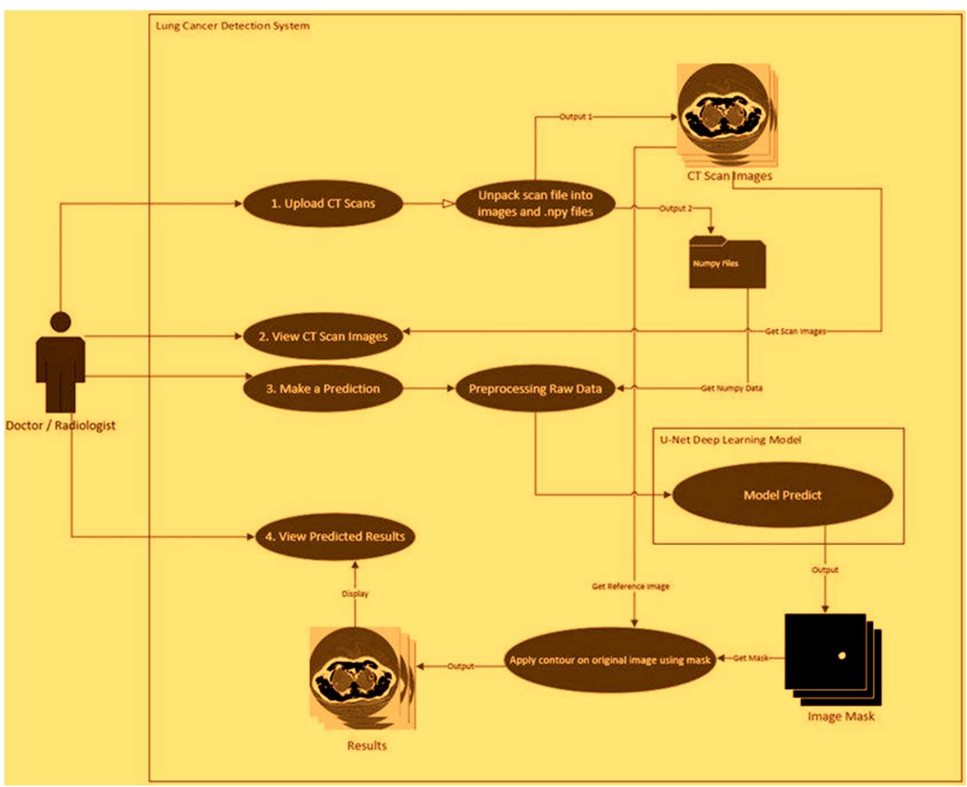


Figure 23: Proposed System Implementation(Lung Cancer Detection System)

4. RESULTS & DISCUSSION

COMPUTATION OF CONFUSION MATRIX

The confusion matrix is a way to determine whether the model is good or not. Here we implemented confusion matrix for predicted labels vs actual labels. The 0's represent no cancer and the 1's represent cancer. Ideally the false positives and the false negatives value should be low. We have calculated for 10 patient ID'S and the confusion Matrix we got was

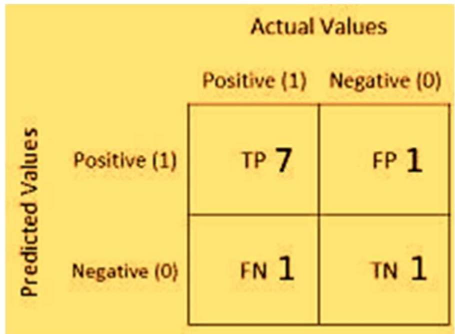


Fig-24: Confusion Matrix

PERFORMANCE ANALYSIS

True Positives (TP) - These are the correctly predicted positive values which means that the value of actual class is yes and the value of predicted class is also yes. E.g. if actual class value indicates that this patient survived and predicted class tells you the same thing.

True Negatives (TN) - These are the correctly predicted negative values which means that the value of actual class is no and value of predicted class is also no. E.g. if actual class says this patient did not survive and predicted class tells you the same thing.
False positives and false negatives, these values occur when your actual class contradicts with the predicted class.

False Positives (FP) – When actual class is no and predicted class is yes. E.g. if actual class says this patient did not survive but predicted class tells you that this patient will survive.
False Negatives (FN) – When actual class is yes but predicted class in no. E.g. if actual class value indicates that this patient survived and predicted class tells you that patient will die.
Once you understand these four parameters then we can calculate Accuracy, Precision, Recall and F1 score.

Accuracy - Accuracy is the most intuitive performance measure and it is simply a ratio of correctly predicted observation to the total observations. One may think that, if we have high accuracy then our model is best. Yes, accuracy is a great measure but only when you have symmetric datasets where values of false positive and false negatives are almost same. Therefore, you have to look at other parameters to evaluate the performance of your model. For our model, we have got 0.803 which means our model is approx. 80% accurate.

Accuracy = TP+TN/TP+FP+FN+TN

Precision - Precision is the ratio of correctly predicted positive observations to the total predicted positive observations. The question that this metric answer is of all patient that labeled as survived, how many actually survived? High precision relates to the low false positive rate. We have got 0.788 precision which is pretty good.

Precision = TP/TP+FP

Recall (Sensitivity) - Recall is the ratio of correctly predicted positive observations to the all observations in actual class - yes. The question recall answers is: Of all the patient that truly survived, how many did we label? We have got recall of 0.631 which is good for this model as it's above 0.5.

Recall = TP/TP+FN

F1 score - F1 Score is the weighted average of Precision and Recall. Therefore, this score takes both false positives and false negatives into account. Intuitively it is not as easy to understand as accuracy, but F1 is usually more useful than accuracy, especially if you have an uneven class distribution. Accuracy works best if false positives and false negatives have similar cost. If the cost of false positives and false negatives are very different, it's better to look at both Precision and Recall. In our case, F1 score is 0.701.

F1 Score = 2*(Recall * Precision) / (Recall + Precision)

3D CNN COMPUTATION

This section consists of the steps involved taking the processed data and using it to determine the accuracy of the model, to predict whether a person could be affected with cancer or not. To understand the composition of what goes into creating a Convolutional neural network and the layers that are used to process the data, a summary of every layer and its functions that we used in the paper is provided, the summary is an amalgamation of inferences that we achieved based on various research papers whose links are also provided (references).

The 3D images given as input are pre-processed and various layers are set with values, there is no hard and fast rule that values are fixed, hence we had to test the layers' multiple times with different values and arrive at a set of values that were optimal.

So, when we train the model, we send in a part of the data (majority) and keep the rest of it for validation purposes to check is the model is well trained. We trained 1595 images in total, out of which 1495 images as input for training the model and 100 images for validation.

Machine Learning Methods	Accuracy	F1 Score	Recall
ANN	82.43%	82.60%	84.44%
KNN (for k=5)	83.33%	79.17%	82.35%
CNN	90.78%	85.57%	82.18%
3D CNN	94.53%	85.71%	87.50

Table 2 : Performance of Machine Learning Methods

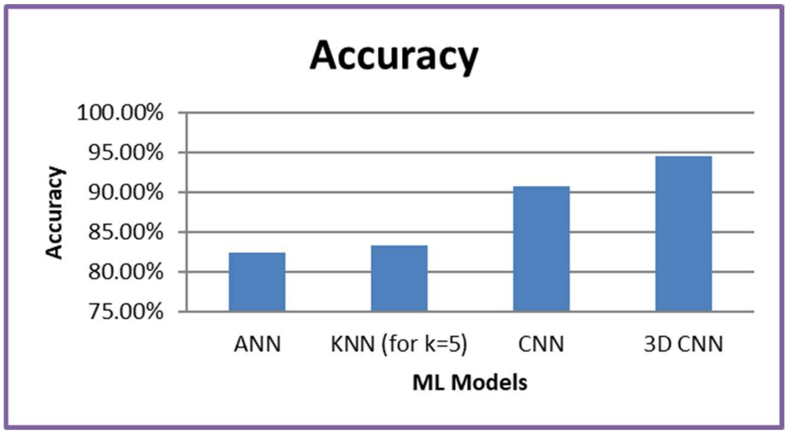


Fig- 25 Accuracy Comparison

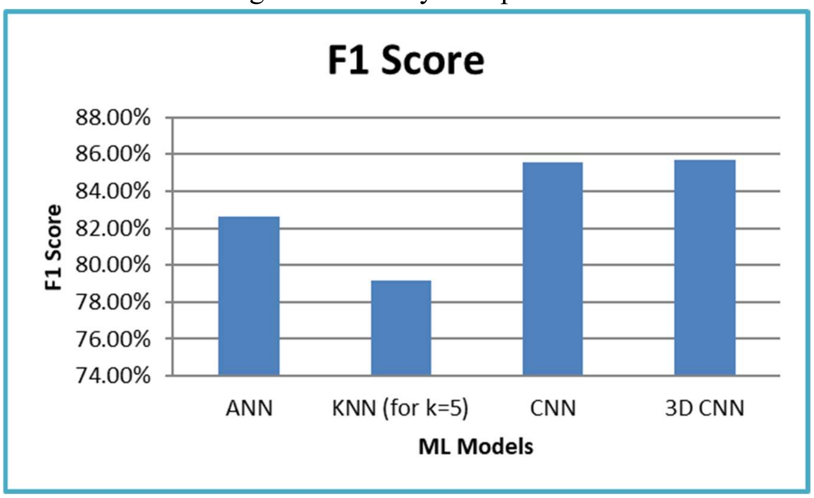


Fig-26 F1 Score Comparison

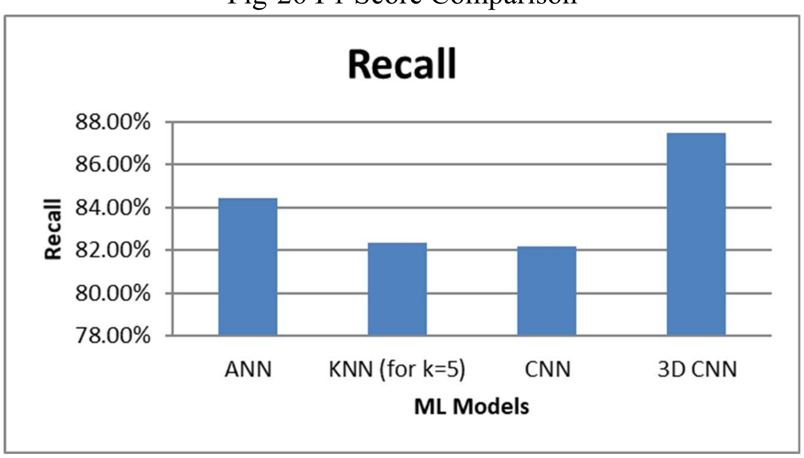


Fig- 27 Recall Comparison

CONCLUSION

Detection and the examination of cancerous cells is one of the finest ways to fall off the cancer-related death. We have presented a new methodology on 3D CNN for detecting lung cancer in humans using CT Scan images. In Machine learning or deep learning CNN gives the best result on imaging type of dataset especially 3D CNN whereas other algorithms also work well but mostly on non-image type datasets. But most of the problems in the existing methodologies faced dataset related problems, getting less accuracy. Because of the nature of the dataset, problems may occur while testing the model. Thus, Medical Imaging Technique and image availability with annotation are very important for the computer aided system to train their models. CNN was especially used for image the image dataset. By using 3D CNNs, the tedious task of manually extracting features can be eliminated and can improve the lung cancer detection in terms of Accuracy, time, and cost.

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