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Autonomous Detection and Classification of Pulmonary Nodules with Mobile Deployment

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Abstract: ***Pulmonary nodules are round oval shape growth found in the lungs. These growths may or may not be cancerous in nature. False detection of these nodules has severe effect on the patient. Detection of these nodules in the early stage can increase the rate of survival. Nowadays CT (Computer Tomography) scan is widely used for imaging to X-Ray images and cost efficient when compared to MRI (Magnetic Resonance Imaging) and PET (Positron Emission Tomography). However, the problem merges due to time constraints in detection of these modules and human error classifying them as malignant or benign. Hence pulmonary nodule detection system uses image processing technique to detect the nodule present in the CT scan image. The image processing procedure includes image acquisition, preprocessing, segmentation, and feature extraction. The machine learning helps in classifying the nodules as malignant or benign. After classification of the nodules all the results from the previous steps and it is uploaded in the server. These data can be accessed by the doctors globally with proper authentication. The aim is to improve the system accuracy by different segmentation and classifiers.***

Index Terms: Digital image-processing, Detection, Machine learning, storage, and retrieval from Server.

I. INTRODUCTION

Pulmonary Nodules are oval shape growth found in the lungs. These growths may or may not be cancerous. False detection of these nodules can have adverse effect on the patients. If left unattended these nodules can turn into cancer. The mortality rate of lung cancer is the highest among all other types of cancer. It is one of the most serious cancer type in the world, with the smallest survival rate diagnosis. Survival from lung cancer is directly related to its growth at its detection time, but the people do have a higher chance of survival if the cancer can be detected in early stages. As for the stages in general there are four stages of lung cancer;

I through IV. Presently, CT (Computer Tomography) are said to be more effective than plain chest X-ray in detecting and diagnosing the lung cancer. An estimated 85% of lung cancer cases in males and 75% in females are caused by cigarette smoking this paper we propose an automated system for detection and classification of these nodules and also upload all the related data into a globally accessible server.

Image processing is the processing of image using mathematical operations by any form of signal processing for which the input is an image. Machine Learning gives the computers the ability to learn without being explicitly programmed. Here we concentrate on utilizing the image processing and machine learning concept to help a detection and classification of nodules. The process of detection and classification alone is however not sufficient in fulfilling the needs of the user. There is no way of system being completely representative if the message cannot be communicated. Therefore, we upload the data into a globally accessible server so the user can access it anywhere and anytime with any smart device.

A. Digital Image

Digital image is a numeric representation of a (normally binary) two-dimensional image. Depending on whether the image resolution is fixed, it may be vector or raster type.

Raster images have a finite set of digital values called picture elements or pixels. The digital image contains a fixed number of rows and columns of pixels. Typically, the pixels are stored in computer memory as raster image or raster map, a two-dimensional array of small integers. These values are often transmitted or stores in a compressed form. The field of digital image processing is the study of algorithms for their transformation.

B. Digital Image Processing

Digital image processing is the use of computer algorithms to perform image processing on digital images. It has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems

such as the buildup of noise and signal distortion during processing. Since images are defined over two-dimension digital image processing may be modeled in the form of multidimensional systems.

C. *Image Format*

Image file formats are standardized means of organizing and storing digital images. An image file format may store data uncompressed, compressed, or in vector formats. Once rasterized an image becomes a grid of pixels, each of which has a number of bits to designate it color equal to the color depth of the device displaying it.

D. *Image Resolution*

Image resolution is the detail an image holds. Higher resolution means more image detail. Resolution quantifies how close lines can be each other and still visibly resolved.

II. LITERATURE SURVEY

From analyzing many papers from IEEE and other journals related to image processing, we understand that there are several image processing models that detects the tumor from the lung image.

This project focusses on developing a system that detects nodules from the lung image. Then the project file classifies the nodules detected as malignant or benign. If the nodule is classified as malignant then it classifies the stage of cancer.

The previous image processing modules focus only on getting the parameter from tumor region. But the automated detection and classification interface the image processing system and machine learning technique to perform both detection and classification together. Though the system is complete with the previous step, the utilization of the system will not be much without the means of communication.

The data from detection and classification are then uploaded to the server and stored in a database. Then the project focuses on the developing an application that can run on the smart device to view the data on the server. The doctors can be provided with the application. And they can use their credentials to view their patient record without waiting. Using a server for storage and retrieval reduces the time and also gives space for many future scopes to be envisioned.

Thereore, creating an exclusive system to detect and classify the nodules autonomously helps in faster diagnosis and prompt care for the patient. Using mobile deployment, the reports can reach the doctors, even more, faster with better accuracy which can help the doctors to treat the patient better.

III. SYSTEM DESIGN FOR DETECTION

The image processing system is used to acquire the CT scan image of the patient. It then prepares the image for segmentation. After segmentation of the tumor, features of the tumor is detected. Then the data is given to the classification system.

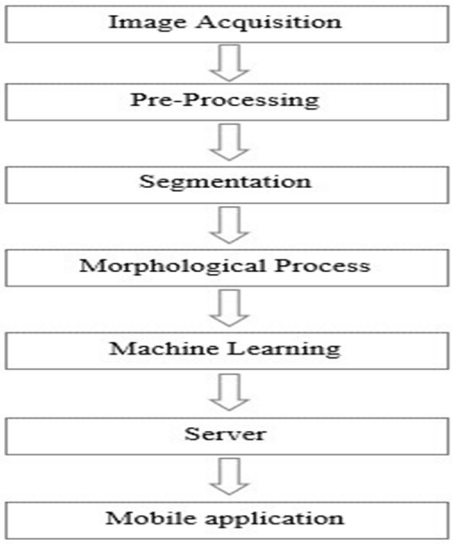

Figure 1-Structure of Detection System.

A. *Image Acquisition*

Digital imaging or digital image acquisition is the creation of photographic images, such as of a physical scene or of the interior structure of an object.

The term is often assumed to imply or include the processing, comparison, storage, printing, and display of such images. In this project we use CT scan images for detection purpose because it has less noise compared to X-ray and cost effective when compared to PET and MRI images.

B. *Ct Scan*

A CT scan makes use of computer processed combination of many X-ray images taken from different angles to produce cross-sectional images of specific areas of scanned object, allowing the user to see inside the object without cutting. Digital image processing is used to generate a three-dimensional image of the inside of the object from a large series of two-dimensional radiographic images taken around a single axis of rotation. Medical imaging is the most common application of X-ray CT. Its cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines.

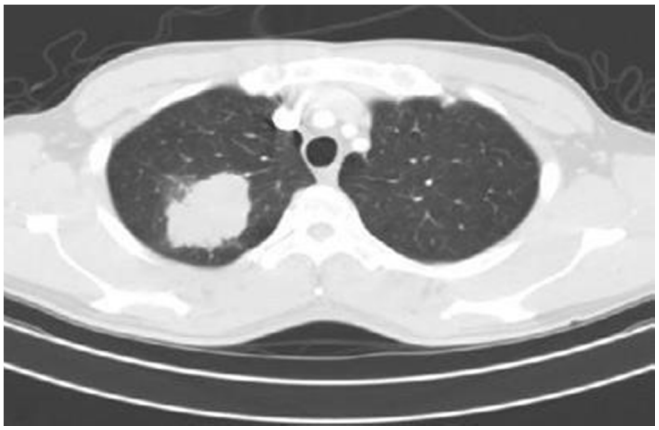

Fig:2 CT scan image of lungs

C. *Pre-Processing*

Pre-processing is common name for operations with images at the lowest level of abstraction, both input and output are intensity images.

The aim of pre-processing is an improvement of the image data that surpasses unwilling distortion or enhances some image features important for further processing.

In this project Median Filtering is performed to remove the noise. It is selected for its better performance with impulse noise edge preserving property.

D. *Median Filtering*

In signal processing, it is often desirable to be able to perform some kind of noise reduction on the image or signal. The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is typical preprocessing step to improve the results of later processing. Median filtering is a very widely used in digital image processing because under certain conditions, it preserves edges while removing noise.

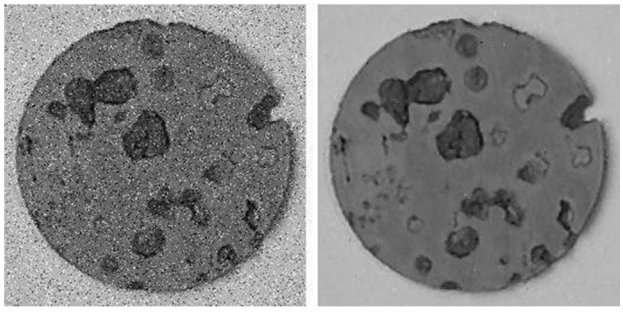

Fig:3 Noisy image before and after Median filtering

E. Edge Preservation Property

Median filtering is one kind of smoothing technique. All smoothing techniques are effective at removing noise in smooth patches or smooth regions of a signal, but adversely affect edges. It is important to preserve the edges. Edges are if critical importance to the visual appearance of images. For small to moderate levels of noise the median the median filter demonstrably better than Gaussian blur at removing noise whilst preserving edges for a given fixed window size. Whereas for speckle noise and salt and pepper noise, it is particularly effective. Because of this median filtering is very widely used in digital image processing.

F. Segmentation

In computer vision, image segmentation is the process of portioning a digital image into multiple segments. The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries in image. More precisely, image segmentation is the process of assigning label to every pixel in an image such that pixels with the same label share certain characteristics.

The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region are similar with respect to some characteristics or computed property, such as color, intensity, texture. adjacent regions are significantly different with respect to the same characteristics. When applied to a stack of images, typical in medical imaging, the resulting contours after image segmentation can be used to create 3D reconstructions with the help of interpolation algorithms. In this project watershed algorithm is used to segment the tumor from the lung image.

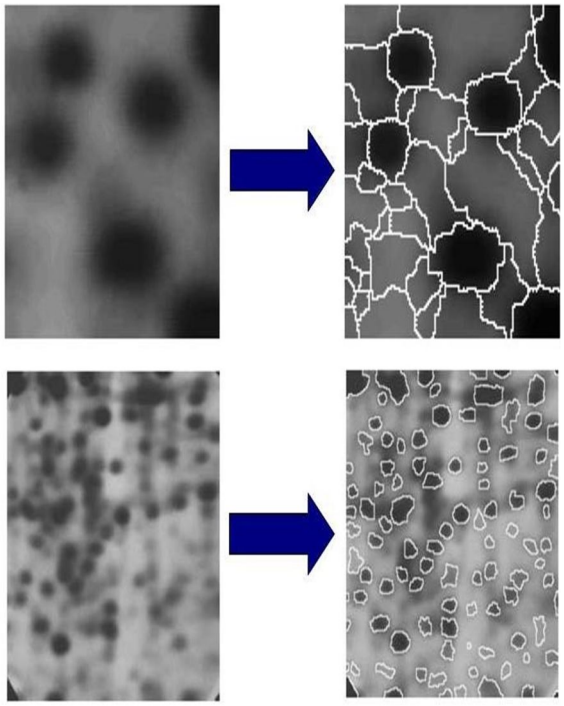

Fig:4 Image before and after Segmentation

G. Watershed Segmentation

In the study of image processing, a watershed is a transformation defined on gray scale image. The nest refers metaphorically to the geological watershed, a drainage divide, which separates adjacent drainage basins. The watershed transformation treats the image it operates upon like a topographic map, with the brightness of each point representing its height, and finds the lines that run along the top of the ridges.

There are different technical definitions of a watershed.in graphs, watershed lines may be defined on the nodes, ln the edges, or hybrid lines on both nodes and edges. Watershed may also be defined in the continuous domain. There are also many different algorithms to compute watersheds. Watershed algorithm is used in image processing primarily for segmentation purposes. the segmentation can be implemented using various algorithm here Meyer's Flooding algorithm is used to perform watershed segmentation.

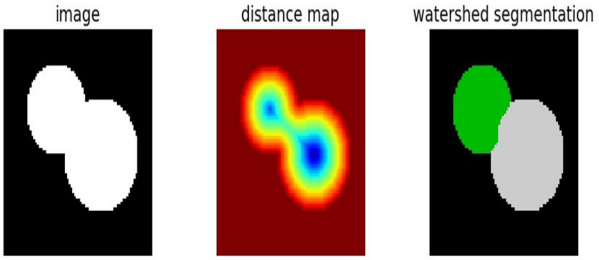

Fig:5 Watershed segmentation

H. Meyer's Flooding Algorithm

The algorithm works on a gray scale image. During the successive flooding of the gray value relief, watersheds with adjacent catchment basins are constructed. This flooding process is performed on the gradient imagemaker the basins should emerge along the edges. Normally this will lead to an over segmentation of the image, especially for noisy image material, e.g. medical CT scan data. Either the must be pre-processed or the regions must be merged on the basis of similarly criterion afterwards.

A set of markers, pixels where the flooding shall start, are chosen. Each is given a different label.

he neighboring pixels of each marked area are inserted into a priority queue with a priority level corresponding to the gradient magnitude pixel. The pixel with the lowest priority level is extracted from the priority queue. If the neighbors of the extracted pixels have already been labeled all have the same label, then the pixel is labeled with their label. All the non-marked neighbors that are not yet in the priority queue are put into the priority queue.

I. Feature Extraction

In machine learning, pattern recognition and in image processing, feature extraction starts from an initial set of measured data and builds derived values intended to be informative and non-redundant, facilitating the subsequent learning and generalization steps, and in some cases leading to better human interpretations. Feature extraction is related to dimensionality reduction.

When the input data to an algorithm is too large to be processed and it is suspected to be redundant, then it can have transformed into a reduced set of features. Determining a subset of the initial features is called feature selection. The selected features are expected to contain the relevant information from the input data, so that the desired task can be performed using this reduced representation instead of the complete initial data.

IV. SYSTEM DESIGN FOR CLASSIFICATION

A. Classification

In the process of classification, the value obtained from the previous process is used to classify the tumor into different stages. This is done by giving the input data to a classifier which is already trained by a dataset called training dataset. The test data is compared with the training data using various classification algorithms to detect the stages of the nodules.

B. Machine Learning

Machine learning is the subfield of computer science that gives computers the ability to learn without being explicitly programmed. Evolved from the study of pattern recognition and computational learning theory in artificial intelligence. Machine learning is employed in a range of computational tasks where the designing and programming explicit algorithms is infeasible; example application include spam filtering, detection of network intruders.

C. Types

1) *Supervised learning:* the computer is presented with example inputs and their desired outputs, given by a “teacher”, and the goal is to learn a general rule that maps inputs to outputs.
2) *Unsupervised learning:* No labels are given to the learning algorithm, leaving it on its own to find structure in its inputs. Unsupervised learning can be a goal in itself or a means towards an end.
3) *Reinforcement learning:* A computer program interacts with a dynamic environment in which it must perform a certain goal. The program is provided feedback in terms of rewards and punishments as it navigates its problem space.

D. K-nearest neighBour

In pattern recognition, the k – nearest neighbor algorithm (k-NN) is a non – parametric method for classification and regression. In both cases, the input consists of the k closest training examples in the features space. The output depends on whether k – NN is used for classification or regression.

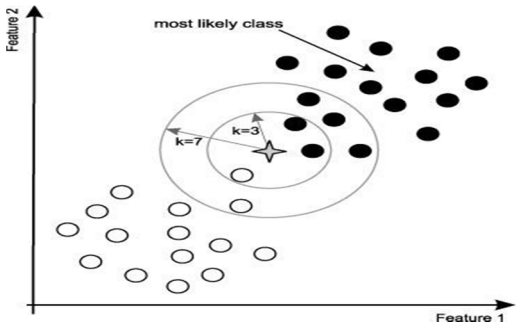

Fig:6 K-nearest neighbor

In k-NN classification, the output is a class membership. And object is classified by a majority vote of its neighbors, with the object being assigned to the class most common among its k nearest neighbors. If k = 1, then the object is simply assigned to the class of that single nearest neighbor. In k=NN regression, the output is the property value for the object. This value is the average of the values of its k nearest neighbors.

The best choice of k depends upon the data; generally, large values of k reduce the effect of noise on the classification, but make boundaries between classes less distinct. A good k can be selected by various techniques. The special case where the class is predicted to be the class of the closest training sample (i.e., when k = 1) is called the nearest neighbor algorithm.

E. Neural network(mlp)

Neural network or connectionist system are a computational approach used in computer science and other research disciplines, which is based on a large collection of neural units, loosely mimicking the way a biological brain solves problems with large clusters of biological neurons connected by axons. Each individual neural unit may have a summation function which combines the values of all its inputs together. There may be a threshold function or limiting function on each connection and on the unit itself, such that the signal must surpass the limit before propagating to other neurons. These systems are self-learning and trained

Dynamic neural networks are the most advanced, in that they dynamically can, based on rules form new connections and even new neural units while disabling others. Neural networks are based on real numbers, with the value of the core and of the axon typically being a representation between 0.0 and 1.

An interesting fact of these systems is that they are unpredictable in their success with self-learning. In order to train them, several thousand cycles of interaction typically occur. Like other machine learning methods –systems that learn from data –neural networks have been used to solve a wide variety of tasks, that are hard to solve using ordinary rule-based programming.

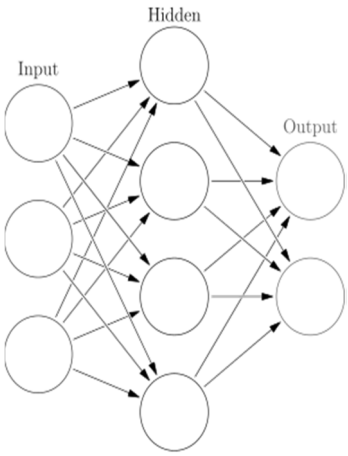

Fig:7 Artificial Neural network

F. Multilayer Perception

An MLP is a network of simple neurons called perceptron. The basic concept of a single perceptron was introduced by Rosenblatt in 1958.The perceptron computes a single output from multiple real-valued inputs by forming a linear combination according to its input weights and then possibly putting the output through some nonlinear activation
function. Mathematically this can be written as

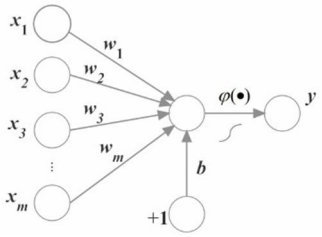

Fig:8 Signal flow graph of perceptron

$$y = \varphi(\sum_{i=1}^{n} w_i x_i + b) = \varphi(\mathbf{w}^T\mathbf{x} + b)$$

Where w denotes the vector of weights, x is the vector of inputs is the bias and φ is the activation function. A signal- flow graph of this operation is shown in figure. A typical multilayer perceptron (MLP) network consists of a set of source nodes forming the input layer, one or more hidden layers of computation nodes, and an output layer of nodes. The input signal propagates through the network layer-by-layer. The signal -flow of such a network with one hidden layer is shown in Figure. The computation performed by such a feed forward network with a single hidden layer with non-linear activation functions and a linear output layer can be written
mathematically as

$$\mathbf{x} = \mathbf{f}(\mathbf{s}) = \mathbf{B}\boldsymbol{\varphi}(\mathbf{A}\mathbf{s} + \mathbf{a}) + \mathbf{b}$$

Where s is a vector of inputs and X a vector of outputs. A is the matrix of weights of the first layer, a is the bias vector of the first layer and b are respectively, the weight matrix and the bias vector of the second layer. The generalization of the model to more hidden layers is obvious.

MLP networks are typically used in supervised learning problems. The supervised learning problem of MLP can be solved with the back-propagation algorithm. The algorithm consists of two steps. In the forward pass, the predicted outputs corresponding to the given inputs are evaluated before. In the backward pass, partial derivatives of the cost function with respect to the different parameters are propagated back through the network.

The MLP network can also be used for unsupervised learning by using the so-called auto-associative structure. This is done by setting the same value for both the inputs and outputs of the network. The extracted sources emerge from the values of the hidden neurons. This approach is computationally rather intensive. The MLP network has to have at least three hidden layers for any reasonable representation and training of such a network.

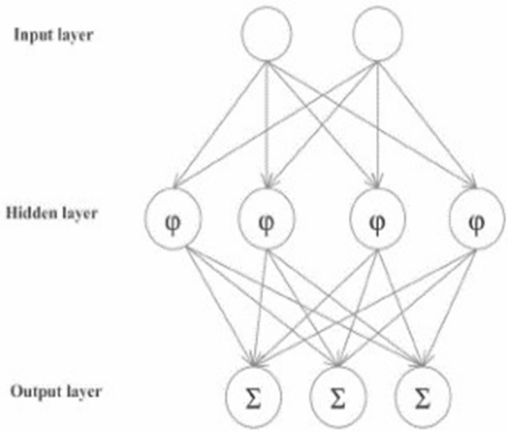

Fig:9 Signal flow graph of MLP

V. SYSTEM DESIGN FOR UPLOADING AND RETRIEVAL

A. Upload To Server

The data from the detection and classification process are combined and these data are uploaded into the Firebase database. The Firebase is NO SQL (Structured Query Language) database. The data such as patient name, age, sex, id, contact number along with the nodule region's area, perimeter, radius, and density is saved in the database. The image of the CT scan is also stored so the doctor can use it for further reference.

B. Retrieve From Server

The data in the server should be available to the doctors globally with proper authentication. In order to access globally an application is developed for both android and iOS so the doctors can install this application in their smart device and view all the details of the patient. Thus, by using the application the doctors can give prompt care to the patients without waiting for the results from the laboratory.

VI. SOFTWARE DESCRIPTION

A. Matlab

The name MATLAB stands for MATrix Laboratory. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a model programming language environment. It has sophisticated data structure, contains built-in editing and debugging tools and supports object-oriented programming. These factors make MATLAB an excellent tool for teachings and research. It has powerful built-in routines that enable a very wide variety of computations. It also has an easy to use graphics commands that make the visualization of results immediately available. There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering.

B. Firebase

Firebase is a mobile and web application platform with tools and infrastructure designed to help developers build high-quality apps. Firebase is made up of complementary features that developers can mix -and-match to fit their needs. Firebase's initial product was a real-time database, which provides an API (Application Programming Interface) that allows developers to store and sync data across multiple
clients. Over time., it has expanded its product line to become a full suite for app development. The company was acquired by Google in October 2014 and a significant number of new feature were featured in May 2016 at Google.

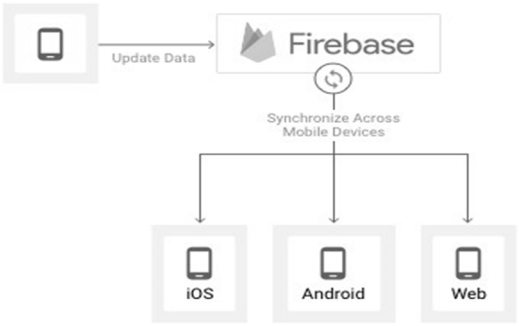

Fig:10 Firebase infrastructure

C. Firebase Auth

Firebase AUTH is a service that can authenticate users Using only client – side code. Additionally, it includes a user management system where by developers can enable user authentication with email and password login stored with Firebase. Most apps need to know the identity of a user. Knowing a user's identity allows an app to securely save user data in the cloud and the provide the same personalized experience across all of the user's devices.

Fire base authentication provides back end services, easy to use SDKs (Software Development Kit), and readymade UI (User Interface) libraries to authenticate users to the app it supports authentication using passwords, popular federated identity providers like Google, Facebook & Twitter.

To sign user in to the app we get the authentication credentials from the user. Our backend services will then verify those credentials and return a response to the client. After a successful sign-in, we can access the user's basic profile information, and can control the user's access to data stored in other Firebase products.

Firebase storage provides secure file uploads and downloads for our firebase apps, regardless of network quality. The developer can use it to store images, audio, video, or other user generated content firebase storage is backed by Google Cloud Storage, a powerful, simple, and cost – effective object storage service.

VII. CONCLUSION

Lung cancer is one of the most dangerous and very deadly type of cancer. Early and correct diagnosis of the nodules can increase the rate of survival. The present techniques include study of x-ray, CT scan, MRI, PET images. The expert physicians diagnose the disease and identify the stage of cancer by experience. The treatment include surgery, chemotherapy, radiation therapy and targeted therapy. These treatments are time consuming, costly, and painful. Hence, an attempt is made to automate this procedure to detect the lung nodule using image processing techniques. The CT scan images are acquired from scan centers and have relatively less noise compared to other techniques images. The CT captured image is processed. The region of interest i.e. nodule is identified accurately from the image. Watershed segmentation gives the best results. Three features are extracted i.e., area, perimeter, and eccentricity. These features along with density of the ROI (Region of Interest) help to identify the stage of lung nodule. The results indicate that the tumours are of different dimensions. By measuring the dimensions of the tumor, the lung cancer stage can be detected accurately. The results show good potential for early stage detection. Also, for classification purpose, Support vector Machines, Neural Network, Decision Tree and K-Nearest Neighbor methods are compared and Neural Networks provide highest accuracy. The accuracy can be increased by detecting several images. For future improvement we can also consider MRI, X-RAY, PET images. So, one can justify which type of images give better result for lung cancer detection. Firebase provides reliable backend service for data storage. The mobile application can be enhanced for improved and prompt treatment to the patients.

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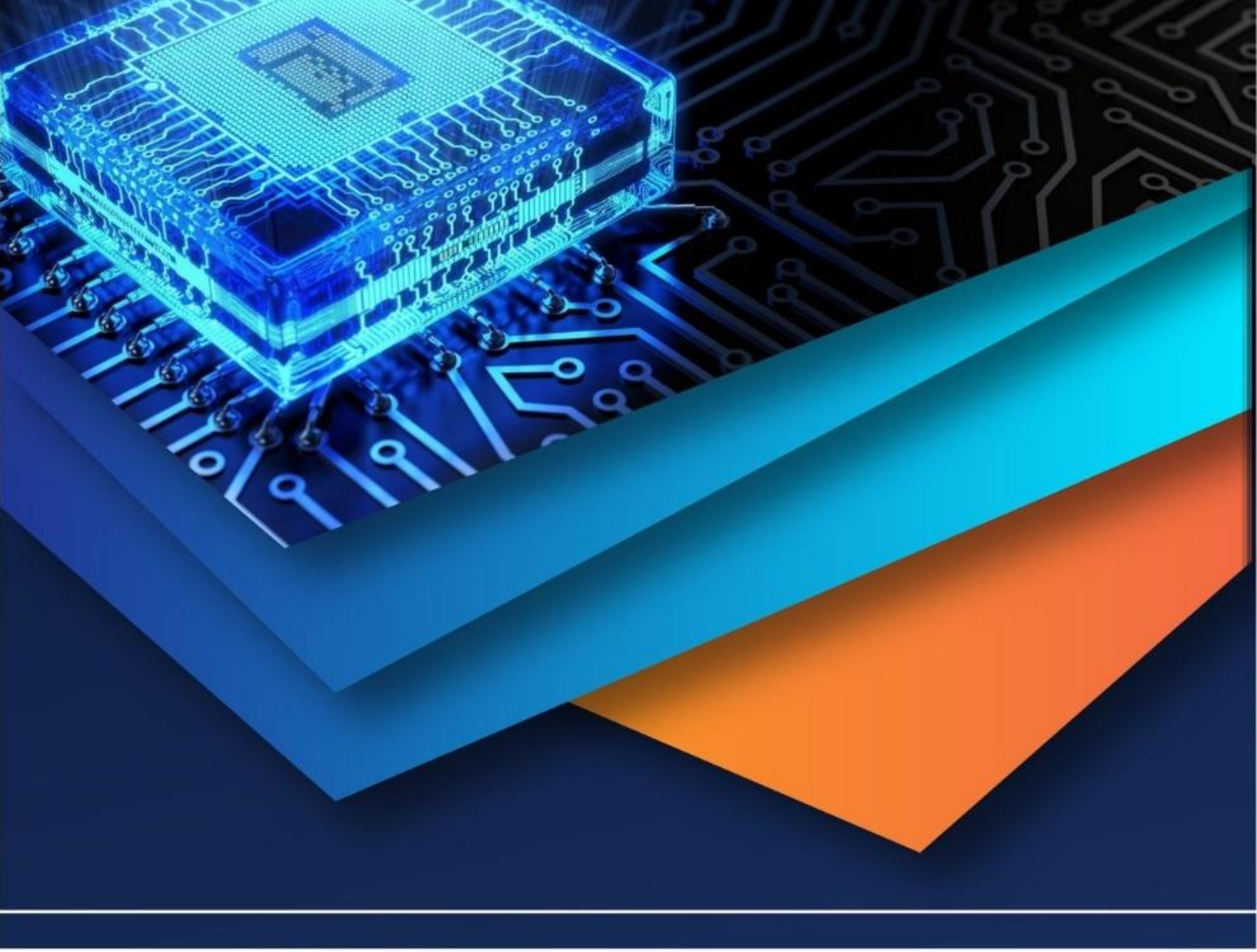

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