Morphed Sobel Approach for Detecting Cancer Cells in Lungs

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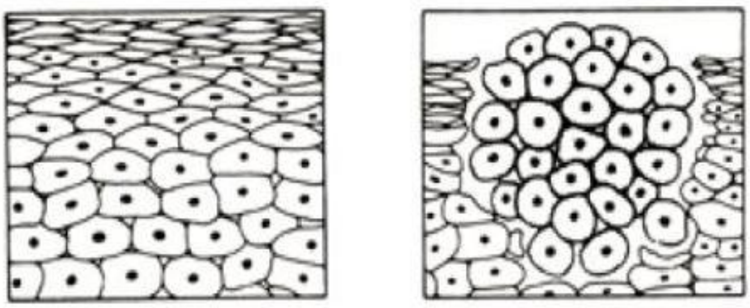
***Abstract*—One of the gravest health problem has been lung cancer in the world in the present scenario. Automatic detection of lung cancer has provided a cutting-edge in the field of medical technology. This is because identifying cancer cells in lungs has been a tedious task as scarce or probably no symptoms are obtained in the premature stage of the disease. This project was undertaken to contribute in the field by using different techniques to identify and optimize the occurrence of cancer cells in lungs. Not only more treatment options are available, but also the increase in survival rates is observed when cancer patients are treated in their premature stages. Change in gradient provides an excellent way to identify objects present in an image. Morphing techniques play a very important role in the process of finding gradient in the images. Any edge detection methods can be applied on any type of medically computed images, like CT scan, X-Ray, MRI or Ultrasound; in which the objects inside the lungs are obtained. Here the use of Computed Tomography scan images have been made because these images are exceptional in identifying nodules as small as 2-3 mm in lungs. This technique was developed using MATLAB 8.1. A new approach named Morphed Sobel Approach has been proposed which makes use of Sobel edge detection algorithm along with a handful of Morphological operators to reduce the noise level as much as possible, and provide better image output that can be compared with the original image and the difference can be viewed with the naked eye. The framework will make use of any color type of CT scan image, i.e., RGB, Gray-scale or Binary, that contains some visualized objects by naked eye. Application of Morphological operators used day-to-day in every digital image processing operations. Moreover the paper provides the implementation of modified edge detection process which consists of Sobel followed after Morphing and comparison of the results obtained by the proposed method with the already existing method.**

***Index Terms*—Morphological Operators, Edge Detection, Sobel Operator, Image Processing, CT scan, Lung cancer, Matlab.**

I. INTRODUCTION

Unrestrained development of abnormal cells leads to Cancer disease. The persistence rate has been found out to be as low as 15% in patients of most of the developed nations after 5 years of medical diagnosis. Cancer constitutes to 25% of deaths in the United States [8]. Lung cancer accounts for almost 29% of all cancer deaths, the others include breast, prostate and colorectal; making it the supreme cause of cancer deaths in the developed nations across the globe [7]. Cancer is a term used for malicious tumour. Tumours can either be benevolent or malicious. These malicious tumours need to be attended, or else the cells will spread from original location to new parts of the physique with the help of bloodstream or lymphatic system, in the process forming metastasis, referred to as secondary tumours. Figure 1 shows normal cells and the cells forming a tumour.



a) Normal Cells b) Cells Forming Tumours

Fig. 1 Normal Cells and Cells Forming Tumours

Unrestrained cell development inside lungs causes lung cancer [1]. Smoking has proven to be the supreme cause of lung cancer, moreover other cases including genetic factors, asbestos, radon gas, and air pollution together with passive smoking attributes to lung cancer as well. Current as well as former smokers constitute 90% of all lung cancer occurrences. Estimations have been made by the American Cancer Society that 164,000 fresh cases of lung cancer are detected every year in the United

States alone and of that about 157,000 individuals die because of the sickness each year. Symptoms occur only after the disease is fairly advanced. As a result of which the cancer is diagnosed amongst the ages of 55 and 65 in most cases. CT scan and chest radiograph can be used to detect lung cancer [2]. Chest radiograph explores the existence of the disease but the type of disease is exposed only by CT scan [3]. CT scans are Computed Tomography scans which is also known as Computer Axial Tomography scans (CAT). CT or CAT scanner is a distinct type of X-RAY machine, in which with the assistance of a computer multiple x-ray images are combined, instead of just one. Usually a cross-section of the body is portrayed in the CT scan images. A typical CT scan image of lungs is shown in fig. 2. Pictures of any part of the body like brain, lungs, kidney and liver can be taken with the help of a CT scanner.

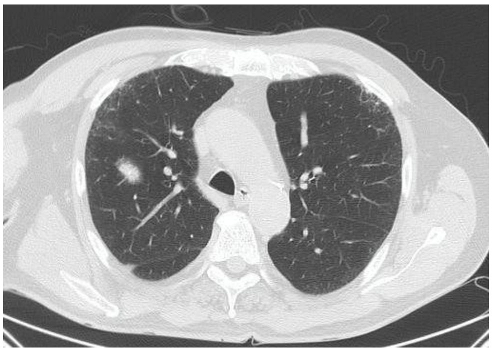
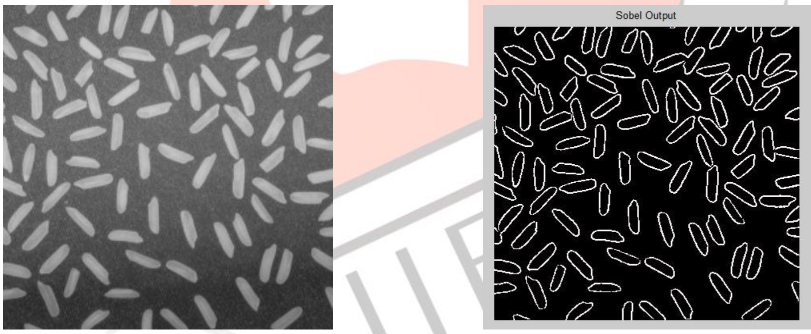


Fig. 2 CT Scan Image

In medical image processing, segmentation plays a vital role for feature extraction, image measurements, and image display. Medical image processing concentrates on two stuffs. First, obtain the image that is more suitable for human observing and understanding. Second, let computers handle the image automatically for computations. Most elementary assignment in image processing and pattern recognition is edge detection. Basic characteristic of an image is the edge. The edge is an assembly of pixels whose neighbouring pixels have a grayscale step like changes. Edge appears between the background and the objects. A symbol and a mirror image of discreteness of partial image is what an edge is essentially [11]. It implies the conclusion of one area and the commencement of the other area. Therefore, edge detection is the fundamental research work in image processing. Beforehand a number of edge detection algorithms have been developed. Sobel operator is one of the classic algorithms [10]. Other edge detection techniques like Prewitt [4], Roberts [6] and Canny [9] have been offered for identifying changeovers in images. Figure 3 shows a typical edge detected image, the algorithm used is Sobel. MATLAB [12] tool is used to obtain these images.



a) Original Image b) Sobel Edge Detected Image

Fig. 3 Original Image and Sobel Edge Detected Image

The significant importance of classical edge detection algorithm is the choice of threshold; threshold directly regulates the success of edge detection. One of the complications of edge detection has been about inevitably getting the best threshold. If the nominated threshold is too low, it will not only produce false edges, but edges are very thick; these edges will need to be polished again and the locations of the recovered edges are often not precise enough. If the threshold is too high, then many of the edges may not be detected or the detected edges are too segmented.

II.RELATED WORK

Management of image representation that is deposited on a mainframe computer is known as image processing. Increasing or decreasing image intensity, zooming, red-eye reduction, conversion to gray-scale, edge detection and its analysis are the processes which are undertaken on images comprise of image processing. All the pixels in the image undergo the above mentioned processes or tasks. Image is handled in two phases, in medical image processing, which are a) Edge detection and b) Object analysis with the usage of various Morphological operators.

Fundamentals of Edge Detection

It is an important task to identify a border, an edge or a boundary in the image while dealing with image processing. The edges differentiates each and every object from one another and also from the background of the image. For this reason various edge detection techniques have been developed. Edge detection operator provides an alteration in the nature of the image edge to examine the edge. Discontinuities in gray are observed when the edge of an object is obtained. Two main types of edge detection;

one is the first order derivatives, like Roberts, Prewitt and Sobel operators, which uses gradient values to acquire the edges. The other is the second order derivatives, like LOG and Canny operator, which uses zero crossing.

The changes in location, detection and measurement in image gray constitutes edge detection. Edges are most important features in image because identifying the edges provides a better object structure. The basic idea behind detecting edges is to first and foremost apply thresholds to enhance the edges of the image and after that apply suitable techniques to obtain edges.

Edge Detection Algorithms

Edge detection refers to the practice of recognizing and uncovering sharp discontinuities in an image [10]. Grayscale images of CT scan or MRI (Magnetic Resonance Imaging) scan are used in edge detection process. As discussed above there are two ways to perform edge detection. First, the gradient method perceives the edges by considering the maxima and minima in the first spatial derivative of the image. Second, the zero crossing technique provides more accurate edge points as compared with the gradient method.

1. Roberts Cross Operator

The Roberts Cross operator [6] executes a simple, fast paced, 2-D spatial gradient dimension on an image. To find the edge it makes use of a partial differential operator. A pair of 2x2 convolution kernels are used as shown in the fig. 4 below.

$$G_x = \begin{bmatrix} +1 & 0 \\ 0 & -1 \end{bmatrix}; \quad G_y = \begin{bmatrix} 0 & +1 \\ -1 & 0 \end{bmatrix}$$

Fig. 4 Roberts Cross Operator

One kernel is obtained from other by rotating it 90°. The absolute magnitude is achieved by linking the two kernels as shown in Eq. 1. The gradient magnitude is given by G. The angle of orientation of the edge giving rise to the spatial gradient relative to the pixel grid orientation is given by, Eq. 2.

$$|G| = \sqrt{Gx^2 + Gy^2} \tag{1}$$

$$\theta = \tan^{-1}\frac{Gx}{Gy} - 3\pi/4 \tag{2}$$

The outcomes of this procedure will highlight fluctuations in intensity in a diagonal direction. The most tempting characteristic of this operation is its simplicity; the kernel is trivial and comprises of integers only. Suffers greatly from sensitivity to noise.

2. Sobel Operator

Sobel operator is a pair of 3x3 convolution kernels as shown in fig. 5 [5]. The second kernel is obtained by rotating the first by 90°; the two kernels are orthogonal to each other. This operator works as a filtering operator. One checks for maximum response of vertical edge and the other checks for maximum response of horizontal edge. Provides precise edge direction information but also detects many false edges.

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}; \quad G_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Fig 5 Sobel Operator

The magnitude of the gradient will remain the same as of Roberts in eq. 1 but the angle of orientation will change, which is shown in eq. 3.

$$\theta = \tan^{-1}\frac{Gx}{Gy} \tag{3}$$

3. Prewitt Operator

Prewitt operator is similar to the Sobel operator and is used for detecting vertical and horizontal edges in images. At each point in the image, the result of the Prewitt operator is the corresponding gradient vector. It is one type of edge model operator. Figure 6 shows the two convolution kernels of Prewitt.

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix}; \quad G_y = \begin{bmatrix} +1 & +1 & +1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

Fig 6 Prewitt Operator

Morphological Operators

Mathematical Morphology is a notion and modus operandi used for the analysis and processing of geometric structures, which includes images, based on various functions like erode, dilate, open, closed, reconstruct, etc. It is a tool for mining image components that are useful in the demonstration and portrayal of region shapes.

III.PROPOSED METHODOLOGY

The system presented in this paper uses a simple algorithm like Sobel operator along with a handful of Morphological operators in order to provide the best possible results in detecting lung cancer edges inside CT scan images. First the RGB images or gray CT scan images are obtained. The obtained image is converted to grayscale if it is an RGB image by using the toolbox function *im2bw*. After converting the image into grayscale the Gaussian filter is applied to filter out the noise from the image. The filter used is a 2-D Gaussian filter shown in eq. 4. Further smoothening of the image is done by using soft threshold of 0.5. Next the image is binarized to make the image clearer. After that the image is again converted back to grayscale equivalent.

$$G(x, y; \sigma) = \frac{1}{2\pi r^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (4)$$

Furthermore, a morphological structuring element of the type specified by shape, that is, 'disk' is created by using *strel* function of the toolbox as shown in eq. 5. It helps in removing the noise from the image, if present. Structuring element created is used with several morphing techniques like opening, erosion and dilation. Erosion is used so that the small particles can be neglected and the focus can be made only on bigger objects obtained inside the images. Lastly before going for edge detection the image adjustments are done.

se = strel(shape,parameters) (5)

After the image adjustment is done, the edge detection is done by using Sobel operator because it is the best when compared with Prewitt and Roberts, and simple as compared to Canny. It is important to detect border or edge of the objects in image when dealing with image processing. Sobel finds the edges in the image by finding the image gradient. Image gradient is the change in the intensity of the image. The intensity of the image will be of maximum value where there is separation of two regions. At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. Sobel operator is the partial derivative of f(x, y) as the central computing 3x3 neighbourhood at x, y direction. In order to suppress noise, a certain weight is correspondingly increased on the centre point, and its digital gradient approximation equations may be described as follows:

$$G_x = \{f(x+1, y-1) + 2f(x+1, y) + f(x+1, y+1)\} - \{f(x-1, y-1) + 2f(x-1, y) + f(x-1, y-1)\} \quad (6)$$

$$G_y = \{f(x-1, y+1) + 2f(x, y+1) + f(x+1, y+1)\} - \{f(x-1, y-1) + 2f(x, y-1) + f(x+1, y-1)\} \quad (7)$$

Sobel operator uses two 3X3 kernels and filters the image to estimate the value of each pixel by convolving with the original image. The value of one kernel is simply taken obtained and the other is obtained by rotating it by 90°. The kernels are called Gx and Gy respectively as shown in equations 6 and 7. The filters help to estimate the value of gradient along both the axis, the X-axis horizontally and the Y-axis vertically. If our image is defined as a matrix I then for,

Horizontal Edges:

$$Gx = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * I \quad (8)$$

Vertical Edges:

$$Gy = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * I \quad (9)$$

These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by the equation 1, and the angle of orientation of the edge relative to the pixel grid giving rise to the spatial gradient is given by the equation 3.

With the given proposition the edges can be detected in the images. Subsequently, the obtained edges of cancer cells are marked and the image is thereafter overlaid on the original image to show the cancer cells.

Functional Steps

The above mentioned methodology can be visualized and concluded by the following steps:

Step 1: Convert CT scan image to gray-scale.
Step 2: Apply Gaussian filter to the image.
Step 3: Use a soft threshold on the image.
Step 4: Structuring element is followed after the image is binarized and again converted back to gray-scale.
Step 5: Opening and erosion of images are followed by image dilation.
Step 6: Image adjustments are done.
Step 7: Sobel operator is used to obtain the edges.
Step 8: Cancer cells are marked and the image is overlaid on the original image.

Flow Chart of the Proposed System

The following shows the flow chart of the above mentioned steps of the proposed system. The Morphology analysis step shown in the flow chart involves the opening, erosion, dilation and image adjustments steps.

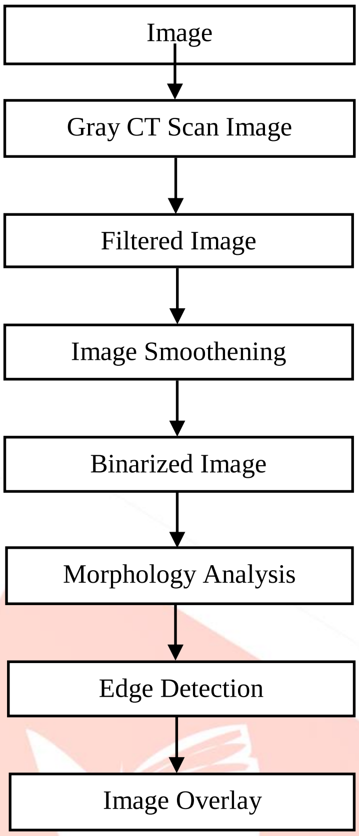
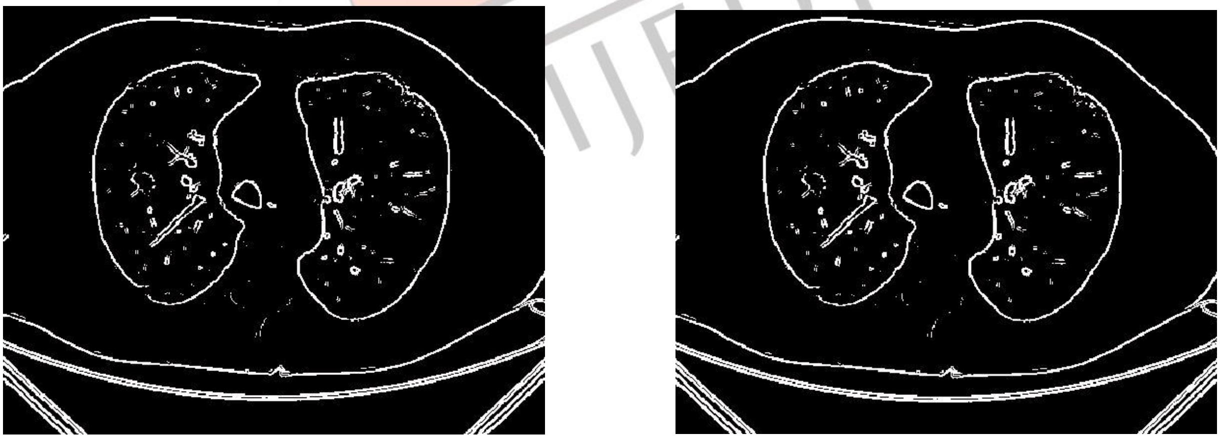


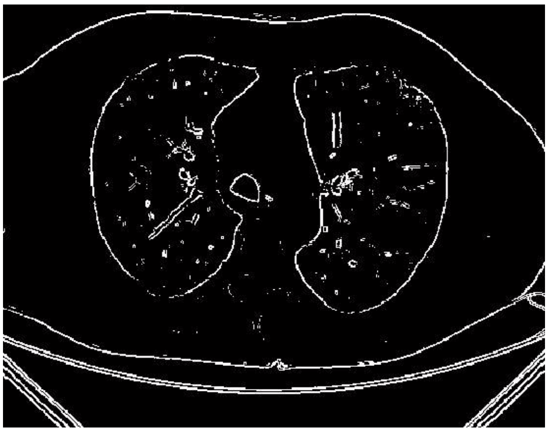
Fig. 7 Flow Chart of the Proposed System

IV.RESULTS AND DISCUSSION

The results of the existing techniques as well as of the proposed methodology have been obtained using the MATLAB tool. Figure 8 shows the differences between the already existing techniques of edge detection. The image taken into consideration is the one shown in fig. 2.



(a) Sobel Edge Detected Image (b) Prewitt Edge Detected Image


(c) Roberts Edge Detected Image

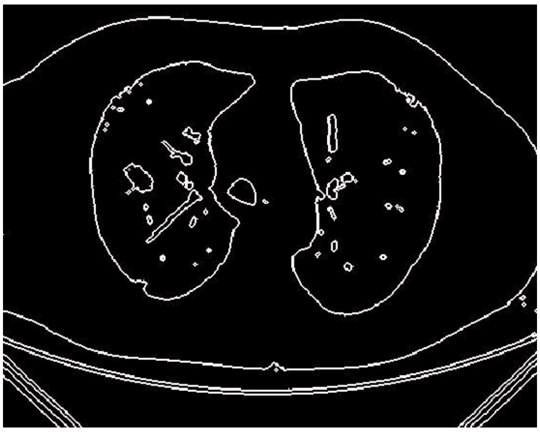
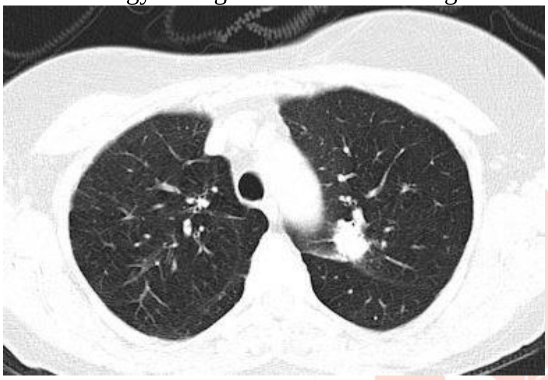
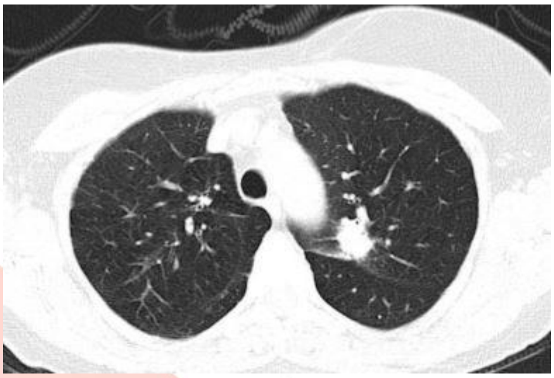
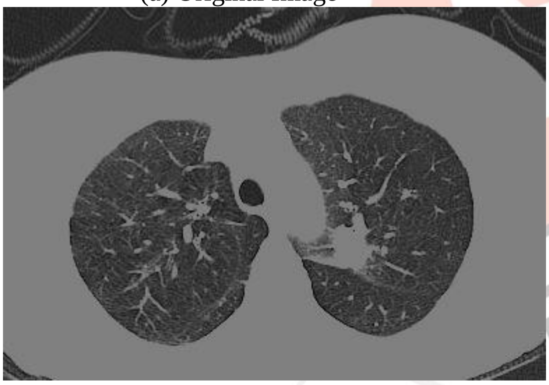

(d) Morphed Sobel Edge Detected Image

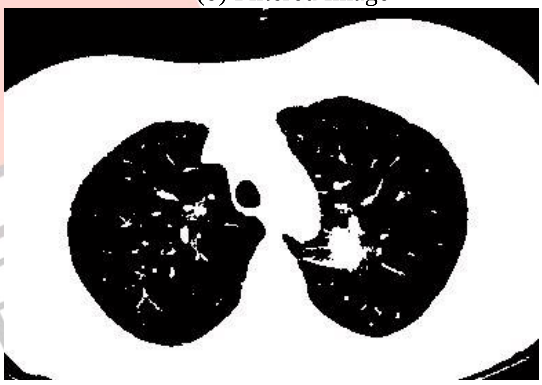
Fig. 8 Comparison of Existing Techniques with Proposed System

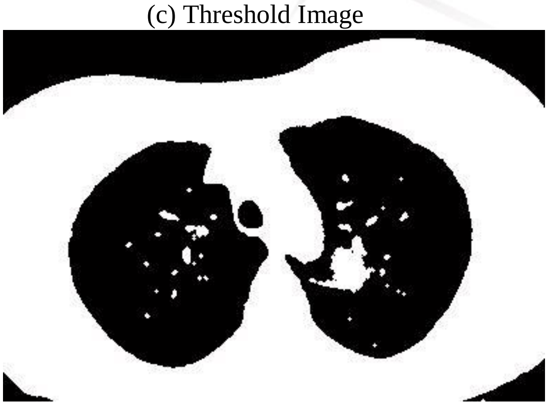
Now, the figures that are displayed in the fig. 9 are the outputs of every single stage that have been developed in the proposed methodology. Altogether a different image is used to show these results.

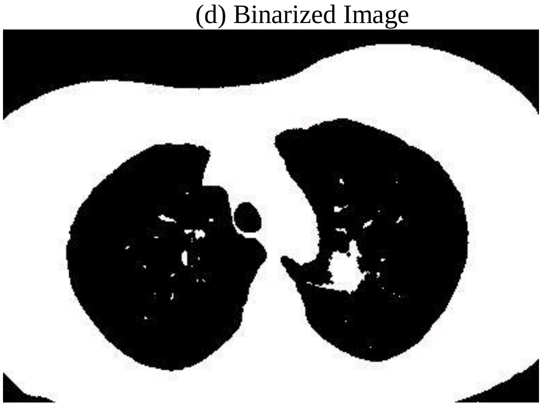

(a) Original Image

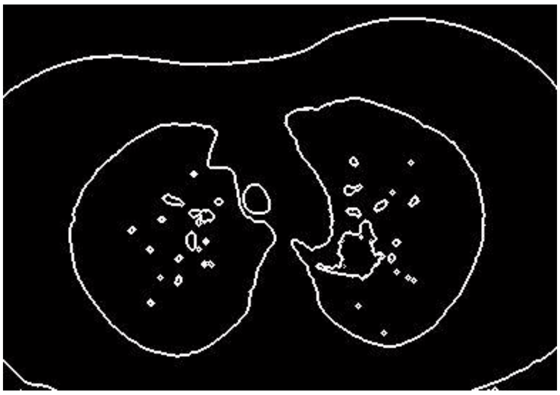

(b) Filtered Image


(c) Threshold Image


(d) Binarized Image


(e) Opening Image


(f) Eroded Image


(g) Edge Detected Image


(h) Cancer Cells Isolated Image

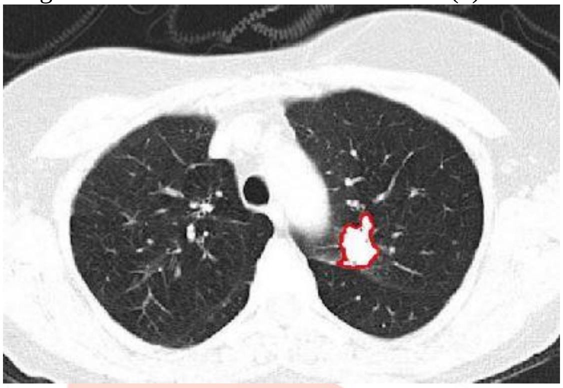

(i) Marked Cancer Cells Superimposed on Original Image

Fig. 9 Edge Detection and Marking of Cancer Cells by Morphed Sobel Approach

The fig. 9(i) shows the marked cancer cells are superimposed on the original image of fig. 9(a). With this we can conclude that the approach discussed hereby is able to obtain, detect and mark the cancerous nodules found inside the lungs. These images also show that the morphed sobel approach proposed is good enough to detect complete edges as compared to classical edge detection techniques of Sobel, Prewitt and Roberts, which can be visualized clearly in figure 8.

It is clearly shown that if the noise level is reduced considerably before enhancing the image, the results obtained are very convincing. The morphed sobel approach is useful in eliminating the noise level because it first uses Gaussian filter, then applies soft threshold for smoothening the image and at last makes use of binarization. It is not possible to detect edge completely by using a single fixed scale edge detection operator. Classical edge detection techniques are extremely sensitive to noise because neither the filtering is done nor the smoothening of the image is done. As a result of which a good edge detection technique should have a better noise immunity.

V. CONCLUSION AND FUTURE WORK

The new approach of edge detection named Morphed Sobel Approach was proposed in this paper. The proposed technique took into account the usage of Morphological operators, Gaussian filters, de-noising as well as simple Sobel operator. The combination of which was able to produce better outputs and results as compared to the existing techniques of edge detection which suffer badly from noise. The edges that were detected by the proposed system were in good shape unlike those poorly detected edges in classical techniques of edge detection. This idea can be visualized form the images presented in the figure 8. Hence, the physicians can obtain better results by implementing this scheme instead of having to look at the images with naked eye. Furthermore, to add more balance to the proposed idea, the technique was used to obtain the edge and later was also used to mark the detected edges, this proposition can be envisioned in the images presented in figure 9. Moreover, in near future this technique can be further optimized and even better results can be obtained by implementing this scheme using artificial neural networks. Neural networks can also learn by themselves as time progresses and even better results can be provided by the machines itself.

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