Enhancement and Segmentation of Lung CT Images for Efficient Identification of Cancerous Cells

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Abstract

In recent years the image processing mechanisms are used widely in several medical areas for improving earlier detection and treatment stages, in which the time factor is very important to discover the disease in the patient as fast as possible, especially in various cancer tumors such as the lung cancer, breast cancer. Locating lung cancer at an early stage is a challenging task since there are few or no symptoms in this stage of the disease and majority of the cases are diagnosed in the later stages of the disease. In the present paper we provide a more efficient and more accurate analysis of the CT scan image. The principal objective of the paper is to identify the cancerous portion in the lung CT scan image. This system produces a resultant image suitable for identification of the cancer infected area. It implements several techniques including histogram equalization, Sobel (edge detection) and Otsu (image thresholding) and many other vital functions (medfilt2, graythresh, bwconncomp and cellfun) of MATLAB for optimum performance in retrieving meaningful information from original scans. Finally, the detected edge of the segmented region is overlaid on to the original image.

Keywords: *Segmentation, Sobel, histogram, Otsu algorithm,*

INTRODUCTION

Graph Theoretical Approaches to Image Segmentation.

Image segmentation is a fundamental problem in computer vision. Despite many years of research, general purpose image segmentation is still a very challenging task because segmentation is inherently ill-posed.

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Among different segmentation schemes, graph theoretical ones have several good features in practical applications. It explicitly organizes the image elements into mathematically sound structures, and makes the formulation of the problem more flexible and the computation more efficient in systematic survey of graph theoretical methods for image segmentation, where the problem is modeled in terms of partitioning a graph Into several sub-graphs such that each of them represents a meaningful object of Interest in the image. These methods are categorized into five classes under a uniform notation: the minimal spanning tree Based methods, graph cut based methods with cost functions, graph cut based methods on Markov random field models, and the shortest path based methods and the other methods that do not belong to any of these classes. Image segmentation is a classical and fundamental problem in computer vision. It refers to partitioning an image into several disjoint subsets such that each subset corresponds to a meaningful part of the image. As an integral step of many

computer vision problems, the quality of segmentation output largely influences the performance of the whole vision system. A rich amount of literature on image segmentation has been published over the past decades. Some of them have achieved an extraordinary success and become popular in a wide range of applications, such as medical image processing [1-3], object tracking [4-5], recognition [6-7], image reconstruction [8-9] and so on. Since the very beginning,
Image segmentation has been closely related to perceptual grouping or data clustering. Such a relationship was clearly pointed out by Wertheimer's gestalt theory [10] in 1938. Early edge detection methods such as the Robert edge detector, the Sobel edge detector [11] and the canny edge detector [12-13] are based on the abrupt changes in image intensity or color. Due to the distinguishable features of the objects and the background, a large number of thresholding based methods [14-16] have been proposed to separate the objects from the background. In recent years the image processing mechanisms are used widely in several medical areas for improving earlier detection and treatment stages, in which the time factor is very important to discover the disease in the patient as fast as possible, especially in various cancer tumors such as the lung cancer, breast cancer [20 26]. Locating lung cancer at an early stage is a challenging task since there are few or no symptoms in this stage of the disease and majority of the cases are diagnosed in the later stages of the disease.

LUNG ANATOMY

The lungs are a pair of sponge-like, cone-shaped organs. The right lung has three lobes, and is larger than the left lung, which has two lobes. Oxygen is brought into the lungs when air is inhaled. Lung tissue transports oxygen to the bloodstream to go to the rest of the body. Cells release carbon dioxide as they use oxygen. The bloodstream carries carbon dioxide back to the lungs and the carbon dioxide leaves the body when air is exhaled.

LUNG CANCER

Lung cancer is a disease of abnormal cells multiplying and growing into a tumor. Cancer cells can be carried away from the lungs in blood, or lymph fluid that surrounds lung tissue. Metastasis occurs when a cancer cell leaves the site where it began and moves into a lymph node or to another part of the body through the bloodstream.

Lung Cancer Types

Cancer that starts in the lung is called primary lung cancer. There are several different types and these are divided into two main groups
- Small cell lung cancer
- Non small cell lung cancer

a) Small cell lung cancer
About 20 out of every 100 lung cancers diagnosed are this type. Small cell lung cancer is called this because the cancer cells are small cells that are mostly filled with the nucleus. This type of cancer is usually always caused by smoking. It is very rare for someone who has never smoked to develop it. Small cell lung cancer often spreads quite early on and so doctors often suggest chemotherapy treatment rather than surgery.
b)Non small cell lung cancer
There are three types of non small cell lung cancer. These are grouped together because they behave in a similar way and respond to treatment in a different way to small cell lung cancer.

PROBLEM STATEMENT

In the currently existing system, the procedure starts with the study of the CT scan image of the lung. The major problems with the current procedure are:
(i) The diagnosis process starts with the analysis of the CT scan image by the naked eyes. So, the result of this analysis depends primarily on the experience and intuition of the physician.

(ii)Since the process relies on the human interpretation of the raw image, the probability of occurrence of error is quite high which is not desirable.

(iii) The initial stages of the diagnosis process are not only error prone but are also quite costly.

(iv) Quite often, the result of the CT scan image analysis turns out to be inaccurate.

(v) The analysis process is generally time-consuming. As a result of inaccurate analysis of the original CT scan image, the patient May undergo a biopsy test even when there's no cancer, or worse, the patient may miss out on biopsy even when there's cancerous portion in the lung.

PROPOSED SOLUTION

The proposed system works on providing a more efficient and more accurate analysis of the CT scan image. The main objective is to identify and highlight the cancerous portion in the lung. This is achieved by:

(i) The original CT scan image is processed using various image processing tools, both inbuilt and custom.
(ii) Processing mainly includes enhancement of the original image, noise removal, segmentation and edge detection among others.
(iii) Since the processing stage in the proposed system is carried out with the help of powerful tools developed using efficient algorithms, the probability of occurrence of error is reduced drastically.
(iv) The degree of human interference is kept at minimum; hence, chances of human errors creeping in are very low. As a result, the accuracy of the analysis is appreciably high.
(v) As the system runs on a powerful machine, the execution time is effectively low, thereby saving precious time.

SYSTEM DESIGN

Since the proposed system is basically based on the Image Processing techniques, we have used the Image Processing features provided by the MATLAB development environment.

HISTOGRAM EQUALIZATION

The histogram of a monochrome image is a graphical representation of the frequency of the occurrence of each gray level in the image. The data structure that stores the frequency values is a 1D array of numerical values h, whose individual elements store the number or percentage of image pixels that correspond to each possible gray level. To compute the histogram of an 8-bit (256 gray levels) monochrome image, an array of 256 elements (each of which acts as a counter) is created and initialized with zeros. The Image is then read, one pixel at a time, and for each pixel the array position corresponding to its gray level is incremented. After the whole image is processed, each array element will contain the number of pixels whose gray level corresponds to the elements inside

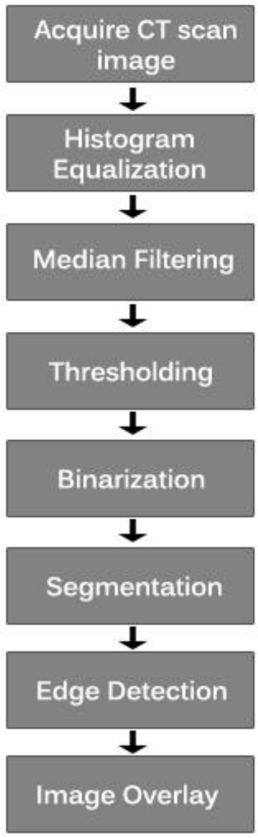

Fig.1: Flow diagram of the proposed system

These values can then be normalized, dividing each of them by the total number of pixels in the image. For images with more than 8 bits per pixel, it is not practical to map each possible gray level k ($0 \leq k \leq K$) to an array element: the resulting array would be too large and unwieldy. Instead, we use a technique known as binning, by which an array of B elements—where B is the number of histogram bins (or buckets), $B \leq K$—is created and initialized with zeros. Histogram equalization is a technique by which the gray-level .Distribution of an image is changed in such a way as to obtain a uniform (flat) resulting histogram, in which the percentage of pixels of every gray level is the same. MATLAB's IPT has a built-in function to perform histogram equalization of a monochrome image: histeq. For the sake of histogram equalization, the syntax for histeq is usually J = histeq(I,n), where n (whose default value is 64) is the number of desired gray levels in the output image. In addition to histogram equalization, this function can also be used to perform histogram matching. This will result in an enhanced version of the original image wherein the different contrasting features of the image will be more clearly visible to the naked eye.

MEDIAN FILTERING

Filtering is the Image Processing term used to refer the mechanism used for removing the noise components from the original image. Here, we have used filtering technique on the enhanced image because there is a probability that the enhancement technique might also have enhanced the noise components present in the original image along with the non-noise components. We have used the Median Filter technique. It is a popular non-linear filter used in Image Processing. It works by sorting the pixel values within a neighborhood, finding the median value and replacing the original pixel value with the median value of that neighborhood. The median filter works very well (and significantly better than an averaging filter with comparable neighborhood size) in reducing "salt and pepper" noise (a type of noise that causes very bright—salt—and very dark—pepper—isolated spots to appear in an image) from images.

THRESHOLDING

Thresholding an image is a common pre-processing step in machine visual systems in which there are relatively few objects of interest whose shape is more important than the surface properties and whose average brightness is relatively higher or lower than the other elements in the image. We have applied thresholding to help in identifying and eliminating the non-cancerous parts from the whole image. This step is the beginning of the segmentation procedure. There are several thresholding techniques, out of which we have used the Optimal Thresholding strategy. These strategies usually rely on assumed statistical models and consist of modeling the thresholding problem as a statistical inference problem. Unfortunately such statistical models usually cannot take into account important factors such as borders and continuity, shadows, non uniform reflectance, and other perceptual aspects that would impact a human user making the same decision. The most popular approach under this category is the use of the gray threshes function provided in the Image Processing Toolkit of MATLAB. This function implements the Otsu's algorithm.

BINARIZATION (BIPARTITE GRAPH)

This is the process where the image is converted from grayscale to binary (bipartite). This means that the resultant image will contain only black and white components. This step follows thresholding because the conversion of the image into binary is dependent on the threshold value of the image obtained by the thresholding technique. The threshold value is used to decide the grayscale values of pixels that are to be converted
Into black and pixels that are to be converted into white. We have used the im2bw function provided in the Image Processing Toolkit to convert the enhanced noise-free image into a binary image using the threshold value obtained earlier. This function converts the grayscale image I to a binary image. The output image BW replaces all pixels in the input image with luminance greater than level with the value 1 (white) and replaces all other pixels with the value 0 (black). Specify level in the range [0,1]. This range is relative to the signal levels possible for the image's class. Therefore, a level value of 0.5 is midway between black and white, regardless of class. To compute the level argument, we can use the function gray thresh. If we do not specify level, im2bw uses the value 0.5.

SEGMENTATION

Segmentation is defined as the process of partitioning an image into a set of non-overlapping regions whose union is the entire image. Once an image has been segmented, the resulting individual regions (or objects) can be described, represented, analyzed, and classified. Some authors explored the segmentation techniques in medical imaging depending on the region of interest [17]. The most relevant ones for our problem are atlas-guided techniques and region growing segmentation methods [18,19]. Some of them use a semi-automatic algorithm and still need some user interaction, while others are fully automatic and the user has only a verification role.

ALGORITHM FOR SEGMENTATION

After the CT scanned image is developed by histogram equalization method, we use the median filtering function *medfilt2 (img-heq)* which does the two dimensional median filtering. Using *Otsu's* method we calculate the optimum global threshold and convert the image into binary image using the threshold calculated by the *graythresh* method. Diamond structuring is used to erode the unwanted parts from the lung. MATLAB function *bwconncomp(),* returns the structure containing information about all connected components, 8 connectivity is used on which *cellfun()* function calculate the number of pixels in each connected component and store them in an array. After finding the element with largest number of pixels and its index in array set the pixels to 0 of that largest component. Again *bwconncomp()* function is used to get the new structure to hold the information and this time we will remove all the objects with number of pixels less than the largest component (which is suspected part), and our malignant part will remain alone and get segmented. Using square structuring element we will get the thick edges around the segmented part which helps in highlighting the cancerous part Segmentation of the binary image will ultimately result in the separation of the suspected cancerous portion from the rest of the lung components. In graph theoretical point of view segmentation can be defined as.

Let $\mathrm{G} = (\mathrm{V}, \mathrm{E})$ be a graph where $V = \{v_1, \ldots, v_n\}$ is a set of vertices corresponding to the image elements, which might represent pixels or regions in the Euclidean space. E is a set of edges connecting certain pairs of neighboring vertices. Each edge $(\mathrm{v}_i, \mathrm{v}_j) \in \mathrm{E}$ has a corresponding weight $w(\mathrm{v}_i, \mathrm{v}_j)$ which measures a certain quantity based on the property between the two vertices connected by that edge. For image segmentation, an image is partitioned into mutually exclusive components, such that each component A is a connected graph $\mathrm{G}' = (\mathrm{V}', \mathrm{E}')$, where $\mathrm{V}' \subseteq \mathrm{V}$, $\mathrm{E}' \subseteq \mathrm{E}$ and E' contains only edges built from the nodes of V'. In other words, nonempty sets $\mathrm{A}_1, \ldots, \mathrm{A}_k$ form a partition of the graph G if $\mathrm{A}_i \cap \mathrm{A}_j = \phi$ $(i, j \in \{1, 2, \ldots, k\}, i \neq j)$ and $\mathrm{A}_1 \cup \ldots \cup \mathrm{A}_k = \mathrm{G}$.

The well-accepted segmentation criteria [10] require that image elements in each component should have uniform and homogeneous properties in the form of brightness, color, or texture, etc., and elements in different components should be dissimilar. In graph theoretic definition, the degree of dissimilarity between two components can be computed in the form of a graph cut. A cut is related to a set of edges by which the graph G will be partitioned into two disjoint sets A and B. As a consequence, the segmentation of an image can be interpreted in form of graph cuts,

EDGE DETECTION

Edge detection is a fundamental image processing operation used in many computer vision solutions. The goal of edge detection algorithms is to find the most relevant edges in an image or scene. These edges should then be connected into meaningful lines and boundaries, resulting in a segmented image containing two or more regions. Subsequent stages in a machine vision system will use the segmented results for tasks such as object counting, measuring, feature extraction, and classification. Edge detection is a hard image processing problem. Most edge detection solutions exhibit limited performance in the presence of images containing real-world scenes, that is, images that have not been carefully controlled in their illumination, size and position of objects, and contrast between objects and background. The impacts of shadows, occlusion among objects and parts of the scene, and noise—to mention just a few—on the results produced by an edge detection solution are often significant. Consequently, it is common to precede the edge detection stage with pre-processing operations such as noise reduction and illumination correction. An edge can be defined as a boundary between two image regions having distinct characteristics according to some feature. We have focused primarily on detecting those edges in the grayscale image which are usually associated with a sharp variation of the intensity function across a portion of the image. In the proposed system, we have used the Sobel method to detect the edges. After the edges are detected, we have noticed that the detected edge is quite thin. So we have applied dilation operation on the detected edge to thicken the edge by a suitable degree thereby making the detected edge clearly visible. The edge detection and dilation functions are explained in detail in the implementation section.

IMAGE OVERLAY

In this step, the suspicious cancerous portion detected and separated in the previous steps is superimposed on the enhanced noise-free image in order to make it easy to realize the exact location on the lung where the suspected cancerous portion resides. This will result in a final image which will highlight the suspected cancerous portion on the CT scan image. The suspected cancerous part will be highlighted in green color thereby making it easier for the naked eye to identify the suspected cancerous portion. MATLAB's Image Processing Toolbox (IPT) has a built-in function to add two images or add a constant (scalar) to an image: imadd. When adding two images, you must be careful with values that exceed the maximum pixel value for the data type being used. There are two ways of dealing with this overflow issue: Normalization and truncation. Normalization consists in storing the intermediate result in a temporary variable (W) and calculating each resulting pixel value in Z using equation:

$$g = \frac{l(\max)}{f(\max) - f(\min)}\left(f - f(\min)\right)$$

Where f is the current pixel in W, L(max) is the maximum possible intensity value (e.g. 255 for uint8 or 1.0 for double), g is the corresponding pixel in Z, f(max) is the maximum pixel value in W, and f(min) is the minimum pixel value in W.

RESULT ANALYSIS

This is the primary input to the proposed system. As is evident from the below screenshot, the original image is not clear enough to be used for the identification of the suspected cancerous part.

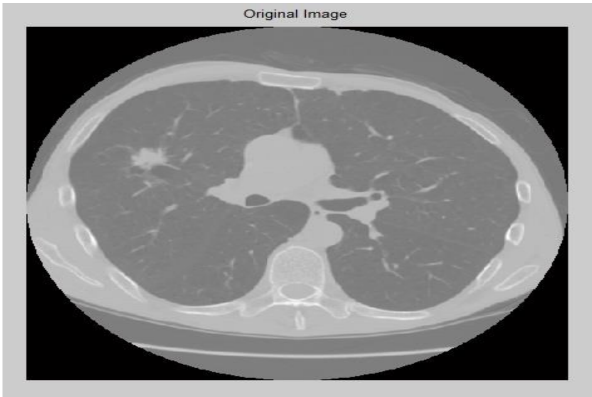

Fig. 2: Original Lung CT scans Image

Fig. 3: Histogram Equalized Image

The above screenshot shows the resultant image after histogram equalization has been applied on to the original image. This image is the enhanced version of the original image. From this screenshot, it is evident that the enhancement technique is properly working in the proposed system. Also, from the resultant image, it can be seen that the histogram equalized image is much clearer than the original image and hence more suitable for use in further processing.

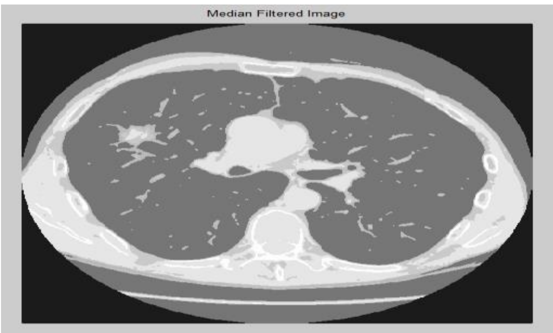

Fig. 4: Median Filtered Image

The above screenshot shows the resultant image after Median Filtering has been applied on to the Histogram Equalized image. In this stage, the noise components which were present in the previous image have been removed and therefore, the image that we see here is a noise-free image.

Fig. 5: Binarized Image (bipartite image)

Binarization is carried out base image. The threshold value is obtained by using a thresholding function. It can be seen that the resultant binary image consists of pixels belonging to only two colors Black or White. The binary image obtained in this stage is then used for identifying the largest connected component and removing it. The screenshot below shows the isolated suspected cancerous portion. This is achieved by removing all the smaller parts. This gives a brief idea about the suspected tumor present in the lung of the patient.

Fig. 6: Isolated Suspected Tumour

The edge of the isolated suspected cancerous portion is detected by using an edge detection function. The Sobel method for edge detection is applied in this stage. The resultant image shows the detected edge of the suspected cancerous portion.

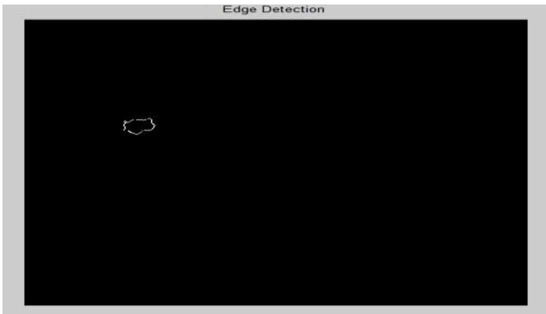

Fig. 7: Edge Detection

In order to achieve the adequate level of thickness, the detected edge has been made To undergo a dilation process where a dilation function is operated on the detected edge. The resultant image is that of the edge of the suspected cancerous part which is thick enough to be overlaid onto the original enhanced image

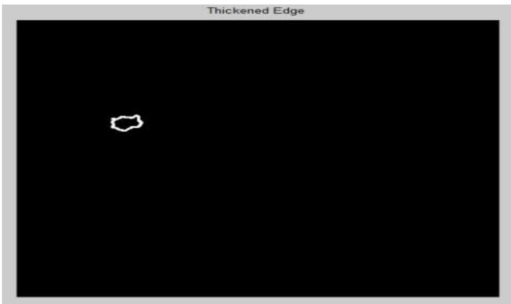

Fig. 8: Thickened Edges

The edge is then overlaid onto the original image. Here, extreme care has been taken to avoid overflow. The overlaying of the highlighted edge over the original image makes it easier to locate the suspected cancerous part with respect to the original CT scan image.

Fig. 9: Final Result image

Thus we can easily locate the suspected cancerous portion with respect to the original image.

Below is the result of another patient.

Fig. 10: Original Lung CT scans Image

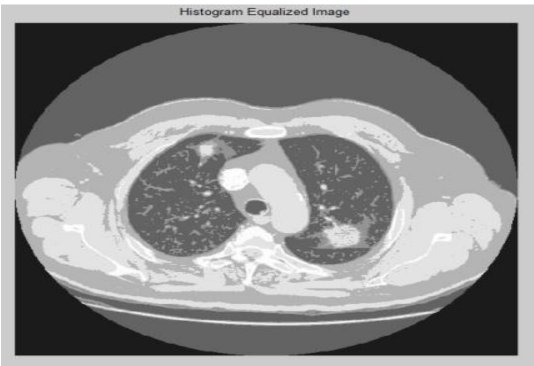

Fig. 11: Histogram Equalized Image

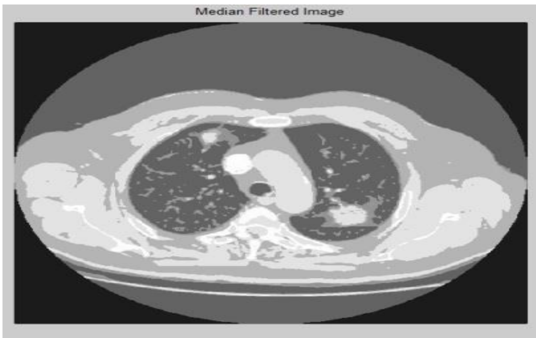

Fig. 12: Median Filtered Image

Fig. 13: Binarized Image (bipartite image)

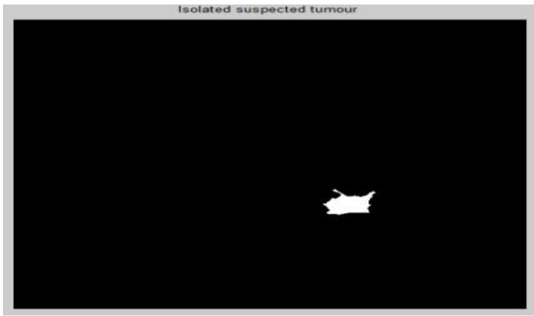

Fig. 14: Isolated Suspected Tumour

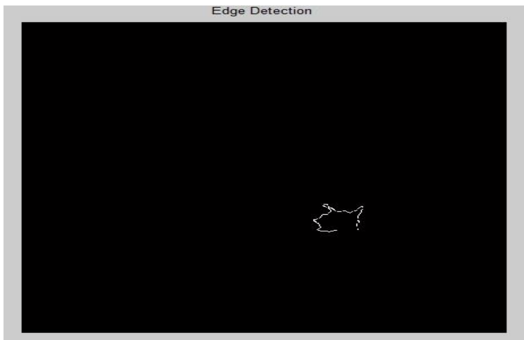

Fig. 15: Edge Detection

Fig. 16: Thickened Edges

Fig. 17: Final Result image

Thus we can easily locate the suspected cancerous portion with respect to the original image.

CONCLUSION

After the successful execution of the proposed system and the analysis of the results, it can be concluded that the proposed system has been successful in identification of the suspected cancerous portion from the original lung CT scan image provided to it as the primary input. It completed its entire operation in a very short span of time and produced results that are much easier to analyze and understand thereby indicating its high efficiency. It also provides an easy way to operate without any technical jargon which accounts for its high usability. Hence, the proposed system has fulfilled all the functionalities expected from it.

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