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Research Article

Various Techniques Used for Segmentation of CT Image of Lungs

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Abstract

Segmentation of images plays a vital role in designing various computer aided detection system in medical world. Large number of computer aided system has been proposed by researchers to assist the doctors and physicians to diagnose their patients more efficiently. In designing these systems, the segmentation of image one of the image processing technique acts as a very important part and the computer tomography (CT) images provide a very good technology for detection of lesion. This paper presents a review of the literature from 1989 – 2010 on various techniques used for segmentation of CT images of lungs. These techniques can be used for segmentation of lungs CT images in automated detection of pulmonary nodules in lungs cancer patients.

Keywords*: CT, computer aided detection, pulmonary nodule, segmentation, GGN, Thresholding, Region Based, Fuzzy C-Mean*

1. Introduction

According to the statics, lung cancer is the primary cause of cancer-related death in India as well as all over the world. Pulmonary nodules are the potential demonstration of the lung cancer. If pulmonary nodules are detected at early stage then 5-year survival rate can be increased up to 65 to 80% (Ashis Kumar Dhara et al, 2012).

In lung cancer patients' pulmonary nodule is the round opacity, at least moderately well margin and not greater than 3 cm in the maximum diameter.

Lungs nodules can be divided into various categories based on two main parameters (Ashis Kumar Dhara et al, 2012). According to location and connection with surrounding, lungs nodules can be divided into four main categories; Well-circumscribed nodule, Juxta-vascular nodule, Nodule with pleural tail and Juxta-pleural nodule. According to intensity, lungs nodules can be divided into four categories; Solid nodule and Ground glass nodule.

In the recent years many computer aided pulmonary nodules detection systems have been proposed and designed and in designing these systems image processing and CT images has played a vital role.

Computer aided systems uses a sequence of image processing technologies for detecting the pulmonary nodule in the CT image of lung of lung cancer patients. The flowchart in fig 1 shows the technologies used in computer aided detection.

One of the technologies used is segmentation of image. It is the process which is applied on images to identify the regions of interest in the image. (Ashis Kumar Dhara et al, 2012) Segmentation of lung CT image is task of separating the lung region from the other anatomical portion of the body in chest CT image. The lung field segmentation can be done with a minimal amount of user interaction using automated lung region segmentation techniques.

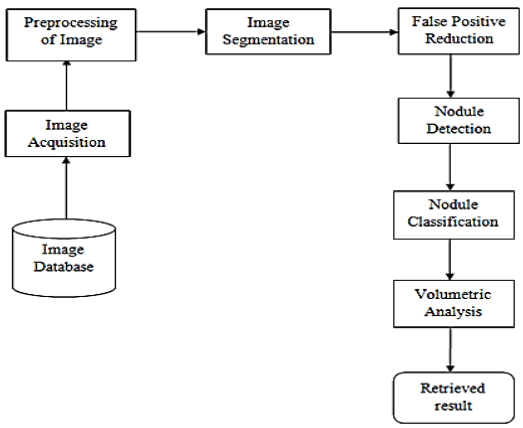

Fig1. Flow chart of the pulmonary nodule detection system

According to (Ashis Kumar Dhara et al, 2012), the advancement of lungs segmentation techniques can be

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studied into three generation. In this paper we have briefly described some of the methods of every generation.

Further sections are organized as: description of first generation segmentation techniques, second generation segmentation methods and third generation segmentation technologies in section II, III and IV respectively.
Finally the future work and a conclusion of the discussion are provided in last section.

II. First generation of CT image segmentation techniques

The first generation techniques are the low level techniques where a little prior knowledge of the lung CT image is required such as the intensity value of a pixel of image. The first generation technologies include the Thresholding, multiple Thresholding optimal Thresholding, region growing, connected component labeling etc.
Two of these technologies are briefly discussed in this paper.

- **Thresholding**

In simple Thresholding the image is segmented into two region one object part and second background of the image in such a way that object and background pixels have intensity levels grouped into two dominant modes. This is done on the basis of intensity value selected from the histogram of the image. This selected intensity value is known as threshold.

Then any point (x, y) for which f(x, y) >= T is called an object point; otherwise, the point is called a background point.

The different Thresholding techniques are local Thresholding, global Thresholding, Multiple Thresholding and Optimal Thresholding.
In local Thresholding the threshold value varies for an image and in global Thresholding the threshold value remains same for an image.
For detailed study of multiple Thresholding and optimal Thresholding you can study (S.G. Armato et al, 1999) and (S. Hu et al, 2001) respectively.

- **Region Based**

In region base method one pixel is compared with its neighbors. If the similarity condition is satisfied, the pixel can be set belong to the cluster as one or more of its neighbors. This method mainly relies on the assumption that the neighboring pixels within one region have similar value. Thus, by deciding one similarity criteria similar regions in the image are identified in region based technology.

Based on the logic of region based techniques there are different algorithms that we can study. In this paper we have discussed four different algorithms based on the region based techniques.

The **first** algorithm is *Seeded Region Growing*, this algorithm performs a segmentation of an image with examine the neighboring pixels of a set of points, and determine whether the pixel could be classified to the cluster of these set of points. This set of points is known as **Seed Points**.

The **second** algorithm is *Unseeded Region Growing*, this algorithm was the modified version of seeded region growing.

The modification is that no explicit seed selection is necessary. During the segmentation procedure, the seeds could be generated automatically. So this method can perform fully automatic segmentation.

The **third** algorithm is *Region splitting and Merging*, in this algorithm the image is subdivided initially into a set of arbitrary, disjointed regions and then merge and/or split the region in an attempt to satisfy the basic conditions of the region based segmentation
(a) The segmentation must be complete
(b) The point in region be connected in some predefined sense
(c) Region must be disjoint

The main aim of the region splitting and merging is to distinguish the homogeneity of the image. its hypothesis is based on quad-trees, which means each node of trees has four descendants and the root of the tree corresponds to the entire image. Besides, each node represents the subdivision of a node into four descendant nodes.
For instance, let *R* represent the entire image region and decide a predicate *P*. The purpose is that if; we divide the image *R* into quadrants. If *P* is FALSE for any quadrant, we subdivide that quadrant into sub quadrants, and so on. Until that, for any region *Ri*, P (Ri) = TRUE. After the process of splitting, merging process is to merge two adjacent region R_j and R_k if P (R_J U R_K) = TRUE.

The **fourth** algorithm is *Fast Scanning Algorithm*, this algorithm id based on the concept of scanning the image from the upper-left corner to the lower-right corner and and determine if we can merge the pixel into an existed clustering. The merged criterion is based on the assigned threshold. If the difference between the pixel value and the average pixel value of the adjacent cluster is smaller than the threshold, then this pixel can be merged into the cluster (Yu Hsiang et al, 2009).

On comparing these algorithms, segmenting the image using SRG has no fragmentary problem but still it has two drawbacks, first it is difficult to select the initial set seed points because different sets of seed points cause different segmentation results and second problem is time consuming.

Thus, we can use unseeded region growing algorithm over seeded region growing for better results.
The results of region splitting and merging algorithm are not as good as the color image ones because that intensity alone is not as discriminative as color. This can be applied in gray level images where the intensity values are quantized the same as the colors. While the fast scanning algorithm has its own advantages over above discussed three algorithms
a. The pixels of each cluster are connected and have similar pixel value
b. The computation time is faster than both region growing algorithm and region splitting and merging algorithm

c. The segmentation results exactly match the shape of real objects.

For the detailed study of these above discussed algorithms you can refer to (Yu Hsiang Wang et al, 2009).

III. Second generation of CT image segmentation techniques

In the second generation methods heuristic methods have been tried to avoid by introducing model based method and the optimization techniques.

These methods are based on the clustering and classification of the pixels in the image. All the methods are either supervised or unsupervised based on their concepts.

This generation includes the methods like Bayesian classifier, Discriminant analysis, fuzzy C-mean, active counter model, graph-based method, mean shift filtering followed by clustering etc (Ashis Kumar Dhara et al, 2012).

In this paper we will briefly describe the two of these techniques.

- **Graph Cut**

Graph cut is a segmentation optimization technique. It is used to obtain an optimized segment of image. It becomes difficult to describe ones perception of what constitutes foreground in an arbitrary image through low level cues because distinguishing between foreground and background becomes harder and requires a higher level of scene understanding. In such situation graph cut technique can be used.

In the graph cut technique the concept is of partitioning a directed or undirected graph into disjoint sets. An undirected graph is constructed from an image. Each pixel is viewed as a node in a graph, edge are formed between nodes with weights corresponding to how alike two pixels are, given some measure of similarity, as well as the distance between them. In order to reduce the number of edges in the graph only pixels within a smaller, predetermined neighborhood say N of each other are considered. The two terminal nodes, the source and the sink are viewed as representing the object and background respectively and do not correspond to any pixel in the image.

Now, we briefly describe the method used in the graph cut technique. Now consider a graph G = {V, E, W}, where V denotes nodes of graph, E edges of the graph and W associates a weight to each edge in E. A cut on a graph is a partition of V into two subsets A and B such that

A U B = V, A intersection B = NULL;

The simplest and best popular graph cut method is min-cut formulation. The min-cut of a graph is the cut that partitions G into disjoints segments such that the sum of the weights associated with edges between the different segments is minimized. That is, the partition that minimizes

$$C_{min}(A, B) = \sum_{u,\, v} W_{uv}$$

Where, u belongs to A and v belongs to B

The min-cut of the resulting graph will then be the segmentation of the image. For the further study of graph cut you can refer to the (Akinobu Shimizu et al, 2011) and (Asem M. Ali et al, 2008).

- **Fuzzy C-Mean**

In standard fuzzy C-Mean technique of segmentation each point is joined with a membership value for each class after FCM clustering. The basic objective of FCM is to determine the cluster centers and to generate the class membership matrix. In other words, we can say it assigns a class membership to a data point, depending on the similarity of the data point to a scrupulous class relative to all other classes. The class membership matrix is a cXN matrix; in which c is the number of groups and N is the number of samples. Although the original FCM algorithm yields good results for segmenting noise free images, it fails to segment images corrupted by noise, outliers and other imaging artifact.

In order to tackle these problems in (M. Gomathi et al, 2010), they have proposed some of techniques that are the modified and more efficient versions of FCM. These proposed techniques are briefly described below.

The modified FCM algorithm is designed by modifying the distance measurement of the standard FCM algorithm to allow the labeling of a pixel to be influenced by other pixels and to restrain the noise effect during segmentation.

The Possibilistic C-Means (PCM) algorithm, interprets clustering as a Possibilistic partition. Instead of having one term in the objective function, a second term is included, forcing the membership to be as high as possible without a maximum limit constraint of one.

And the Fuzzy Possibilistic C-Means (FPCM) algorithm, it includes both possibility and membership values.

- **Mean shift filtering**

Mean shift filtering algorithm, finds the target candidate that is the most similar to a given model in terms of intensity distribution, with the similarity of the two distributions being expressed by a metric based on the Bhattacharyya Coefficient. This process is achieved by mean shift iteration.

The derivation of the Bhattacharyya coefficient involves the estimation of the target density q and the candidate density p, for which the histogram formulation is employed.

Mean shift filtering followed by clustering is a nonparametric clustering technique which does not require prior knowledge of the number of clusters, and does not constrain the shape of the clusters.

The mean shift filtering followed by clustering provides a better segmentation results as compared to the FCM (Ashis Kumar Dhara et al, 2012).

This is the brief discussion on the second generation segmentation techniques for further research on implementation of these techniques you can refer to the (Ashis Kumar Dhara et al, 2012), (M. Gomathi et al, 2010) and (D. J. Withey et al, 2007).

IV. Third generation of CT image segmentation techniques

The third generation methods incorporates the high level knowledge such as a priori information, expert-defined rules, and models such as shape based of a desired object. Image primitives are usually derived from the first and second generation techniques and then interpreted using anatomical and image knowledge to form a set of rules.

Third generation includes the hybrid algorithms which are the combination of the first and second generation algorithms. For instance, (Ashis Kumar Dhara et al, 2012) an active appearance model (AAM) is an extension of the active-shaped model, where shape plus intensity of an object are integrated to get the segmented lung.

The latest approach is atlas based segmentation, an atlas is a composite image formed from segmented and co-registered images of several subjects.

(E. M. Rikxoort et al, 2009) combined region growing and atlas based method and achieved 95% volumetric overlap (Ashis Kumar Dhara et al, 2012). (Akinobu Shimizu et al, 2011) combined statistical atlas and graph cuts to improve the segmentation accuracy (Ashis Kumar Dhara et al, 2012).

In this paper we will study the method of segmentation proposed by Shimizu et al.

- **Combination of statistical atlas and graph cut**

One of the second generation segmentation technique is the Graph cut which is the one of the recent noteworthy development in the segmentation of the image, in the graph cut technique minimum for certain types of energy function is guaranteed.

On the other hand statistical atlas based segmentation of 3-D medical image provides a framework of effective utilization of shape priors inherent in the target anatomical structure. In order to achieve this, SSMs (Statistical Shape Model) have been used but the problem of this approach is that segmentation accuracy becomes insufficient for shapes that are not covered by training datasets.

In respect to overcome this problem in (Akinobu Shimizu et al, 2011), they have proposed a method which is the combination of the graph cut and statistical atlas. In which statistical atlas work with graph cut. Two constraints in graph cut are categorized into two constraints such as ellipse and star shape and specific constraints such as a user defined scaled rigid template. One of these two constraints i.e. shape constrained energy is derived from statistical atlas based segmentation and other is for constraint from a neighboring structure. In this way effective combination of these two strong approaches is needed and desirable for robust and accurate segmentation.

Conclusion and future work

In this paper we have briefly discussed and reviewed the various segmentation techniques. The evolution of the algorithms for handling particular task has been discussed along with their performance. All the algorithms have their own field of use. The algorithms that require less user interaction can be used for better segmentation results.

Further research will be focused on studying the other segmentation techniques and on implementing the proposed algorithms in order to get the good results in detecting the GGN (Ground Glass Nodule) in the lung CT image.

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