A New Integrated Methodology for Segmentation of 2D Computer Tomography Images

C.G. Ravichandran and G. Ravindran

This research study proposes and implements a new hybrid approach for segmentation of 2D Computed Tomography Images which aims at increasing the performance and minimizing the user intervention. It is a hybrid method that integrates both the edge and region information in a coherent manner. In addition the proposed method incorporates parallel region growing process. Segmentation results indicate that the performance of our method is very good. A remarkable strength of the outcome of this research is that the segmented image sequence can also be used to reconstruct a 3D model.

Key words: Medical imaging, computed tomography, image reconstruction, hybrid segmentation

1Center for Medical Electronics, Department of Electronics and Communication Engineering, Anna University, Chennai 600 025, India
2Faculty of Information and Communication Engineering, Anna University, Chennai 600 025, India
INTRODUCTION

This study is part of a major research concentrating on Volumetric Medical Image Analysis, which aims to help physicians in 3D visualization of brain tumors and assist them in their diagnosis and further treatment.

As one of the first stages of this major research activity, the authors have undertaken this study which proposes and implements a new approach for segmentation of 2D Computed Tomography (CT) Images which aims at increasing the performance and minimizing the user intervention.

This research study is the outcome of painstaking research efforts of the authors to obtain robust segmentation results from 2D Computed Tomography Images. A great deal of effort and study had been put into the effort of finding a segmentation technique that gives robust segmentation results in 2D Computed Tomography images. But there was little success in identifying a suitable technique. Moreover, not much of detailed analytical studies have been published. Thus there is an inadequacy in literature sufficient for in-depth studies.

Hence, the authors propose their own hybrid algorithm which combines edge detection and region growing to obtain a robust result. This is a new hybrid algorithm proposed by the authors for segmentation of 2D Computed Tomography Images.

A major outcome of this and further research is that this research outcome can be extended into Volumetric Medical Image Analysis. The following paragraphs give a brief introduction to the task and the survey undertaken.

STUDY OF PREVIOUS METHODS

Segmentation is a process in which an image is subdivided into constituent regions or objects. It is one of the vital steps in image analysis task. Prior to 3D reconstruction of 2D image sequence, a segmentation process should be done to identify the region of interest, i.e., the major issues in medical imaging applications.

The earliest studies on Segmentation were done as early as 1985 (Haralick and Shapiro, 1985), but yet research on Segmentation has been steadily progressing for the last few decades due to the need for automatic processing of images in the industrial and medical realm. Also, electronics technology has been making rapid strides in development. This has also inspired research on segmentation due to this and various other specific requirements.

Therefore literature on segmentation is available and the authors have made an analytical study regarding feasibility of using any existing technique for their research study on segmentation of 2D Computed Tomography Images. But yet, there was no suitable technique available for the authors research study and hence they propose their own hybrid technique for segmentation of 2D Computed Tomography Images.

The following paragraphs outline a few of the techniques that were interesting from the perspective of segmentation of 2D Computed Tomography Images.

Threshold based approaches (Sahoo et al., 1988) are usually semi-automatic and are based on the assumption that all the pixels whose value depends on the brightness lie within a certain range are grouped together into a single class.

If the method is semi-automatic then the user should have prior knowledge about the Segmentation process. In the case of automatic Thresholding (Soltanian-Zadeh et al., 1992, Hu et al., 2001) the image histogram must contain separable modes, modeled as Gaussian distributions. This type of techniques generally sensitive to noise or blurring at boundaries and do not cope up well in such cases. Such methods also neglect all the spatial information of the image.

In Boundary based technique (Davis, 1975, Pathak et al., 2000), the pixel value change rapidly at the boundary between two regions. It is also called as edge based methods.

Gradient methods are most commonly used to detect the boundaries between the regions. In volumetric medical images, partial volume effect results in structures with blurred edges. Therefore, the edge detection process for the structure of interest may be incomplete. High values of this filter provide c and idate for region boundaries, which must then be modified to produce closed curves representing the boundaries between the regions. Post-processing using contour closing approaches is possible but not really practical due to the high-order computational complexity of these techniques (Cocqerez and Philipp, 1995).

Region based methods perform pixel aggregation around seeds using homogeneity and adjacent criterion (Lu et al., 2003). The seeds may be user specified or automatically generated. It is based on the hypothesis that neighboring pixels within the same region have similar brightness value.

The homogeneity criterion applied in this method may be a minimum acceptable difference between the brightness value of the c and idate and the average brightness value of the grown region or may be related to the shape and size of the region depending on the task. If the criterion is satisfied then the pixel can be appended into the region as one or more of its neighbors.

In case of manual seed selection good segmentation result depends on correct choice of seeds. When the input images are noisy, the seeds may fall on typical pixels that are not representative of the region statistics. This can lead to erroneous segmentation results. The success of segmentation in automatic seed generation or
unseeded region growing depends on the choice of homogeneity criterion, which is a very difficult task.

Recently a large number of hybrid methods have been developed which aims to present combinational advantages of the processes and integrates two or more of the above mentioned approaches.

The hybrid segmentation method described in Kang et al., (2003) combines local adaptive Thresholding with region growing for the detection of skeletal structures in CT image sequence. This method requires user interaction as well as continuous input image sequence, with no missing slice and a minimal slice thickness.

The hybrid method presented in Pohle and Toennies (2001) combines adaptive region growing with a homogeneity model. Their algorithm is rather slow, consisting in two steps: first, the homogeneity criterion is learned from the global image appearance and second, the region of interest is grown around a user-specified seed pixel.

The following section proposes a new hybrid segmentation method, which combines edge detection and region growing in order to obtain a robust result.

**METHOD**

Our method is focused on segmenting the 2D Computed Tomography images and involves the following steps, namely

- Noise reduction
- Thresholding
- Boundary detection
- Unseeded region growing

We perform a noise reduction process to eliminate unwanted noise interference in the Computed Tomography images. Thresholding and Boundary Detection are implemented next. Unseeded Region Growing segments the images into regions based on a marker set (seeds) which are generated automatically. The process culminates when the contour is completed. A brief outline of the segmentation procedure is outlined in the following paragraphs.

**Step 1: Noise reduction:** During image acquisition process there is a possibility of observing undesirable components together with the signal carrying the information and these components will not correlate with the signal. Such types of components are referred to as r and om noise. Since r and om noise consists of sharp transitions in gray level the obvious application here is the noise reduction. Edges are also characterized by sharp transitions in gray level, so averaging filters have undesirable side effect that they blur edges.

Gaussian mask (Gonzalez and Woods, 2002) is applied in our method in order to reduce the noise, which can be achieved by means of convolution using 3×3 kernels. Convolution establishes the fundamental relationship between the spatial and frequency domains. Since the succeeding steps in this method involves operations under frequency domain Gaussian filter is employed which is best suits for convolution.

**Step 2: Thresholding:** Thresholding involves a vital role in image segmentation process. The Thresholding approach presented here is the Global Average Thresholding in which the image is traversed in a pixel-by-pixel basis and the average value between two pixels is calculated original value.

By finding the mean for the average value for n-1 (where n is the No. of pixels) pixels a resultant value will be obtained which is used as a threshold value.

**Step 3: Boundary detection:** Laplacian of Gaussian (LoG) function together with the zero crossing of the second order derivative (Gonzalez and Woods, 2002) is employed to detect the boundary of an image. Since Laplacian in its original form is not suitable for original reasons such as the magnitude of the Laplacian produces double edges as a second order derivative it is sensitive to noise and is unable to detect edge direction.

Therefore zero crossing property is implemented for edge location and for the complementary purpose of establishing whether a pixel is on the dark or light side of an edge. A threshold is applied to the convolved image and the pixels that are above the threshold value undergo zero-crossing of the second derivative, which is quite useful for locating the centers of thick edges.

**Step 4: Unseeded region growing:** Unseeded Seeded Region Growing (URG) (Lin et al., 2000) is a well known region based segmentation method that segments intensity images into regions based on a marker set (seeds) which are generated automatically.

**Seed value calculation:** The correct specification of the seed pixel is necessary for the success of the segmentation process. It performs automatic seed selection by employing Discrete Cosine Transform, which gives the sinusoidal waveform output value for all the pixels in an image.

The minimum value and the maximum value pixel within the boundary are selected from the sinusoidal wave and the average value is calculated which gives the initial seed value.

One of the main reasons for the application of DCT is that it minimizes the blocking artifact that results when the boundaries in the sub-images becomes visible.
Region growing: Pixel aggregation around an initial set of seeds plays a vital role in Region Growing. The pixel aggregation process iteratively add the neighboring pixels to the region satisfying a similarity constraint and stops the current region when no c and idate pixel satisfies this constraint and simultaneously it initializes another region by assuming that c and idate as a starting point.

The regions are labeled prior to pixel aggregation. Let us assume the initial region as I, which contains the single seed and the segmentations process involves set of identified regions I_1, I_2, I_3, ..., I_n. The region growing process continues until there are no more c and idate pixels left within the boundary.

The homogeneity is very essential for the success of region growing process.

The criterion in the proposed Region growing process is the minimum difference between the average value of the region and the value of the c and idate to be inserted.

Best candidate selection: During the initialization of pixel aggregation each labeled region will contain only one pixel and is known as the best c and idate among all the c and idates.

To become a c and idate of any region the pixel should satisfy the following criteria

- It should not belong to any other labeled region
- The homogeneity criterion is not yet satisfied.

Each labeled region contains a list of c and idates, which are independent to each other. Successive iteration of pixel aggregation process will result in merging of one or more regions.

If two regions merge together at a certain iteration during region merging process then both the regions are given a same label and will be considered as a single region in the successive iterations. The labeled region decreases while the pixel aggregation process is done repeatedly.

Figure 1 shows the flow diagram of the steps followed to obtain the segmented 2D computed tomography image. Each block represents a stage in the process. The process is outlined beneath the arrows that connect the different blocks in the diagram.

**EXPERIMENTAL RESULTS AND VALIDATION**

The experimental procedure outlined in the previous paragraphs has been successfully implemented. Graphical results are shown in Fig. 2 & 3. Figure 2 and 3 are the input images for segmentation and Fig. 4 and 5 are the segmented output images. Figure 4 and 5 indicate successful accurate segmentation, which can be observed in figures shown.

The actual experimental procedure can be summarized as follows:

- Edge pixels are first detected.
- Seed is generated
- Region growing is done employing the seed as initial value.

After obtaining successful segmentation of 2D CT brain images, the experimental procedure was validated. We compared our experimental procedure, performance and output with those currently available. We noted a
CONCLUSION AND DISCUSSION

We have proposed and successfully implemented a new integrated method for Segmenting 2D Computed Tomography images.

The experimental results and validation section has shed light on the strengths and efficiency of our new hybrid segmentation technique for CT images in terms of accurate segmentation and speed of segmentation, operating on an entire set of CT images within a minute, in about 50 sec itself.

The authors hence conclude that their new hybrid segmentation technique for CT images is successful, accurate and very efficient.

This new hybrid segmentation technique for CT images proposed and implemented by the authors has enormous potential in extending it further to MRI, PET images, etc.

FUTURE STUDY

Future research will be focused to reconstruct a 3D model with this segmented image sequence. This can be done by finding the volume of each slice and by filling the gap between the slices.

This 3D model will be also useful for surgical planning. The authors are currently working on constructing a 3D model with this segmented image sequence.

ACKNOWLEDGMENT

The authors express their heartfelt thanks to The Management, The Secretary and Correspondent, The Administrative Director and The Principal of Velalar College of Engineering and Technology, Erode, India for their patronage and encouragement to this research study.

The authors also wish to thank all those who helped in this research.

REFERENCES


