AUTOMATIC LIVER SEGMENTATION METHOD USING NON-CONTRAST ENHANCED CT IMAGES FOR LIVER FAT EVALUATION BY MATLAB

AHMED ALKINANI[1]   , GHASAN ALI HUSSAIN[2]

[1] *Kansas City Kansas Community College (KCKCC)*, USA, *E-mail:- aaljanabi@kckcc.edu*
[2] Electrical Engineering Department/ University of Kufa, Iraq, *E-mail:- ghasan.alabaichy@uokufa.edu.iq*

ABSTRACT

Evaluating the diffused fat in the liver requires an accurate segmentation for the liver tissues. Miss segmenting the non-liver organs or tissues may lead to a negative impact on the credibility of the obtained results. The segmenting of liver has been proposed as adaptive method by using non-contrast enhanced CT images (NCT). In this method, minimizing the error of segmenting non-liver tissues is the main objective. The proposed method is improved the robustness without utilized training data in building our model or in calculating all parameters. A fully automatic liver segmentation method is suggested in this paper. In this method, the liver of a subject is segmented using NCT data slice-by-slice. The method of segmentation is based on using thresholding operation, gray-level information, Gaussian gradient transformation, region growing algorithm, distance transformation, edge detection and anatomy information. Data sets of 30 subjects are employed to evaluate the proposed method subjectively. Results show a great capability to separate attached organs from the liver. The ability of the method to segment the liver tissues did not reach to a great level. However, the results of segmented liver can be considered as accepted results for the main objective of this study. The method shows a feasible capability to separate non-liver organs and tissues. The results indicate that chances for mistakenly segmentation for non-liver tissues as liver are very low.

KEYWORDS Segmentation of Liver, tomography computation, region growing, thresholding, detection of edge.

INTRODUCTION

he segmentation of Human organs in medical images has become a major concern in the fields of medical image processing lately. Many clinical applications require organs like the kidney, heart, liver to be segmented for diseases diagnose or to extract anatomic information of the organ. The hard task of segmentation the liver in NCT images because blurry edges as well the low level contrast that characterize this kind of CT images. Moreover, neighbour tissues and organs such as kidney, heart, spleen, muscles as well as stomach that has similar gray levels. Furthermore, the same gray levels that may not show in same organ in one subject. In addition to broad variety of liver forms and the complexity, all of these challenges increment the difficulties of task of liver segmentation. The mental work by experts and physicians is the manual segmentation for liver**.** It needs to a long time and depending on inter and intra observer.

Therefore, computerized liver segmentation methods present optimal solution to decrease the needed time and get easily work. Generally, computerized liver segmentation methods utilizing (CT images) have two methods, fully and semi-automatic liver segmentation. These two methods are share much of basics and work keys. In semi-automatic methods, the capability of employee to refine the results gives a huge improvement in these results. But, the important disadvantage of this method is the quality result of segmentation depends on expertise of operator that may made mistakes or biases. Different methods of liver segmentation using computer and algorithms was proposed. Furthermore, a lot of surveys and comparison studies could be found [1-4]. Generally, a lot of facts and observations lead to believe which automatic liver segmentation as yet an open problem since several disadvantages and weaknesses of the suggested works could be processed, and it needs comprehensive solutions. Often, the model of liver form based techniques are unsuccessful specially when the complex shape of liver. Fully automatic liver segmentation approach depending on deformable models [5-7], statistical shape model (SSM) [8-11] and probabilistic atlases [12] need a suitable training data set to build the approach. It is difficult to collect these data sets. It needs to a huge cardinality as well as the training status should capture all the potential forms, that is

really very difficult for working with liver. Also, the computation needs to a long time to get a good matching between CT image and model. Region growing methods [13, 14] can correctly separate the liver based on the defined properties and the selected seed points. The time consuming of region growing is the most serious problem. The method in [4, 15-23] that depends on automatic liver segmentation, it records disadvantages in gray level. In addition to, the approaches that depending on gray level; the estimation of liver gray level is considered the main and primary step thus, the intra and large inter gray level variability will neglect. While it may fail the other approaches of manually segmented samples that utilize a statistical analysis when processed the subject with entirely various gray level characteristics. Also, thresholding the CT images based on using the estimated threshold values usually leads to classify attached organs as liver since special information are ignored using thresholding techniques. While a frequent error is suffered in other techniques, where the approaches unsuccessful to split up correctly the attached organs of the liver. With the advantage of the existing of high performance modern computer systems, the slowness of region growing algorithm is no longer considered as a problem. Given this under consideration and in addition to the problems and issues discussed earlier, a gray level and region growing based techniques are involved in the proposed liver segmentation method. In this proposed method will calculate most of used parameters from NCT image that used itself, thus the matter of large variability in the intensity of CT values will be solved.

A fully automatic liver segmentation approach using NCT images has been suggested in this paper. In this method, the liver is segmented in the NCT slices one by one. Anatomic information and gray level play the main rule in the liver segmentation method. The building of model and calculating of global parameters have been obtained without employing training data. The first NCT slice has been chosen automatically by NCT data set of a subject where cover wide area of the liver. The segmented liver will be used in the beginning slice (I_{SS}) to be considered as a reference for the neighbor slices. To segment the liver in *Iss*, the same techniques will be employed and uses to segment in all different NCT slices of the subject in the liver. Therefore, when segment any new slice in the liver, it will be utilized for the next slice as a reference. This approach will be going in this manner to reaches to the lobe of bottom and top of the liver. Fig. 1 shows the structure of the proposed method.
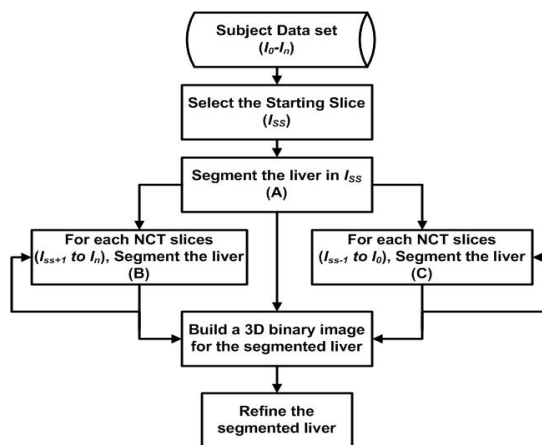

Figure 1, The basic structure of suggested liver segmentation method

MATERIALS AND METHODS

Data sets

Datasets of 30 subjects (Men: 16 subject, age: 36 to 62 years old, mean age: 49. Women: 14 subject, age: 37 to 72 years old, mean age: 51) are employed in this paper. Every dataset consists of 250-300 NCT slices. All of the used data are collected by scanning the lung, abdomen and pelvic for each patient. Those patients are scanned for variety of reasons. The data sets are obtained using SIEMENS scanner for Country Heights Health Tourism Sdn. Bhd. Scanning was performed at 130 kV and 200 mA. The resolutions and thickness of the slices were 512 X 512 pixels, and 2.5 mm respectively for all subjects. The algorithms are implemented by using MATLAB software, as well by also using personal compute have the following specification; Windows, (Core 2Due /2.4GHz) processor and Memory (2GB). Employed images are stored in DICOM format. Fig. 2 explains some samples of the used data in our work where the liver is bounded by a black contour.

When scanning a patient for contrast and non-contrast enhanced CT images the several protocols have been employed. The contrast agents (oral and/or IV) have been usually used to produce contrast enhanced CT images as well as, the scanner itself usually contains on unit of an attenuation correction.
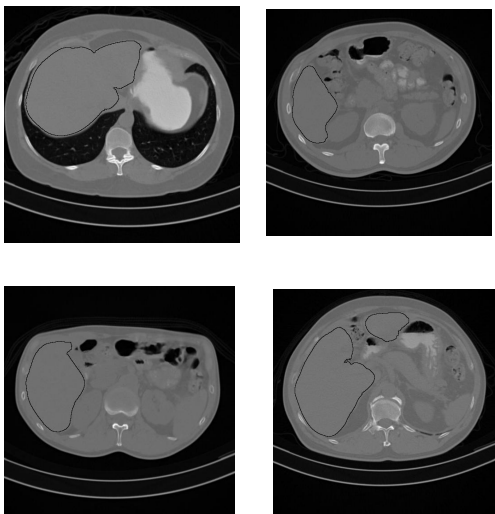
Figure 2, Samples from the employed NCT images, liver is bounded by the black contour in each NCT image

Thus, all of them together uses to highlight on certain areas inside human body that being studied. Manipulation and processing contrast enhanced CT images is easier than manipulation and processing non-contrast enhanced CT images. In the used data set, the used scanner doesn't contain any attenuation correction unit. However, some patients are asked to drink a special liquid to highlight the digestive system.

METHODS

The difficulty of the operation of segmenting the liver in NCT images is due to the large overlap between the liver tissues and other tissues and organs that share similar gray intensities. This situation makes the traditional image segmentation and classification methods fail usually in segmenting the liver in NCT data. The anatomy and edge information play the main role in the process of segmenting the liver in the suggested method. With the knowledge of the fact that the liver shape and size don't change significantly between sequential NCT slices, applying an erosion morphological operation on the previous segmented liver region will produce a region which can be used as a liver seed region for the current NCT slice.

At the beginning, a binary bed mask is created (for each subject) in order to remove the bed from each processed NCT slice. By thresholding a randomly selected NCT image will create this binary mask using an adaptive threshold value estimated by analyzing the histogram of the selected NCT. The area with the maximum number of foreground pixels that shows the body will be eliminated. The remaining pixels present the bed which will be considered as the binary bed mask.

In order to select the I_{ss}, the NCT slices for a subject will be looked starting of the top to the bottom for the slice which contains the liver in first appearance (I_{liver}). In general, finding of I_{liver} depending on the fact which the sequential thresholded NCT slices starting from the top to the first appearance of the liver are similar of each other. When the liver starts to appear, the foreground pixels in the left side of the image will be extensively increased. Once I_{liver} is found, the 25th, 30th and 35th slices are selected as a candidate to be the starting slice (the counting started from I_{liver}). Depending on the distance between the NCT slices and depending on the anatomic information of the liver, a good candidate for I_{ss} could be found between the 25th and 35th NCT slice. In I_{ss} the liver must cover a big area of the NCT slice and should be presented as one connected region. The liver in the 25th, 30th and 35th NCT slices will be segmented, and the slice with one region of liver with the maximum cross area of will be selected as the starting slices. Segmenting the liver in I_{ss} (Block A in Fig. 1) is done by finding a seed region for the liver which is used to calculate some parameters. These parameters are used to segment the liver in I_{ss} in a multi-steps procedure. The structure of the liver segmentation process in I_{ss} has been shown in Fig. 3.
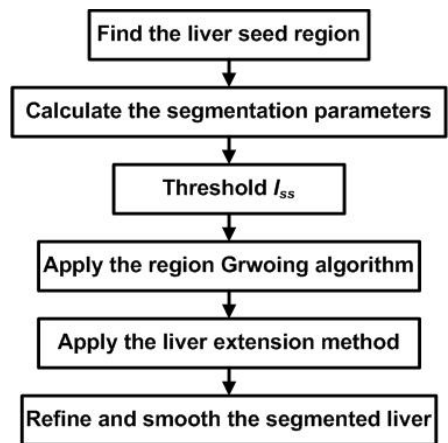

Figure 3, The procedure of segmenting the liver in I_{ss}

In I_{liver}, it is so difficult notice the liver. from slice to slice the cross section area of the liver will be growing progressively for the slices that follow it. When take the I_{liver} and consider it as reference as well choose the tenth slice of NCT, then can be observe the similarity in the left sides of both images, exclude the area in 10th NCT slice of the

liver. where a region of a liver can be noticed. To segment this region, both images are thresholded using Otsu thresholding technique [24]. By subtracting the thresholded I_{liver} image from the 10th slice thresholded image then just take the left side of the created image, it will produce a binary image and a few little isolated regions of the liver region. After filter the resulted image by using a morphological filter all areas will be removed except the areas with the maximum number of foreground pixels. This area is the region of liver that is morphologically eroded then ensure separate all non-liver areas which may still connected to the liver. The resulted region in the 10th slice is considered as the liver seed region which will be used to calculate the parameters employed in the next steps.
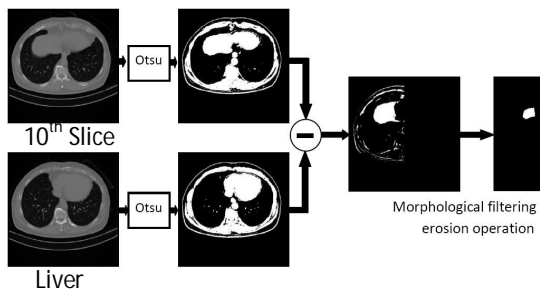

Figure 4, Liver seed detection procedure

In [25] apply gradient transformation on the 10th NCT slice using first order derivative of Gaussian. it is produced three gradient images (horizontal, vertical and diagonal) gradient images. By using the liver seed region and the 10th NCT slice, the standard deviation (Si) and the mean (Mi) for the gray intensities of liver seed region pixels are calculated. Also, a six parameters are calculated as following: the liver's mean and standard deviation horizontal, vertical, and diagonal gradients (Mg_1, Mg_2 and Mg_3) and (Sg_1, Sg_2 and Sg_3). Fig. 4 illustrates the procedure of finding the liver region. I_{ss} will be thresholded two times. In the first thresholding process, I_{ss} is thresholded using Mi and Si as shown in the following equation:

$$I_{bw} = \begin{cases} 1 \ if \ |I_{ss} - Mi| \leq \alpha1 * Si, \\ 0 \ else \end{cases}$$

.... (1)

Where α1 is a gray-scale thresholding factor. The result of this thresholding operation (I_{bw}) is a binary image where foreground pixels present the liver and the other tissues and organs which share similar gray intensities with the liver. The skin will be removed from I_{bw} and detect the boundary of the abdomen wall. When detecting the abdomen wall boundary, by using an adaptive structural element it

will be dilated morphologically. Then, will create a box boundary around the resulted area thus, remove the right bottom quarter. This operation helping removing the spleen and reducing the processing region where the liver is not existing or show in this portion.

Finding the liver seed region in I_{ss} for the region growing algorithm will start with applying the Gaussian gradient transformation on I_{ss} to produce three gradient images: horizontal, vertical and diagonal gradient images. The region with the maximum number of foreground pixels in I_{bw} is selected and multiplied by each one of the gradient images (corresponding elements are multiplied and returns the product in the corresponding elements of the output). The resulting images will be thresholded after that using the gradient parameters as shown in the following equation.

$$Isg_k = \begin{cases} 1 \ if \ |I_{ss} - Mg_k| \leq \alpha2 * Sg_k, & k = 1,2,3 \\ 0 & else \end{cases}$$

……………………………..……… (2)

Where α2 is a gradient thresholding factor. An element wise logical AND operations is applied on the three binary images resulted from the second thresholding operation (I_{sg1}, I_{sg2} and I_{sg3}) and it will be followed by a morphological filtering process to produce the liver seed region. Fig. 5 shows a sample of I_{ss} slices for a subject and the segmented liver seed results. The third column in Fig.5 shows the boundary of the liver seed region inside I_{ss}.

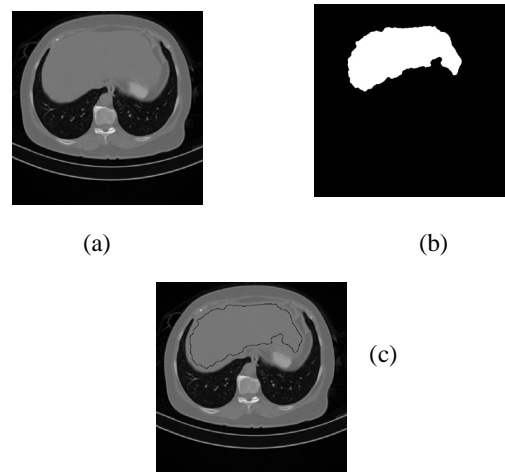(a)   (b)

(c)

Figure 5, Samples from the liver seed segmentation results. (a) Original, (b) seed segmented liver, (c) boundary of the seed segmented liver

The liver seed region and the I_{ss} diagonal gradient image are employed as inputs to the region growing algorithm which is explained as following:

```
        Mini_gradient_value = 0;
        While          (Mini_gradient_value      <
Region_growing_Threshold)
           [Mini_gradient_value  Index] =  mini
(|[3rd column of (Gradient_info)]- Mg|)
           [X Y]= Gradient_info (Index)
           Ls(X,Y)=2
           For i=-1 to i=1
             For j=-1 to j=1
               If Ls(X+i,Y+j)=0  &  |Dg(X+i,Y+j)-
Mg|<Sg
                   Add       Dg(X+i,Y+j)       to
Gradient_info
                   Ls(X+i,Y+j) ←1
               end
             end
           end
           Remove Gradient_info (index)
        end
        Liver_image ← [Ls=2]
```

Where Region_growing_Threshold is a specified threshold value grater then zero, and *Mini_gradient_value* is a value initialized to zero at the beginning of the implementation. *Gradient_info* is a 2D array where the horizontal coordinate, the vertical coordinate and the diagonal gradient value for each boundary pixel are stored in each row in *Gradient_info*. Pixels of the liver in the diagonal gradient image are extracted using the liver seed region in I_{ss}, and the mean (Mg) and the standard deviation (Sg) values are calculated. *Ls* is a 2D array (same size as I_{ss}) where each element is assigned to one of three different values: 2 as a liver pixel (extracted from the liver seed region), 1 as an added pixel to *Gradient_info* and 0 as an un-added pixel to *Gradient_info*. The mini function returns the minimum absolute value of subtracting the diagonal gradient values stored in 3rd column of *Gradient_info* from *Mg* value and assigns it to *Mini_gradient_value*. The mini function returns the index of the minimum absolute value as well. The row in *Gradient_info* pointed by the index contains the location of a pixel which will be considered as a liver pixel. After that, the eight neighbor pixels of the current liver segmented pixel will be tested to check whether each one should be added to the *Gradient_info* or not. Then the row that contains the current liver pixel segmented information is removed from *Gradient_info*. The iteration process will continue in this manner until all the diagonal gradient values stored in *Gradient_info* are greater than *Region_growing_Threshold*. Finally, the segmented liver in the I_{ss} using region growing algorithm will be processed using morphological close operation.

In some cases, region growing result of segmenting the liver in I_{ss} does not reach to a satisfactory level. To improve the segmentation result, a new method to extend the segmented liver region until it reach to the actual boundary of the liver is proposed (liver extension method). The method is presented as following:

Step 1: Apply canny edge detection on I_{ss} (*CE*).

Step 2: Find the boundary of the initial segmented liver.

Step 3: Compute the Euclidean distance transform (*EDT*) using *CE*. Each pixel will be presented by the distance between that pixel and the nearest nonzero pixel of *CE* and the index of the nearest nonzero pixel of *CE*.

Step 4: Locate the coordinates of the segmented liver boundary pixels in *EDT* using the binary image from Step 2.

Step 5: Liver boundary pixels which are indexed to the same nearest nonzero pixel of *CE* are grouped and dilated using a disk structural element. The size of the structural element is equal to the minim distance in the group.

Step 6: The resulted image will be added to the segmented liver resulted from applying the region growing and morphologically filtered and smoothed.

For better understanding for the proposed method, the following illustration is presented. In Fig. 6(a), the inner oblong can be considered as the boundary of the initial segmented liver and the outside edge map can be considered as the results of the canny edge detection operation. In many cases where attached organs present, the canny edge usually fail to find the edge between the liver and the attached organs. Here, the edge map demonstrates a case where an oblong object is attached to a circular object and they both share the same gray-scales.

By ignoring Step 5, pixels inside the red frame in Fig. 6(a) will be indexed to one of the two red dots pixels, and by using the distances from the pixels inside the red frame to these two red dots, the dilated region will pass the desired boundary as shown in Fig. 6(b). In Step 5, the proposed method solved this problem, where half of the pixels in the red frame are indexed to the right red dot pixel and the other half are indexed to the left red dot pixel. By only considering the minimum distances to these two red dots, the dilation will not pass the desired boundary as shown in Fig. 6(c). Fig. 7 shows the final result of segmenting the liver in the staring slices for two subjects. Fig. 7(a) and (c) are the initial segmentation results, and Fig. 7(b) and. (d) are the results of applying the proposed enhancement method.
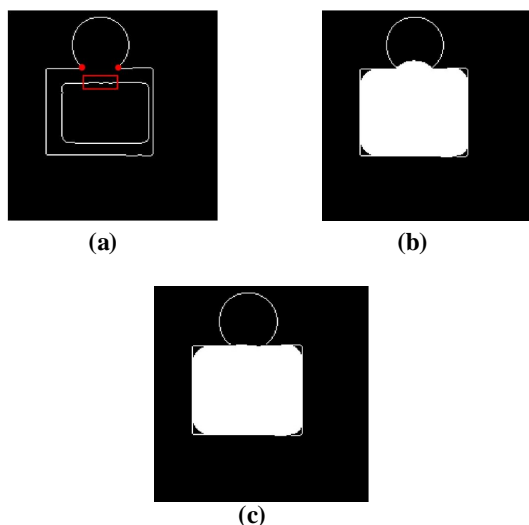
(a) **(b)**

(c)

Figure 6, Liver segmentation enhancement method demonstrations. (a) Original case, (b) result of the conventional dilation, (b) result of the proposed dilation

(a) **(b)**

(c) **(d)**

Figure 7, Final liver segmentation in the starting slices

The liver in the subsequent and previous NCT slices (Block B and C in Fig. 1) in the dataset of a subject will be segmented using the same process used to segment the liver in I_{ss} with some modifications. The liver segmentation process in the subsequent and previous NCT slices can be summarized as following

- The previous segmented liver will be eroded using adaptive structural element. The size of the structural element based on the size of the segmented liver.
- The projection of the eroded region on the current NCT slice will be used to find new parameters. The current NCT slice will be thresholded using the new parameters. The eroded region will also be utilized as the seed region on the region growing algorithm.
- The skin, abdomen wall muscles and the right bottom quarter of the current NCT slice will be removed and the region growing algorithm will be applied to the current NCT slice as in I_{ss}.
- Elementary logical and operation between the resulted binary image from applying region growing algorithm and the segmented liver in the previous NCT slice will be applied.
- Finally, the liver extension method is applied on the resulted image.
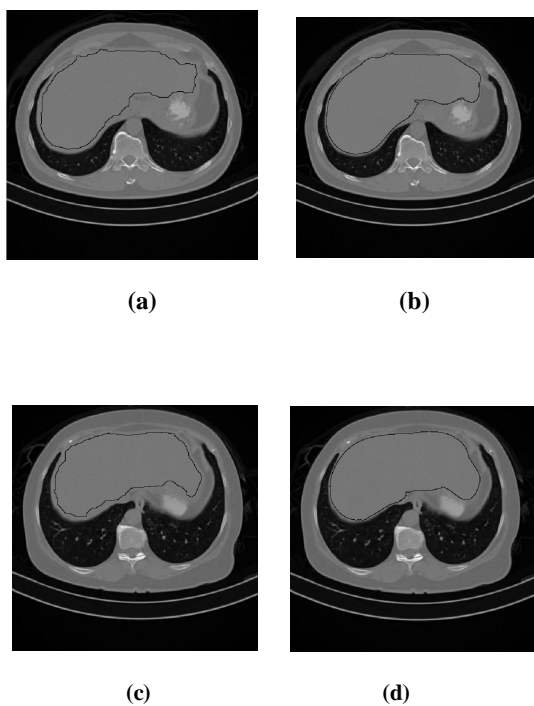
The first point in the modification list states that the segmented liver from the previous NCT slice will be eroded. In the I_{ss} subsequent NCT slices, if the liver is presented in two regions, there is a great chance that the liver region with the smaller size to be removed as a result of the erosion operation. Therefore, each region will be eroded separately using a structural element where its size depends on the size of the region. Having the same situation for the I_{ss} previous NCT slices indicates that one of them is the heart region. To overcome this problem, a simple procedure but yet effective is proposed. Since all the patients are scanned from the top of the lung, the heart will defiantly appear in the first slice. A binary mask for the heart will be created using this first slice. This binary image is produced by thresholding the NCT image using Otsu thresholding and eliminating the skin and the muscles. At this point, the processed NCT image contains the heart and some parts of the muscles. A set of morphological operations will be used to cut any connection between the heart and any remained tissues from the muscles. Then, the region with the maximum number of foreground pixels (which presents the heart) will be selected to present the binary mask of the heart. NCT slices which precede the I_{ss} will be segmented with one additional step. After eroding the segmented liver in the previous NCT slice, the eroded image will be tested to check whether the liver is segmented as two regions or one region. In case where the liver is segmented in two regions, each one of them will be compared to the heart binary mask, and the one with an overlap that exceed a specified threshold value will be considered as the heart and it will be eliminated.

Once the elimination is done, there will be no need for checking the segmented liver any more.

Finally, the segmented liver in the NCT slices will be gathered to build a 3D liver binary image. The 3D binary image will be scanned through the X, Y, and Z axes. For each axis scan, each 2D binary image will be filtered using median filter. Closing and opening morphological operations will be applied as well.

PARAMETERS ANALYSIS

The suggested method consists of different morphological parameters and threshold values related to morphological operations. These values are not decisive values. The values have been selected to serve the purpose of used morphological operation associated with minimizing of any source of error. Thresholding I_{ss} Gaussian gradients image is implemented using α2. This factor has been assigned to a small value (0.75) in order to minimize the chances for non-liver regions to be segmented incorrectly. Results show that the initial liver region in I_{ss} (for all of the employed subjects) has been obtained sufficiently. Fig. 8 shows some samples of the initial liver regions highlighted using black contours.
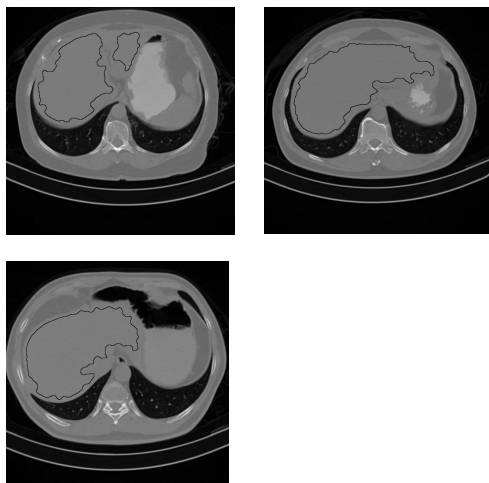

Figure 8, Samples of I_{ss} from different subjects highlighting the liver initial segmented regions

Choosing a value for the factor α1 is an important step which effects on the region growing implementation. Attached organs to the liver like the kidney, gallbladder and pancreases share a very close range of gray levels. Therefore, α1 is required to be assigned to a value that minimizes any error that may accrue because the similarity of pixel intensities of the liver and the other organs. Experimentally, it has been noticed that assigning α1 to a value greater than 1 leads to increases the chances for segmenting some non-liver tissues as liver. It has been noticed also that assigning α1 to a value less than 1 may leads to a miss classification for parts of the liver region in the NCT slice. In the other hand, assigning α1 to a value less than 1 helps to reduce the chances for the kidney, gallbladder, pancreas, heart and the parts of digestive system to be segmented as a liver. To overcome the problem of the liver regions that have been discarded (as a result of using α1 to a value less than 1), a morphological close operation using a disk structuring element with size 2X2 is applied to the thresholded NCT slice. Therefore, α1 is assigned to the value 0.75.

The diagonal Gaussian gradient version of the NCT slice presents the organs surfaces as homogenous regions with low gradient values and the edge areas are presented with higher gradient values. The region growing algorithm utilized this advantage in order to extend the liver seed region to meet the boundary of the liver. Two important parameters control the quality of the results of the region growing algorithm implementation: The standard deviation of the 2D Gaussian kernel (*GK*) and the threshold value (*Region_growing_Threshold*). In addition to those two parameters, specifying the Gaussian kernel window size has been done in an adaptive way. The greater the GK value is the bigger the window size will be. The effects of varies values for *GK* and *Thmp* have been tested on the performance of the proposed liver segmentation method. A general conclusion can be summarized as following:

- Raising *GK* and *Thmp* at the same time will keep the results of the final liver segmentation unchanged.

- Keeping *GK* at a specific value and decreasing the value of *Thmp* leads to miss classifying for some regions of the liver in some cases.

- Keeping *GK* at a specific value and increasing the value of *Thmp* leads to better classifying for the liver tissues (comparing to the previous situation), but it also increases the error of segmenting the attached organs as liver in some cases.

Experimentally, it has been found that using *GK* equal to 3 and *Thmp* equal to 20 with the exists of the previously segmented NCT slice and the help of the liver extending method, all together helps to obtain a satisfactory result.

EVALUATION MESUREMENTS

Due to the lack of the dataset of NCT images where the liver is segmented manually, and due to the fact that the manual segmentation by medical experts is a laborious and expensive process, the proposed liver segmentation method is evaluated subjectively by a two expert radiologists. For each subject, each radiologist is asked to evaluate the results of the segmented liver in each NCT data set based on his/her observation.

RESULTS

The expert radiologists evaluated the suggested liver segmentation method by ranking the segmented liver and the ability of the method to separate the non-liver tissues as well done, with minor error or with major error. Fig. 9 shows side and front views for 4 subjects where the liver is bounded by black contours.

The radiologists reported one subject where the liver is segmented with a major error. The reason for this observation is that the proposed method fails to cover an abnormal lesion in the left lobe. In fact, the proposed method is designed to exclude any abnormal lesions that may appear in the segmented liver in order to have clear vision about the diffused fat in the liver. Regardless of this case, the liver in all the other subjects have been ranked as well segmented and well segmented with miner error. According to the ability of the method to distinguish liver tissues from non-liver tissues, the radiologists reported that the method shows a good capability to implement the task. However, the radiologists noticed that in some rare cases, small parts of the kidney, gallbladder and bowel has been segmented as a liver. They ranked this error as a minor error.

Experimental Results explain that the execution time of the liver segmentation method depends on the number of slices that contain the liver in the data set of a subject. The execution for the liver segmentation in a single slice in the other hand based on the size of the liver in that NCT slice, the greater the area the liver cover in the NCT slice, the longer the execution time will be. The average of the recorded execution times for segmenting the liver in the data sets is found to be equal to 6.02 minutes and the standard deviation is found to be equal to 1.02 minutes. Fig. 10 shows the relationship between the number of the liver NCT slices and the execution time.
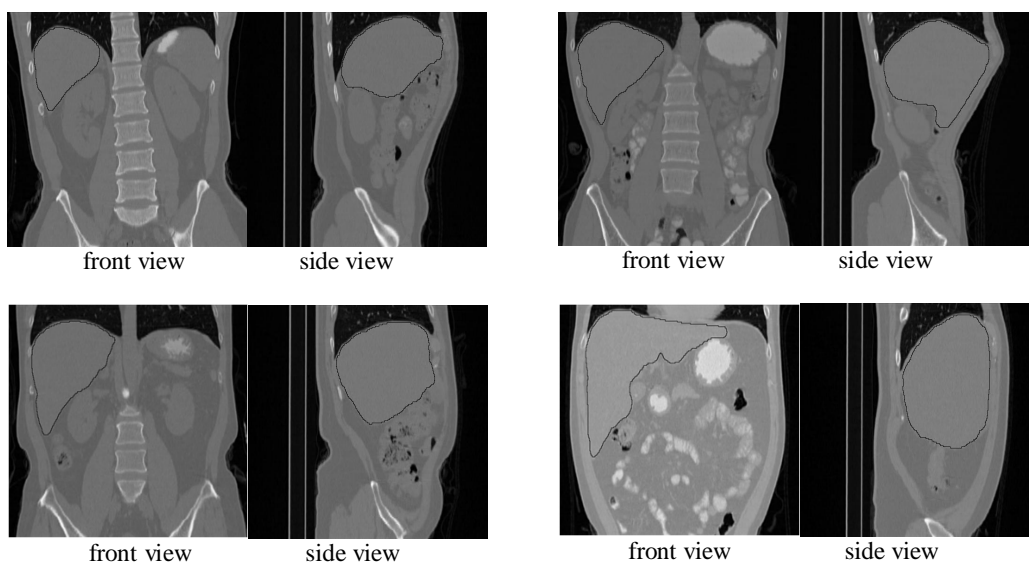

front view   side view

front view   side view

front view   side view

front view   side view

Figure 9, Samples of the results of the liver segmentation method
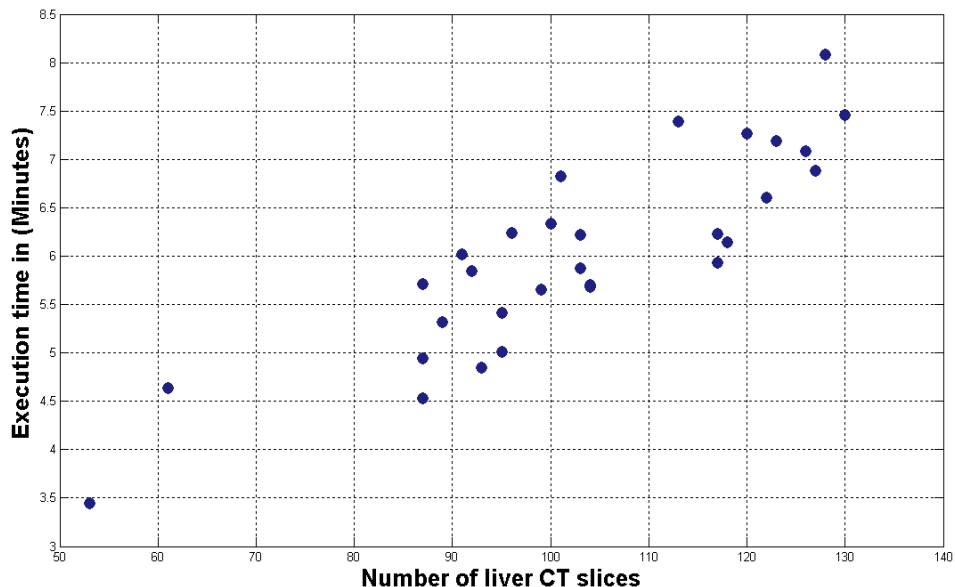
Figure 10, Number of liver slices and the required time for execution

DISCUSSION

A general observation for the total outcomes of applying the suggested liver segmentation method on the entire 30 subjects shows that the method successfully implements the segmentation operation. Also, the proposed method shows a robustness capability to separate non-liver tissues from the liver tissues. With the great overlap between the liver and the kidney, pancreas, gallbladder and muscle tissues, the method almost didn't misclassify any of these organs and tissues with the liver. However, partitions of sharp corners of the liver in some NCT images present a problem, where the liver segmentation method didn't segment these parts. Fig. 11 shows some cases where the ability of the method to separate the liver from the other organs is highlighted and also where the sharp corners of liver are pointed by the red arrows. The segmented liver is bounded by the black contour. The window level system of NCT

Images in Fig. 11 are adjusted so non-liver tissues will be noticeable easier by the human vision system. One of the limitations of the proposed approach is its incapacity to segment abnormal liver tissues. Also in some rare cases, part of the heart is segmented and considered as the liver. Apart from similarities between tissues in NCT, partial volume effects also present a problem where a single pixel may contain a mixture of multiple tissues. However, the set of the employed morphological filtering operations helped to limit this problem by eliminating these pixels. As a side effect of this elimination, the segmented liver looks like an eroded version of a correct segmented liver (i.e. few pixels from the boundary of the liver are no considered as liver).as a final result of this side effect, the evaluation of the diffused fat in the liver will not get effect by these few liver misclassified pixels.
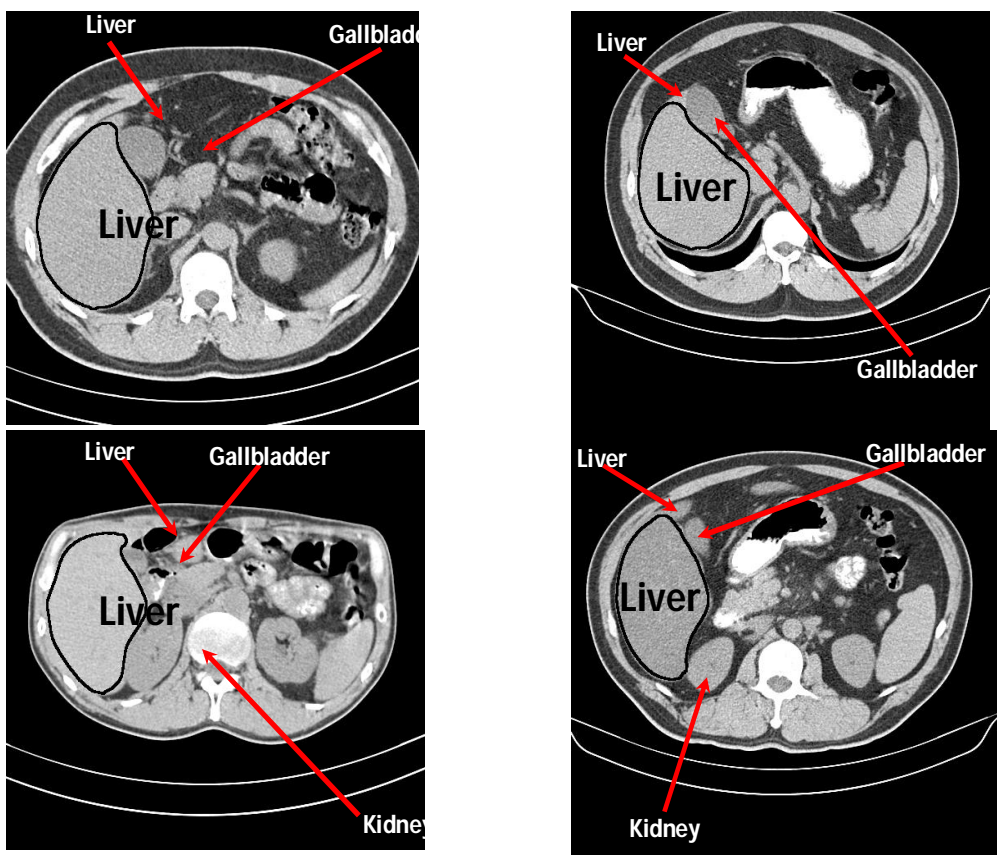
Figure 11, Samples from the segmented liver in cross section CT images

CONCLUSION

A liver segmentation approach is suggested in this paper. This method is designed to minimize the chances for segmenting non-liver tissues as liver tissues. The proposed method is depending on including the Gray level information, Gaussian gradients transformation, area growing algorithm, distance transformation, anatomic information to complete the task and canny edge detector of segmenting the whole liver using non-contrast enhanced NCT data. Due to the lack of a golden standard manually liver segmented data, the method has been evaluated subjectively. The subjective results show a great capability to separate attached organs from the liver. The capability of the method to segment the liver tissues did not reach to a great level as well as the method capability to separate attached organs. However, these results can be considered as satisfactory results according to the main purpose of the study.

REFERENCES

[1] Mharib AM, Ramli AR, Mashohor S and Mahmood RB **"Survey on liver CT image segmentation methods"**, Artif Intell Rev. DOI 10.1007/s10462-011-9220-3, 2011.

[2] Campadelli P and Casiraghi E **"Liver Segmentation from CT Scans: A Survey"**, Applications of Fuzzy Sets Theory, Lecture Notes in Computer Science. 4578: 520-528, 2007.

[3] Heimann T, et.al. **"Comparison and Evaluation of Methods for Liver Segmentation from CT Datasets"**, IEEE Trans Med Imaging. 28(8):1251-1265, 2009.

[4] Campadelli P, Casiraghi E and Esposito A **," Liver segmentation from computed tomography scans: A survey and a new algorithm"**, Art. Intel. in Med. 45(2-3):185-196, 2009.

[5] Gao L, Heath DG and Fishman EK, **"Abdominal image segmentation using three-dimensional deformable models"**, Investiga Radiol. 33(6):348-355, 1998.

[6] Montagnat J and Delingette H,**" Volumetric medical images segmentation using shape constrained deformable models",** Proceedings of the First Joint Conference on Computer Vision, Virtual Reality and Robotics in Medicine and Medial Robotics and Computer-Assisted Surgery. pp 13–22, London, UK, 1997.

[7] Soler L, Delingette H, Malandain G, Montagnat J, Ayache N, Clement J, Koehl C, Dourthe O, Mutter D and Marescaux J,**" Fully automatic anatomical, pathological, and functional segmentation from ct scans for hepatic surgery",** Comput Aided Surg. 6(3):131-142, 2001.

[8] Hans L, Thomas L and Martin S , **"Segmentation of the liver using a 3d statistical shape model",** ZIB Report 04-09, pp. 1-25, 2004.

[9] Dagmar K, Thomas L and Hans L, **"Shape constrained automatic segmentation of the liver based on a heuristic intensity model",** Proceedings of 3D Segmentation in the Clinic: A Grand Challenge, MICCAI Workshop. pp. 109-116, 2007.

[10] Tobias H, Hans-Peter M and Ivo W **"A statistical deformable model for the segmentation of liver CT volumes",** Proceedings of 3D Segmentation in the Clinic: A Grand Challenge, MICCAI Workshop. pp. 161-166, 2007.

[11] Dieter S, Pieter S, Yves L, Jeroen H, Dirk L, Frederik M and Paul S ,**"Landmark based liver segmentation using local shape and local intensity models",** Proceedings of 3D Segmentation in the Clinic: A Grand Challenge, MICCAI Workshop. pp. 135-142, 2007.

[12] Eva VR, Yulia A and Bram VG, **"Automatic segmentation of the liver in computed tomography scans with voxel classification and atlas matching",** Proceedings of 3D Segmentation in the Clinic: A Grand Challenge, MICCAI Workshop. pp. 101-108, 2007.

[13] Rusko L, Bekes G, Nemeth G and Fidrich M,**" Fully automatic liver segmentation for contrast-enhanced CT images",** Proceedings of 3D Segmentation in the Clinic: A Grand Challenge, MICCAI Workshop. pp. 143-150, 2007.

[14] Ruchaneewan S, Daniela SR, and Jacob F, **"A hybrid approach for liver segmentation",** Proceedings of 3D Segmentation in the Clinic: A Grand Challenge, MICCAI Workshop. pp. 151-160, 2007.

[15] Lim SJ, Jeong YY and Ho YS,**" Segmentation of the liver using the deformable contour method on CT images",** Advances in multimedia information processing (PCM 2005), 6th Pacific Rim Conference on Multimedia. 3767:570-581, Jeju Island, Korea, 2005.

[16] Lim SJ, Jeong YY and Ho YS **"Automatic liver segmentation for volume measurement in ct images",** JVCIR. 17(4): 860-875, 2006.

[17] Lim SJ, Jeong YY and Ho YS, **"Automatic segmentation of the liver in ct images using the watershed algorithm based on morphological filtering", Proceedings of SPIE medical imaging, Lecture** notes in computer science. 5370:1658-1666, 2004.

[18] Liu F, Zhao B, Kijewski PK, Wang L and Schwartz LH **," Liver segmentation for ct images using gvf snake",** Med Phys. 32(12): 3699-3706, 2005.

[19] Tsai D and Tanahashi N,**" Neural-network-based boundary detection of liver structure in ct images for 3-d visualization",** Proceedings of IEEE International Conference on Neural Networks. 6(1):3484–3489, Orlando, FL, USA, 1994.

[20] Koss JE, Newman FD, Johnson TK and Kirch DL, **"Abdominal organ segmentation using texture transforms and a Hopfield neural network",** IEEE Trans Med Imaging. 18(7): 640-648, 1999.

[21] Lee CC, Chung PC, and Tsa H ,**" Identifying multiple abdominal organs from ct image series using a multimodule contextual neural network and spatial fuzzy rules",** IEEE Trans Inf Technol Biomed. 7(3):208-217, 2003.

[22] Foruzan AH, Aghaeizadeh ZR, Hori M, and Sato Y, **" Liver segmentation by intensity analysis and anatomical information in multi-slice CT images",** Int J Comput Assist Radiol Surg. 4(3): 287-97, 2009.

[23] Pil UK, Yun JL, Youngjin J, Jin HC, and Myoung NK ,**" Liver extraction in the abdominal CT image by watershed segmentation algorithm",** World Congress on Medical Physics and Biomedical Engineering. 14(15):2563-2566, 2006.

[24] Otsu N ,**" A threshold selection method from gray-level histograms"** IEEE Trans. Syst, Man Cyber. 9(1):62-66, 1979.

[25] Xiaobo Z, Liang JP, Bradley NP, and Stephen W ,**" Automated Segmentation of Drosophila RNAi Fluorescence Cellular Images using Deformable Models",** IEEE Trans. Circ. and Sys. 53(11): 2415-2424, 2006.