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An Automated System for Atlas Based Multiple Organ Segmentation of Abdominal CT Images

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Abstract

In this paper, an efficient atlas based approach for multiple abdominal organ segmentation is presented. This automatic segmentation of different organs such as spine, kidneys, liver, aorta, spleen of abdominal image is based on allocation of spine as landmark. In current years several researches has been done for developing automatic segmentation techniques of abdominal CT images however still it is an incredibly challenging task to segment this efficiently and appropriately. This paper proposed a fully automatic system for abdominal image segmentation by marking spine as landmark to extract different organs using a fuzzy based system. The proposed technique uses the fact that multiple organs of abdominal images are situated at a particular distance and in particular range of angles from the spine and spine is the solitary organ which is frequent in the slices of CT image data set. In this paper we focused for the segmentation of liver, kidney, aorta, spine, spleen. This system is evaluated on the data of several patients (152 CT images which consist all such organs) and obtained significant results by comparing the computed results to the boundaries manually traced by experts.

Keywords: Image segmentation; abdominal imaging; medical imaging; atlas; landmark allocation.

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1 Introduction

Image Segmentation is one of the most important issues of several imaging applications especially in case of Medical Imaging. Efficient automatic segmentation of abdominal image is still a very challenging task as it deals with the internal structure of the patient, these structures can be anatomical organs but also pathological lesions. Automatic segmentation of the anatomical organs from the large image data set is having severe interest by researchers or scientists as it permits the radiologist to assist in diagnosis, by detecting possibly forgotten lesions, and also to accelerate the process of analysis [1]. If we talk about abdominal image segmentation multi-region image segmentation is a major task in abdominal imaging. Due to poor resolution and weak contrast this task is difficult in the presence of noise and artifacts [2,3].

Therefore the automatic segmentation of the abdominal image plays an important role in the study of the function of kidney, liver, spine, aorta etc.

After go through the literature survey we found that till now several techniques has been proposed for automatic individual organ segmentation and multi organ segmentation from abdominal images like Daw-Tung Lin et al. proposed method for kidney segmentation on abdominal CT images by allocation of spine as landmark and adaptive region growing [4] average correlation coefficient obtained in that 88% between automatic and manual segmentation which is significantly good. Oussema Zayane et al. worked on automatic liver segmentation using basic operations of image processing like thresholding, edge detection, median filtering, and basic morphological operations with good results [1]. Ritu punia et al. [5] reviewed techniques of automatic liver segmentation based on neural network based [6,11], Support vector machine based [12,15], Clustering based [16,20], Hybrid techniques [21,24]. Qing Luo et al. used graph cuts method for segmentation of abdomen MR images especially for liver and kidneys. They used region growing method and morphological operations for initial contour detection than shape priors obtained by training the shape template constructed by integrating the shape priors into the kernel graph cuts energy function [25]. Paola Campadelli et al. proposed automated system for abdominal organ segmentation like heart, bones (i.e. ribs and spine), liver and its blood vessels, kidneys, and spleen [26]. A. Shimizua et al. [27] suggested concurrent extraction of multiple organs from abdominal CT images using process of abdominal cavity standardization with feature database and atlas guided segmentation incorporating parameter estimation for organ segmentation. Regina Pohle et al. proposed abdominal image segmentation using adaptive region growing [28].

The objective of this method is to combine efficient segmentation technique of different abdominal organs such as adaptive region growing method for segmentation of kidney, adaptive thresholding technique for liver segmentation, abdominal architecture for spine allocation, watershed method for spleen segmentation and for aorta segmentation we used structural design of abdominal CT image.

2 Implementation

Our implementation consist three major steps given as below

1. Allocation of Spine as landmark (as described as below)
2. Extraction of ROI (Region of Interest) located at particular distance and direction from spine
3. Extraction of Required Organ by applying appropriate algorithm in particular region of interest

Basic flow chart of the above system is given below

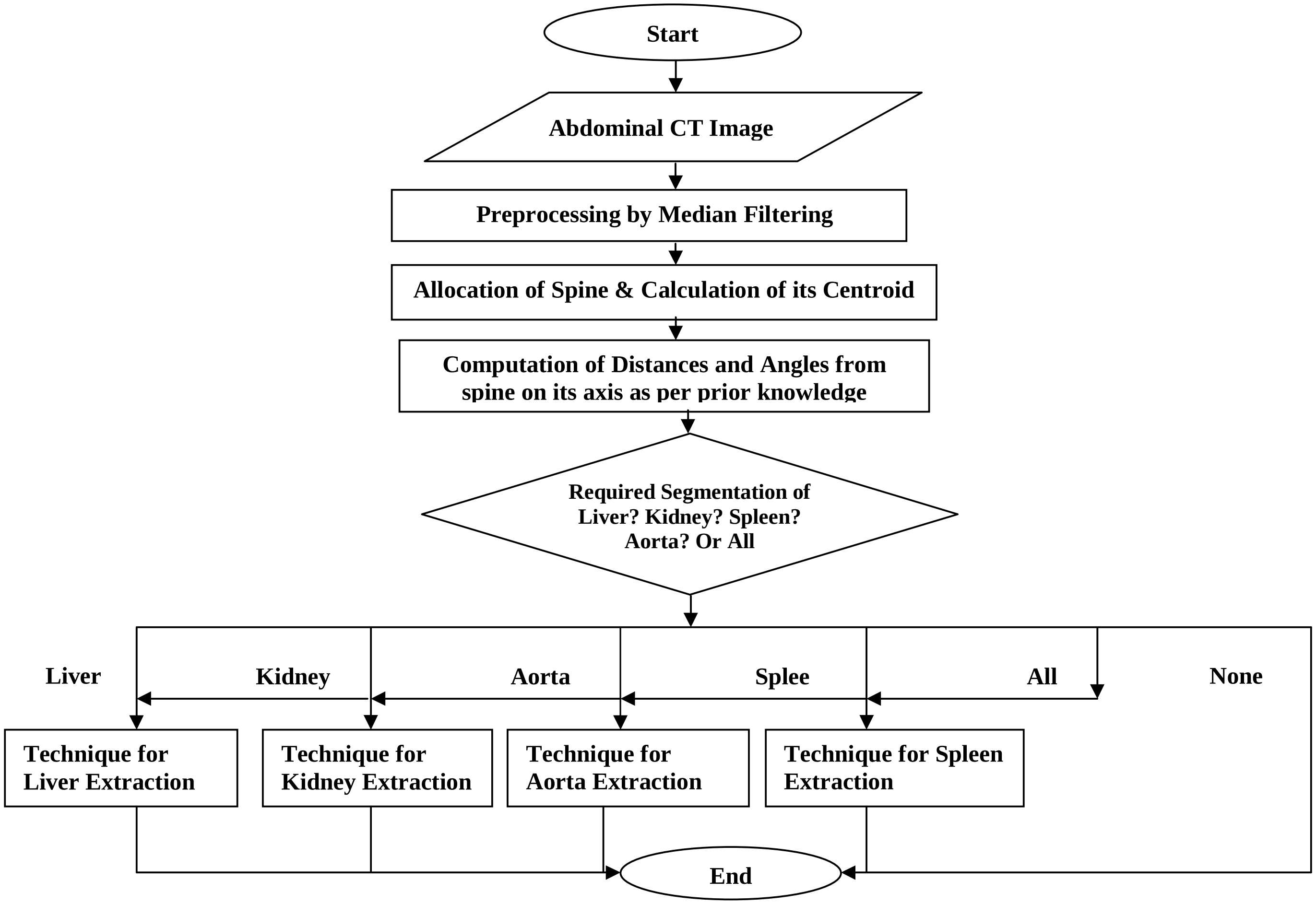

Fig. 1. Flow chart of the proposed system

Description of the major steps are given below.

2.1 Median Filtering

Preprocessing of the abdominal image is very necessary to reduce the noise and for the further image analysis. It is the main and challenging factor in the computer-aided analytic systems [30]. The pre-processing is extremely required for MR/CT images: Images are to be made more suitable for further processing in CAD systems, the image quality needs to be enhanced, and Noise in the image needs to be removed [31]. To reduce the noise and in homogeneities in the image, we used the Median Filtering. Main purpose to use this is to reduce noise and enhancement of the edges of image [32].

Median filtering provides an efficient way to do the same [3 reference]. Basic Steps of median filtering are given below discussed in [29].

It replaces each pixel value with the median of the gray values in the region of pixel:

1. Take a 3 x 3 (or 5 x 5 etc.) region centered around pixel (i,j)
2. Sort the intensity values of the pixels in the region into ascending order
3. Select the middle value as the new value of pixel (i,j)

Computation of Median Value is given below

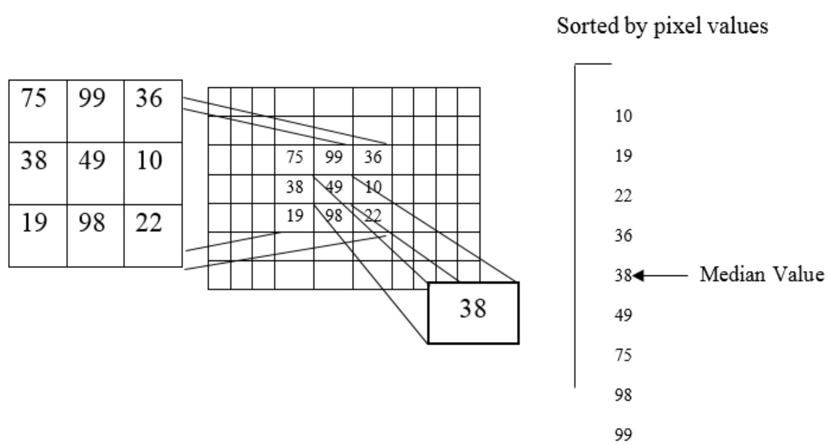

Fig. 2. Computation of median value [29]

2.2 Allocation of Spine and the Measurement of Angles and Distances

To locate spine in an abdominal image after detecting abdominal cavity described as in [4] we have performed the following steps. Let l1 and l2 be the length of the horizontal and vertical axis respectively, spine is positioned at the location ($0.5l_1$, $0.56l_2$) as X in the following Figure.

We have shifted the origin of the axis at centroid of the spine as show in the Fig. 4.

Once the spine is located we started to calculate angles and distance from the horizontal axis of spine from given ten data sets as shown. Than we found that in most of the slices aorta is specifically situated at the angle of 85° to 145°. Liver is situated at certain angle and distance. Spleen is also situated .certain angle and distance and both of the kidneys presents at the inclination of 40° to 80°. We are considering the fact in our research that spine presents frequently in the slices of abdominal set and all other organs like kidney, spleen, liver can be viewed in certain slices for doing the same we have analyzed 152 images consists all such organs and by referring Tsaggaan's Report [33].

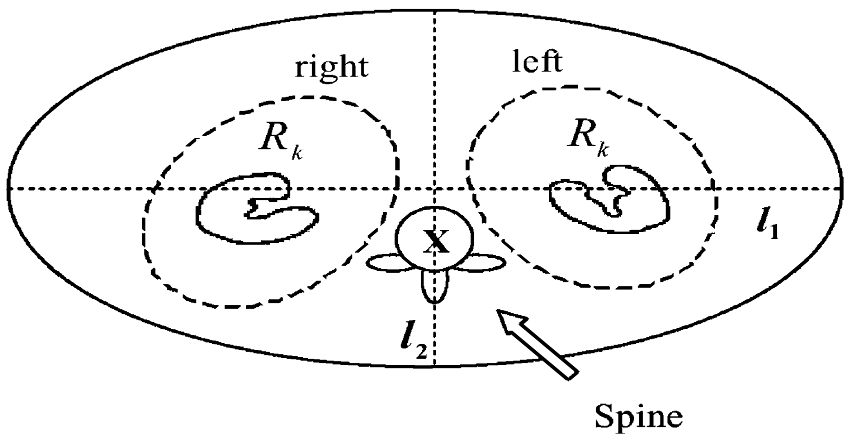

Fig. 3. Abdominal region [4]

2.3 Liver Region Extraction and Its Segmentation

After examined huge data set of abdominal images we found that liver is situated mainly in second coordinate with some portion on part III as per origin on spine shown in the following figure.

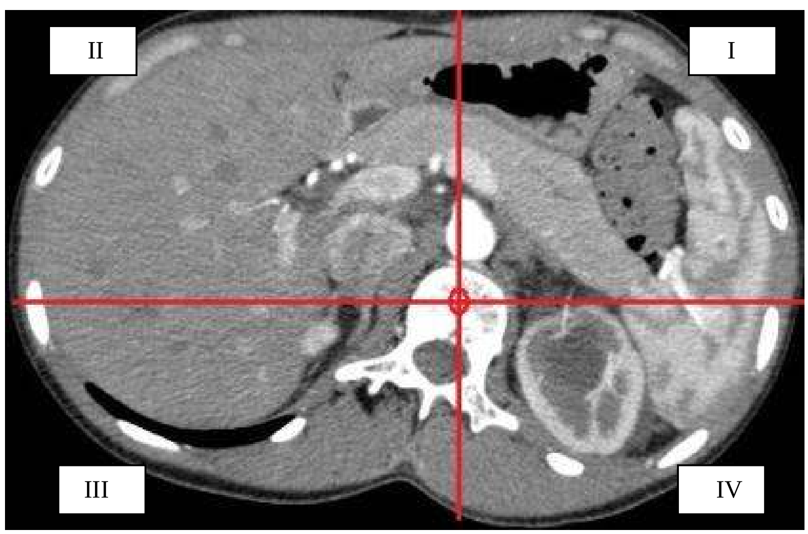

Fig. 4. Origin located at centroid of spine

Basically it is positioned in the higher right quadrant of the abdomen, right part of the abdomen and on top of the intestines. With the relative orientation from spine, liver consisting part of abdominal image has been cropped out automatically and further following operation has been carried out on candidate ROI for liver segmentation [38-41,43].

1. Adaptive Thresholding
2. Basic Morphological Operation
3. Extraction of liver boundary
4. Segmentation of Liver

Adaptive thresholding is also known as dynamic Thresholding. Ideally, In this image is devided into many overlapping sub images. The histograms of all the sub images are constructed and the local thresholds are obtained. Then the threshold value is obtained by interpolating the result of sub images.

For the liver segmentation point of view we have used Mean + Constant or Median + Constant statistics to lo locally apply in to the overlapping sub regions.

After obtaining the thresholded image morphological close operation is applied to fill in holes and small gaps in the extracted image. We used 8-connected neighbors to keep the block whose region is the biggest and set the others to zero. After this step binary liver mask is obtained.

Then we take out the liver periphery by setting a pixel to 0 if its 4-connected neighbors are all 1's, thus leaving only boundary pixels.

Multiply the original liver CT image with the liver masked image to obtain the final segmented liver region with gray level values as those of original image.

2.4 Kidney Region Extraction and Its Segmentation

After analyzing several abdominal CT images and as mentioned in [4] both kidneys appears in abdominal at inclination of 40°-80° if we are considering middle slices of the sequence of CT scan data sets. To extract regions of both the kidneys we implemented the following steps.

1. From the centroid location of spine move towards both the side of spine to extract candidate kidney regions.
2. Elliptic candidate kidney region taking out with progressive positioning on the successive CT slices.
3. Once the candidate kidney region is found for both kidneys adaptive region growing has been applied.
4. Region Modification and both kidney segmentation (Based on the priori knowledge of the shape of kidney)

Detailed description of kidney segmentation is given in our research paper [30].

2.5 Aorta Region Extraction and Its Segmentation

Aorta is also a very important organ for radiologists to analyze abdominal CT images. When we analyzed numerous datasets of abdominal images and after calculating distances and angles from spine we have found that its candidate region is mostly situated between angles 90° to 135° with certain distance oriented from spine. After extracting the interested region we have done basic operations of image processing given as below

1. Extract region of aorta at certain angle by creating circular mask based on prior knowledge of abdominal image.
2. Basic Morphological operations like dilation, filling and erosion one by one.
3. Creation of boundary of aorta.

2.6 Spleen Region Extraction and Its Segmentation

For the point of view of spleen segmentation we used watershed approach as discussed in [34] after detecting the region of interest of spleen at certain angle and distance from spine. After observing several CT data set we found that area of spleen is situated at the right side of spine we certain distance and angle. Our approach is different from [34] in such a way that we firstly extracted ROI of spleen from the landmark pointed as spine. After extracting region of interest we apply following step to segment out spleen.

1. Determination of region of interest marked from the spine at right side from the angle 60° to -70° at certain distance.
2. Smoothing by anistropic filter as given in [34]
3. Basic Morphological operations.
4. Watershed Segmentation
5. Spleen Segmentation

Evaluation of the proposed system is tested by finding the correlation among automatic segmentation S_1 and manual segmentation (Traced by Experts) S_2 using Dice similarity coefficient [4,35-37] with following equation

$$I\ (S_1, S_2) = (S_1 \cap S_2)/(S_1 \cup S_2) \quad (1)$$

3 Experimental Setup and Results

The experiments performed in this paper estimate the performance of the designed automated system to extract multiple soft tissues of abdomen.

Dataset: The Medical data was provided by Department of Radio diagnosis & Imaging, Institute of Medical Sciences, Banaras Hindu University, Varanasi, India of several patients. However, we considered those slices (152 slices) in which all the organs such as liver, kidneys, aorta, spleen appears.

3.1 Computing Environment

3.1.1 Design of Hardware used

Processor: Intel Core i7 -3770 CPU @340 GHz
RAM (Random Access Memory): 4 GB
Hard Disk Drive: 320 GB

3.1.2 Design of Software used

System Type: 64 Bit operating System, x – 64- based processor.

Development Tools: MATLAB

Average Correlation Coefficient for Spine Segmentation: 98%
Average Correlation Coefficient for Aorta Segmentation: 95%
Average Correlation Coefficient for Liver Segmentation: 87%
Average Correlation Coefficient for Kidneys Segmentation: 81.5%
Average Correlation Coefficient for Spleen Segmentation: 78%
Now we are going to present some random results achieved from our implementation

Extraction Result from Arbitrary Slice of Random Data Set

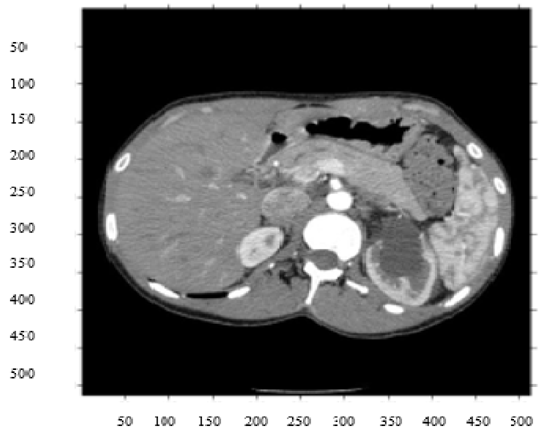

Fig. 5. Original abdominal CT slice

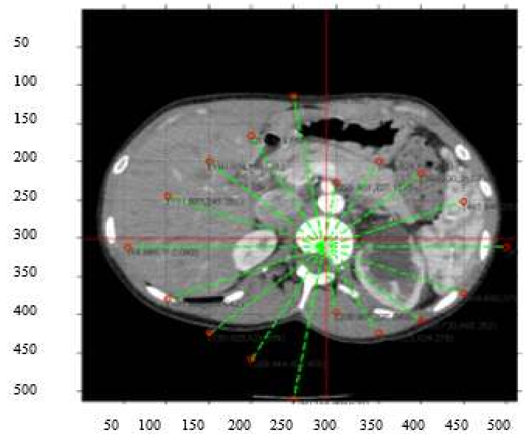

Fig. 6. Angles and distance in different directions from spine

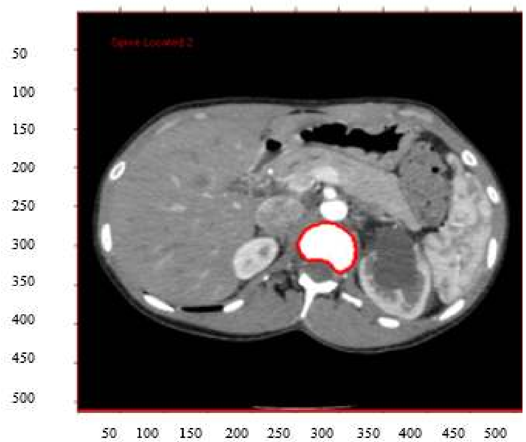

Fig. 7. Spine as landmarks

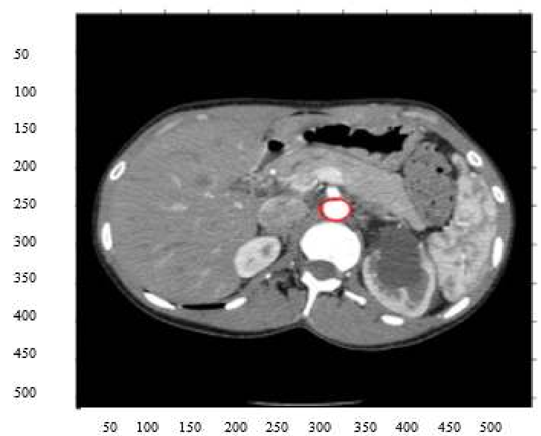

Fig. 8. A Segmented aorta outlined

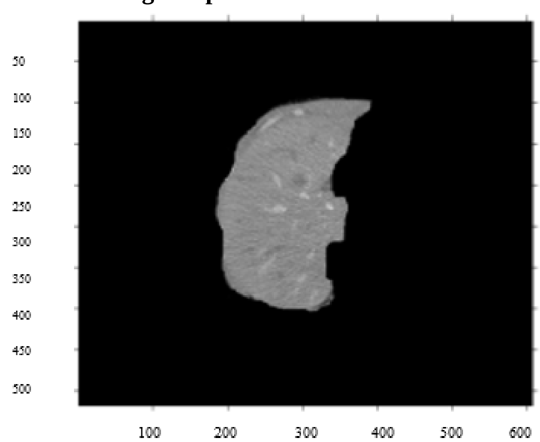

Fig. 8. B Segmented liver

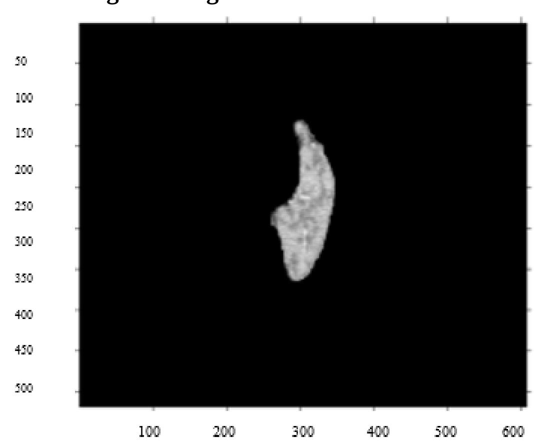

Fig. 9. Segmented spleen

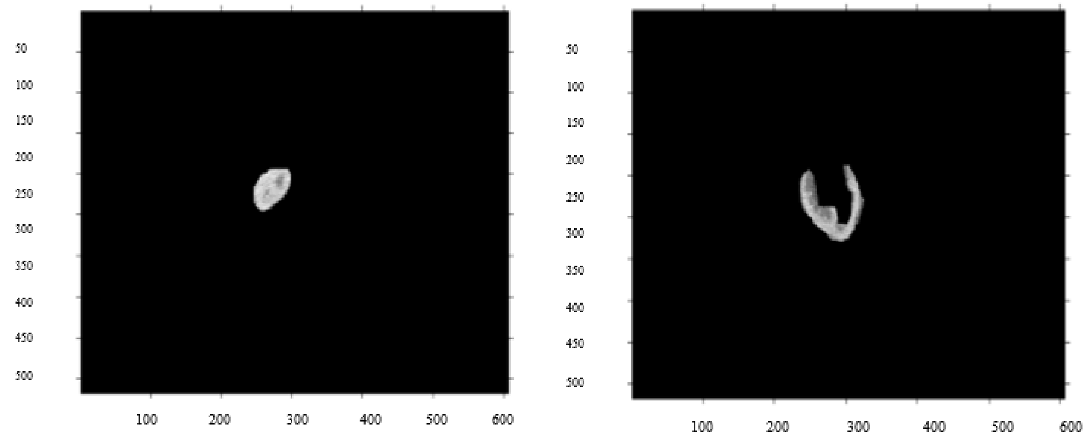

Fig. 10. Segmented kidneys

Extraction Result from Arbitrary Slices of Other Data Set

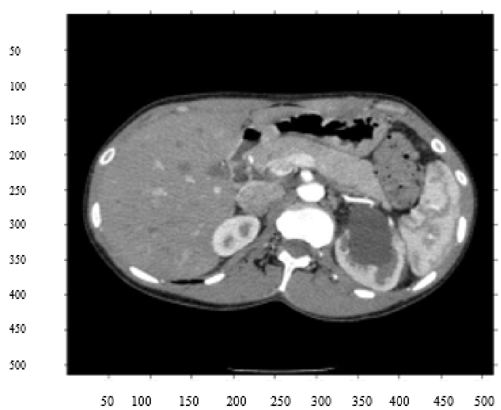

Fig. 11. Original abdominal CT slice

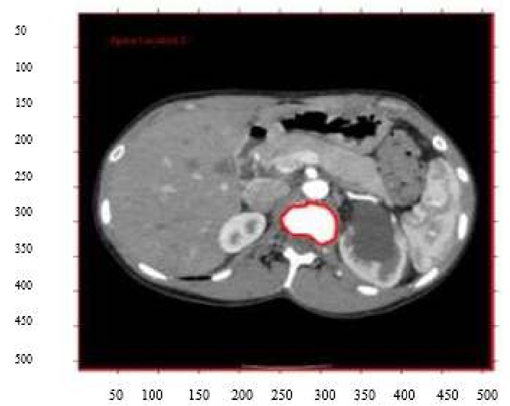

Fig. 12. Spine as landmarks

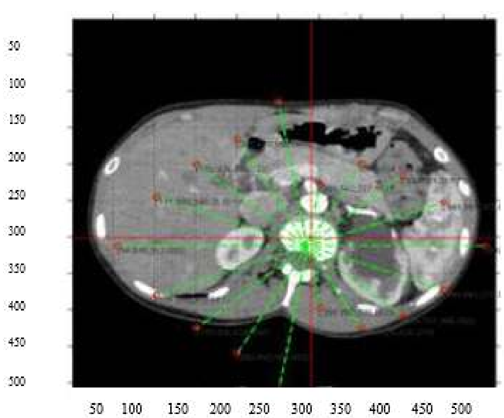

Fig. 13. Angles and distance in different directions from spine

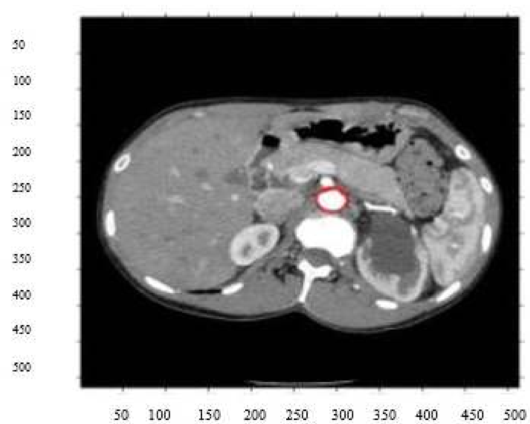

Fig. 14. Segmented Aorta outlined

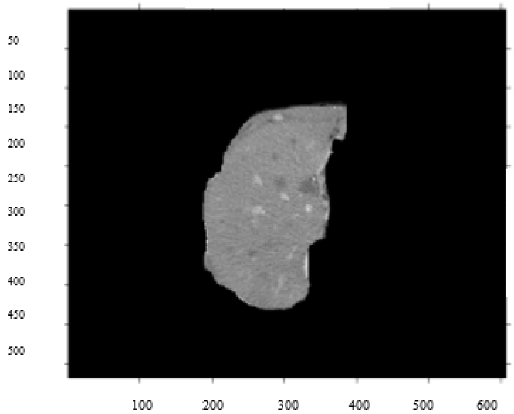

Fig. 15. Segmented liver

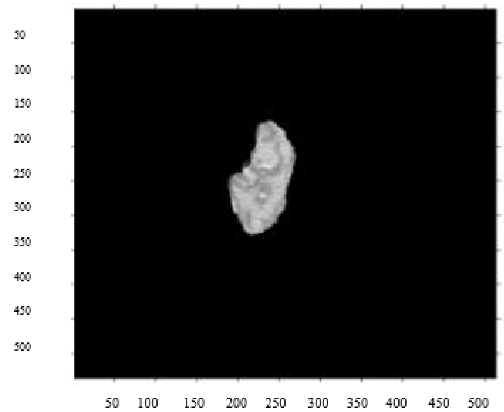

Fig. 16. Segmented spleen

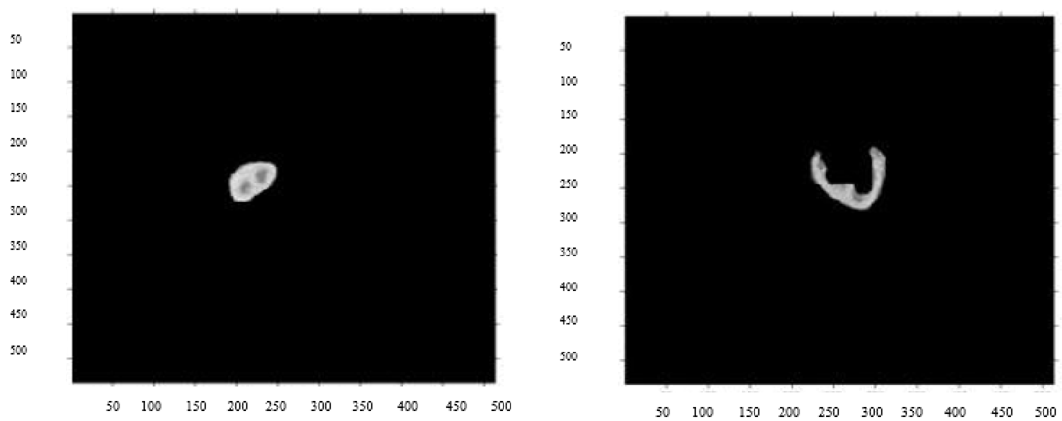

Fig. 17. Segmented kidneys

4 Discussion and Conclusion

An efficient automated system based on atlas is developed for segmenting an abdominal image that contains several regions as per choice of radiologist and researchers. Firstly spine is extracted based on prior knowledge and specific location of spine in abdominal image data set. After this several different organs liver, kidney, aorta and spleen can be found effectively. This intelligent approach can be appropriate for the images of different size as we are considering comparative distance of different organs from spine. Additionally, we extracted circular region for aorta, elliptical region for kidney, rectangle region for spleen and liver as per successive slices of CT data set and produces tremendous results. Another important aspect of this paper is to develop an automated system/tool for clinical purpose to handle radiologists efficiently. We applied this intelligent method to 152 CT images of several patients. Assessment of the performance of the system is done qualitatively and quantitatively. Correlation coefficient for automated system and manual segmentation is found significant as we have already discussed. Though, more data set needs to be tested to validate this system. Another considerable aspect of this system is the time consumption. We saw that if want to extract out multiple organs of abdomen then it takes considerable time to execute as it process one by one. Parallel Computing seems to be the intelligent solution for this. In future, after adding parallel computing to this system can give the extraordinary result. It can be achieve by using GPU (Graphical Processing Unit), Parallel Computing toolbox of MATLAB, Multithreading of Java or any other tool of parallel processing.

Competing Interests

Authors have declared that no competing interests exist.

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