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Liver Segmentation in Computed Tomography Abdomen Images Based on Particle Swarm Optimization and Morphology

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Abstract**:** ***Segmenting liver from abdominal images is a thought-provoking task. A method for segmenting liver region from CT abdomen is proposed in this paper. Particle Swarm Optimization (PSO) method is employed for segmenting multiple regions in the abdomen image. Morphological operation such as Erosion and Dilation is used for segmenting exact portion of liver. Largest connected component and filling holes operation are applied as supporting techniques for image corrections. Experiment on our proposed segmentation approach is carried out and the results are discussed. The quantitative validation was performed with Dice similarity co-efficient metric.***

Keywords: CT Liver, PSO, Morphology, Segmentation

I. INTRODUCTION

Liver is one of the largest and heaviest solid organs in human body weights approximately 1.5kg in adults. Being a soft organ, the shape of the liver is highly dependent on the neighboring organs inside the abdomen [1]. Liver size varies by age, body mass index, gender, height and many other factors of human being day to day activities. It is an important organ in the abdomen area. Liver is located below the diaphragm and surrounded by the right rib cage. Liver is wedge shaped - reddish brown in color. Liver has two lobes (smaller left, larger right) [2] that is divided into eight segments. There is an average of 1000 lobules in each segment and all of these lobules have a small duct that flows towards common hepatic duct. This duct drains bile from the liver to intestine. About 13% of the human body's blood is in liver at any estimated time. Liver secretes bile and aids in digestion. Liver serves many critical functions. It takes care of body's immune system and metabolic functions. Liver synthesis proteins and enzymes those are necessary for blood to clot. Without proper functioning of Liver, it is difficult for human being to survive. Gastrointestinal bleeding, Fluid retention, Encephalopathy, Jaundice are some of the end stage liver diseases. For these diseases the only available treatment is Liver replacement. No machine is devised so far to perform the functions of liver. Liver transplantation surgically replaces failed one with a healthy liver segment. Liver is a brilliant organ which has the unique capacity to regenerate itself even after removal of tissue and it can gain its same weight within a month. To visualize the internal organs of the human body, clinicians use imaging techniques. Medical images have now become an important mode to diagnose diseases accurately. With the evolution of technology, medical imaging modalities have increased to a greater extent. Ultrasound (US), X-Rays, Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) are few of them. CT is most widely used for abdomen imaging, since it can image bone, soft tissues and blood vessels all at a time. CT is a non- invasive imaging technique. It is cheaper and capture images in short span of time. "CT offers the best spatial resolution and the ability to study the entire liver in a single breath-hold." [3]. CT uses two types of contrast agents for better enhancement of liver. They are: Oral contrast agent and Intravenous contrast agent. We have worked on images with intravenous contrast in our method. Detailed knowledge about the anatomy of liver and other organs inside the abdomen is a prerequisite before performing the process of liver image segmentation in CT abdomen images. Medical images are produced in large data volumes and the diagnostic analysis becomes cumbersome. To assist radiologist, image processing techniques are being developed. Liver image segmentation has become an important area in clinical research including radiotherapy, liver volume measurement and liver transplant surgery. One such method in helping the radiologist is proposed here in minimizing the time consumption for diagnosis.

The paper is structured as follows: Section 2 discusses previous literature work in the field of research. Section 3 explains the proposed method. Section 4 gives the details of results and validation. Section 5 concludes the proposed research.

II. PREVIOUS WORK IN LITERATURE

Segmenting pathological livers in contrast enhanced CT images with great accuracy and speed is achieved in [2], a Random Walker based framework for liver segmentation. Amita Das *et.al.*, [4] used Adaptive thresholding for separating liver from CT of abdomen image.

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Huiyan Jiang *et.al.*,[5] proposed a segmentation algorithm based on the snakes and grow cut for liver segmentation in abdominal CT image. K-means is used as pre-processing to reduce the running time. This method is better than the traditional grow -cut algorithm.

Abdalla Mostafa *et.al.*, [6] used morphological operation for filtering, contrast stretching for enhancing the image and region growing to segment liver. Sathya P. Duraisamy *et.al.*, [7] proposed particle swarm optimization based multilevel thresholding and compared the results with Genetic algorithm. PSO results outperform Genetic Algorithm.

III. PROPOSED METHOD

In CT abdomen, soft tissues organs such as liver, heart, lungs, spleen, kidneys, appears in varied shades of gray. Segmenting liver from abdomen image is difficult due to slightly varying intensity and proximity within the adjacent organs. The image analysis is performed on raw input image (I) by selecting n-level thresholding. Particle swarm optimization is used to obtain n-level threshold for multilevel segmentation [8]. The n-level threshold segments the input image into n-2 various segments. The image with liver region is further processed with morphological operations to refine the segmentation. Hole filling operation is used to fill the number of holes in the foreground image area which are removed during erosion. Largest connected component analysis is used to extract liver from the neighboring portions. Dilation is operated on the result of largest connected component region and the liver mask is obtained. The schematic representation of our proposed work is given in Fig.1

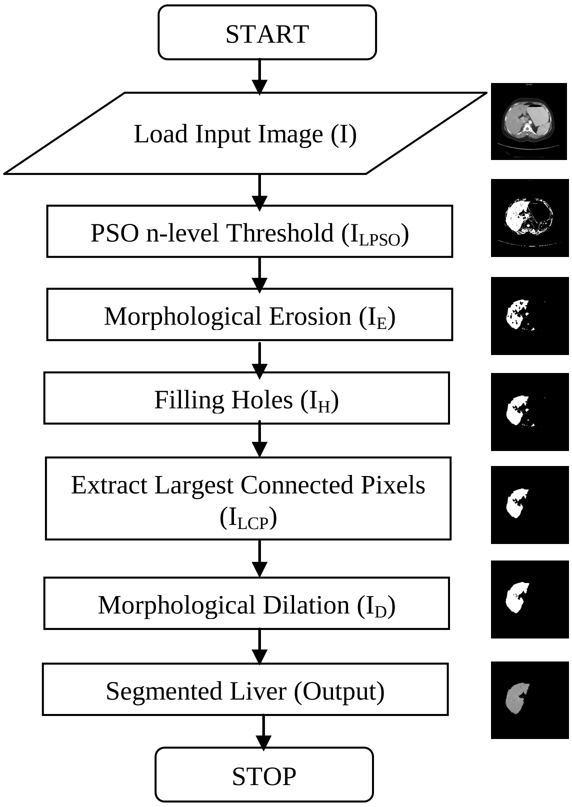


Fig.1 Flow chart of our proposed method

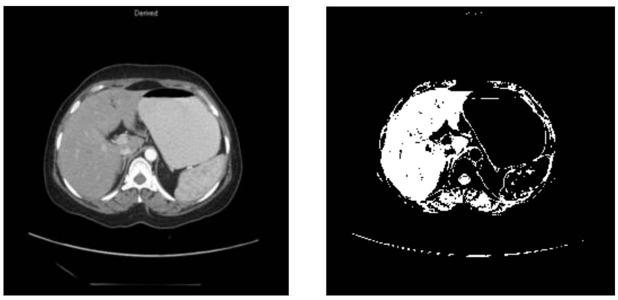
A. Particle Swarm Optimization

Particle Swarm Optimization (PSO) [8] is a stochastic optimization technique developed by James Kennedy and Russell C. Eberhart in 1995. PSO is a population- based search method widely used for optimizing a wide range of functions. PSO computation method is similar to Genetic algorithm. PSO technique is utilized to find the optimum value for n-level thresholding [9]. Segmenting images with multilevel threshold is more efficient with PSO. Optimal threshold value for n number of gray levels can be obtained by maximizing the between class variance. In traditional PSO, the candidate solutions are called particles. These particles are accelerated towards its personal best (local best) and gbest (global best) with the communication of information among the neighbors. At every step the global best is updated to the entire swarm and all the particles are guided towards it. In each step, a fitness function given in Equation.(1) &(2) is used to evaluate the particle success.

$$v(t+1) = wv(t) + c_1 \times rand() \times \left(x_{pbest} - x(t)\right) + c_2 \times rand() \times \left(x_{gbest} - x(t)\right) \quad (1)$$

$$x(t+1) = x(t) + v(t+1) \quad (2)$$

Where, v(t) is the velocity of the particle at the given time t, x(t) is the particle position at the given time t, w is the inertia weight (controlling factor of the velocity history), c_1 & c_2 are the learning factor or accelerating factor, rand is a uniformly distributed random number between 0 and 1, x_{pbest} is the particles best position and x_{gbest} is the swarm global best. The stopping criteria for number of iterations are fixed. The input image is shown in Fig.2(a). Here we have used 6 level thresholding, so that different intensity range in our CT input abdomen image is separated into 4 different output images (by default 2-level threshold: background and foreground is omitted). One of the output images mask (I_{LPSO}) is shown in Fig. 2(b) contains the outer muscular wall of the abdomen, liver boundary of stomach, spleen and few other small parts of the neighboring organs. We then process this image with morphological operations to remove unwanted region.



(a) **(b)**

Fig.2(a) Input image (b) one of the mask image obtained from n-level optimum thresholding that contain liver region

B. Morphological Image Erosion

Morphology [10] is a concept of set theory used in our image segmentation method to reshape the images. A mask or structuring element is designed with odd number of 2 dimensional matrices that is 3x3.

The structuring element can be in any of the following shapes: square, rectangle, diamond, Octagon, line, disk, and ball according to the demand of our processing system. Erosion and dilation are the two major operations used largely, which is the foundation for all other morphological operations.
Both the erosion and dilation operations are used here. The result obtained from the process of n-level threshold is taken as the input for image erosion. Image erosion is the minimum of all pixels in its neighborhood. The structuring element (D) is superimposed on the input image. A structuring element of disk shape with radius 2 is used is shown in Fig.3

0	0	1	0	0
0	1	1	1	0
1	1	**1**	1	1
0	1	1	1	0
0	0	1	0	0

Fig.3: Disk shaped structuring element

The kernel is allowed to run over the original image. I_E is the eroded image which separates liver from the boundary of abdomen, aorta, edges of ribs and other connected tissues. The erosion operation is given in (3). The eroded image is shown in Fig.4

$$I_E = I_{LPSO} \ominus D \qquad (3)$$

Fig.4 Eroded Image

C. Filling of Holes in the Image

This image I_E is then used as input for filling holes to get the parts that are lost during erosion. Using flood-fill [11] operation, the holes in the liver region are filled and the whole liver is obtained. A hole is an area of background pixels surrounded by the foreground borders. Flood fill operation hunts the edges and fills holes until it reaches the object boundary. For filling holes in two dimensional images, 4-connected pixels is used. 4-connected is the four horizontal and vertical neighbors of the center pixel P as shown in Fig. 5(a). Holes are filled if the edges touch the connectivity matrix. The holes filled (I_H)image is shown in Fig.5 (b) .

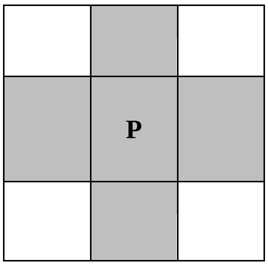


Fig. 5(a) 4-connected pixels

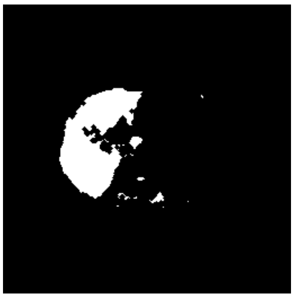


Fig.5 (b) Holes filled Image

D. Largest Connected Pixels

The result of the holes filled image (I_H) is a combination of liver and small leftover portions of neighboring tissues. Since liver is the largest area in the image, largest connected component (I_{LCP}) is used to extract liver from that group. The knowledge about abdomen anatomy helps in eliminating smaller group of pixels. The resultant image I_{LCP} is shown in Fig.6.

Fig.6 Largest Connected Pixels

E. Morphological Image Dilation

This image I_{LCP} is then dilated with disk shaped structuring element (D). The structuring element used in dilation is same as erosion. Image Dilation takes the maximum of all pixels in its neighborhood. Dilation operation is given in (4).

$$I_D = I_{LCP} \oplus D \qquad (4)$$

The dilated image mask is then overlapped with the original input image to extract the liver region.

IV. RESULTS AND DISCUSSION

In our method we have used three volumes of normal liver datasets of CT abdomen images with intravenous contrast agent obtained from Medall Diagnostics, Tiruchirapalli. Experiments are carried out by applying the proposed method on CT abdomen datasets. Fig.7 shows the one sample volume of raw dataset used for our experiment. The liver extracted output by implementing our method is shown in Fig.8 for visual inspection.

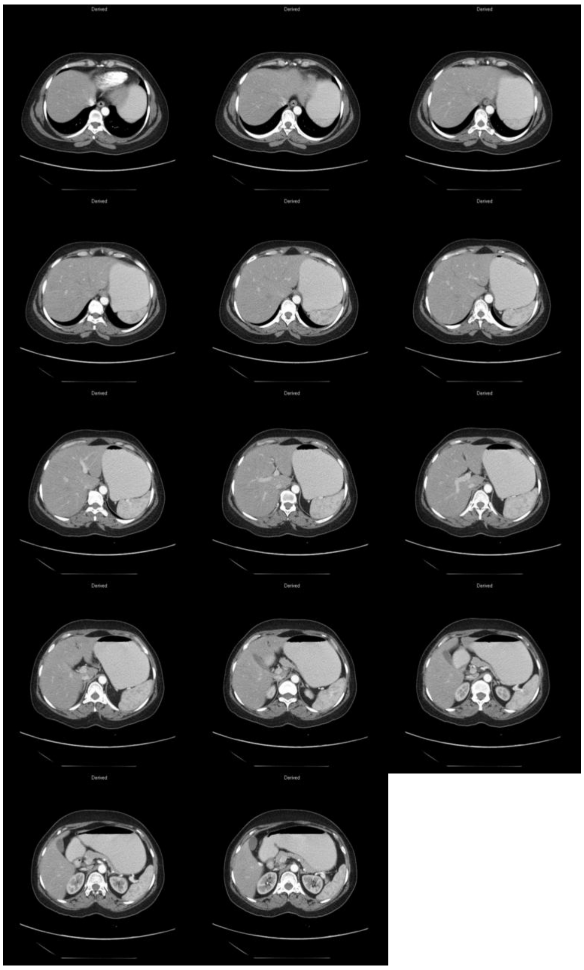


Fig.7 Raw input Image of CT abdomen dataset

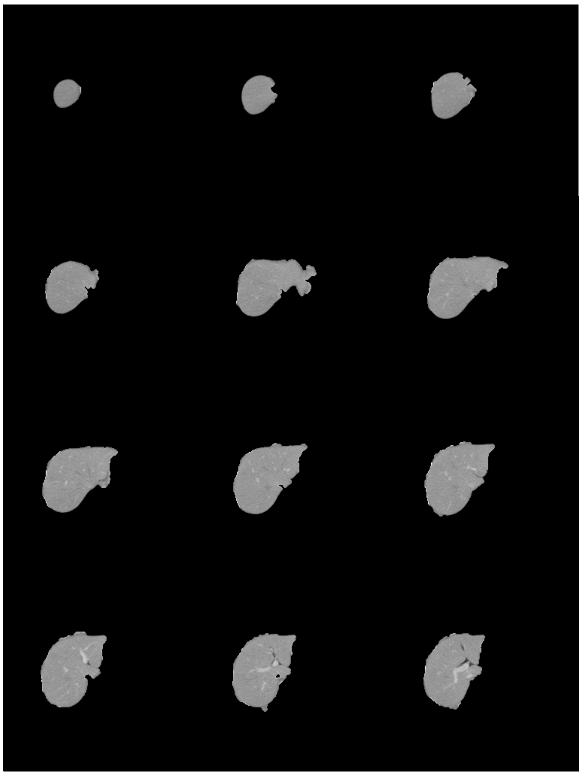


Fig.8 Segmented Liver using our proposed method

Our proposed method is implemented in MATLAB 2013a. The results of our segmentation method are evaluated in terms of precision. Elapsed time is also calculated. It is the amount of time MATLAB takes to execute the method. The average time taken is 9 seconds for the given sample image data. Dice similarity co-efficient [12] is used to evaluate the percentage of agreement of our proposed method to the corresponding ground truth image i.e., manual segmentation done by radiological expert. The Dice co-efficient is calculated as in (5).

$$Dice = \frac{2|P \cap G|}{2|P \cup G|} * 100 \qquad (5)$$

Where, P is the resultant image of the proposed segmentation method and G is the Ground truth segmentation from expert radiologist. Our results are validated with expert segmentation results and the average Dice measure is 91% in accuracy.

V. CONCLUSION

We have combined Particle Swarm Optimization with morphological operations to segment liver from CT abdomen images. With this segmentation technique, the diagnosis time can be reduced and the radiologist can analyze large number of patient's image dataset. The proposed method is simple at computations. We have validated our results in terms of similarity metric and it scores 91%. The only problem that needs to be resolved in our future research experiment is under segmentation in the beginning slices and the end slices of the dataset volume.

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