Bio-medical Diagnostic Imaging System

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CSC 621-821, Spring 2015.

Abstract

We have designed a system that takes a set of DICOM CT scan images as input and segment lungs for different patients. The system was divided into three subsystems and assigned to three subgroups; first for registration, second for segmentation and third for quantification and visualization. Each subgroup worked on the same datasets independently.

The registration subsystem aimed at aligning the image stacks of the same patient at different stages, in order to perform change analysis and used Demons algorithm for this purpose. The segmentation subsystem used watershed segmentation algorithm, and experimented with different parameters to segment the lungs. The quantification subsystem used software applications like Fiji and ITK-Snap to segment the lungs first and then quantify geometry such as volume, image mean and variance. The result was visualized using 3D viewer after selecting the region of interest. The integration of the system was done in such a way that the best registration result was segmented, quantified and the final output visualized on the 3D viewer.

Development was done on Windows platform using ITK with C++ in Visual Studio and CMake was used for building the source files. Quantification and visualization were done using Fiji and ITK-Snap.

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I. Background

We first selected abdominal CT scans of few patients from the NBIA website for preliminary experiments on image processing like filtering, edge detection, etc. Then the group decided to choose CT scan images of four patients as the dataset required for our project.

The input was divided among our three group members so that each person can work on the datasets. We experimented on the dataset based on what we learnt in class, and decided on some image processing operations required for segmentation. ITK-Snap was used for active contour based segmentation and the volume and statistics were obtained. Fiji was used for 3D volume rendering.

II. Goal

The main goal of our subgroup was to come up with a way to view the segmented body parts which is first registered and quantify the results. Since this was dependent on the output from other subsystems, we decided to segment the actual datasets using GUI and quantify those results first. In this way we could familiarize ourselves with the segmentation results. Once the segmentation subsystem could produce a satisfactory output, we visualized it using 3D volume rendering in order to emphasize the important aspects of the image (Lungs in our case).

The input was a set of CT scan images loaded as a 2D stack to form a 3D image set. Image was pre-processed using suitable thresholding methods like Otsu, and automatic segmentation was done using both Fiji and ITK-Snap. My aim was to quantify the segmented result and visualize it.

III. Technical challenge

We first had a rough idea as to what algorithms and methods we could use in our project and as we started implementing, we experimented with different cases using trial and error.

Some of the challenges faced while doing the project are given below, and shall be considered during future work.

1. MS Windows platform was used for implementation and I faced memory issues with virtual machine on MAC.
2. Fiji was used to segment the dataset. Classical segmentation resulted in over-segmentation, thus morphological segmentation was used. Since the segmentation results were only average with a lot of noise, we tried using ITK-Snap.
3. We wanted to compare the geometrical features like volume and mean obtained from automatic segmentation with the statistics of output from watershed segmentation algorithm. But were unable to do this, since we could only open the watershed segmentation result in ITK-Snap as a main image and not as a segmentation image.

IV. Design

The system follows the steps below:

1. Load the input datasets
2. Pre-process the images using thresholding and/or edge detection depending on whichever produces images with less noise.

3. Initialize the bubbles (seed) in the case of ITK-Snap segmentation and select gradient and tolerance for morphological segmentation in Fiji.
4. Flood the selected region of interest.
5. Analyze the volume and statistics of the segmented lungs.
6. 3D volume rendering of the images obtained from ITK-Snap, Fiji and segmentation output from the watershed algorithm.

V. Resulting implementation

During implementation phase, we first used Fiji. The image was processed by type conversion, resizing, thresholding and edge-detection. Thresholding method used was global thresholding and the available methods were compared to choose the one with least noise (Fig. 2). Then segmentation was done to see the different parts. After trying a few segmentation methods like classical watershed, marker based watershed, etc, the subgroup decided to use morphological segmentation (Fig. 1), which is a kind of watershed segmentation. It mainly required two parameters namely, gradient and tolerance and after some trial and error with different values for each of these parameters, suitable values (Table 2) were chosen that resulted in a properly segmented image.

Since the results from morphological segmentation were not satisfactory, we tried automatic segmentation using ITK-Snap. First the region of interest was selected before beginning the segmentation. Then the image was pre-processed using thresholding (Fig. 5). The lower threshold was set to a minimum (-1024 in our case) and upper threshold adjusted so as to obtain a clear binary image. Then bubbles were added as seed points on the regions of interest (Fig. 6). Once required bubbles were added (bubbles were added on the left and right lungs and the air pipe), they were filled (Fig. 7) in iterations by varying the step sizes from 2 to 5 (iterations varied from 700 to 1500). After updating the 3D view of the segmentation result, it was accepted if satisfactory. The statistics of the segmented lungs were obtained (Table 1).

Once the segmented image was created, we did 3D volume rendering of the image using the 3D viewer plugin of Fiji (Fig. 10). By setting the mode to start animation, we could view the segmented image set as a 3D image. Fig. 3 and Fig. 4 show how the 3D view changes by changing threshold and transparency respectively. ITK-Snap segmentation results can be viewed as 3D in the Snap window itself by updating the 3D view after segmentation (Fig. 11). Fig. 8 shows the 3D view of segmented lungs and Fig. 9 shows the labelled components like left lung, right lung and air pipe colored using the 3D scalpel tool of ITK-Snap.

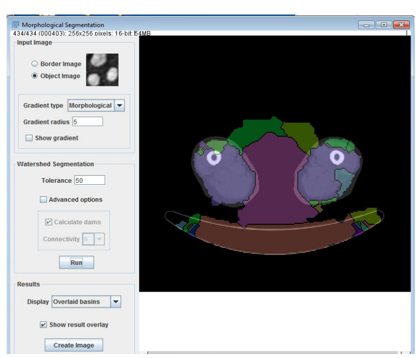

Fig. 1. Morphological Segmentation

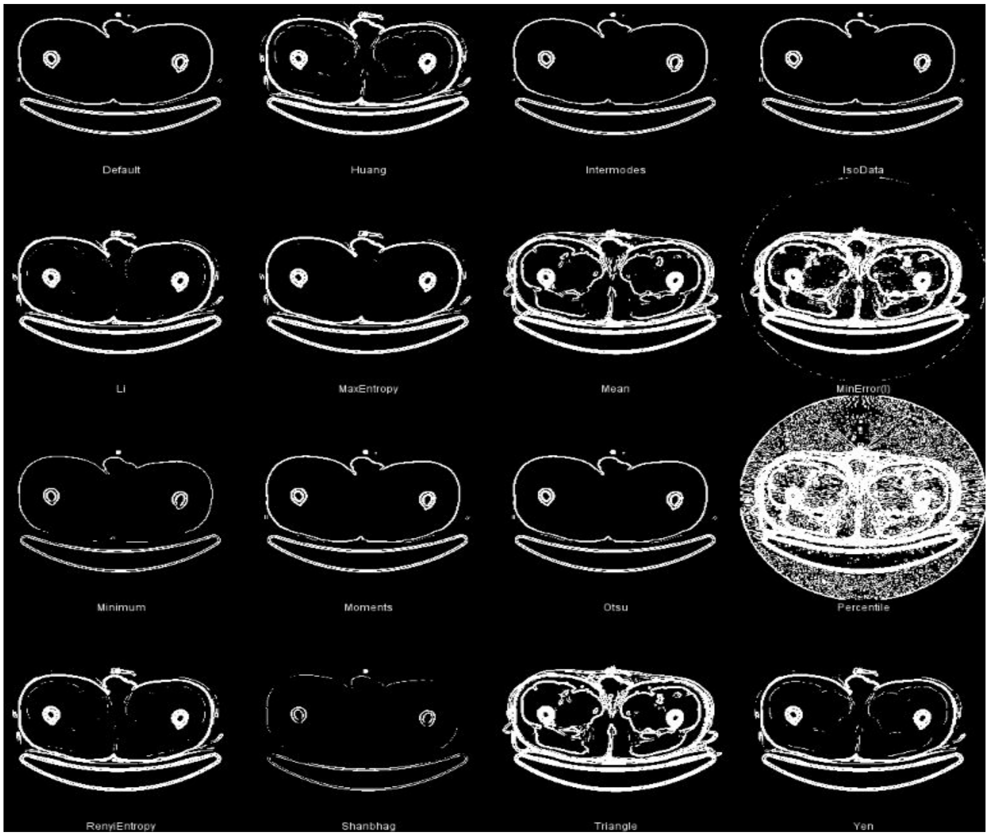

Fig. 2. Different thresholds in Fiji under Global thresholding

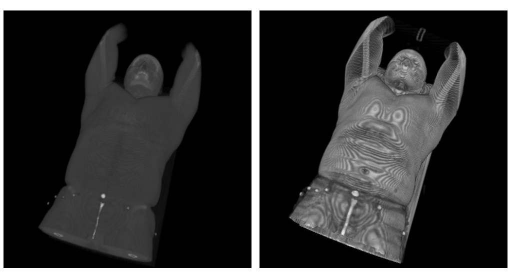

Fig. 3. The impact of adjusting threshold

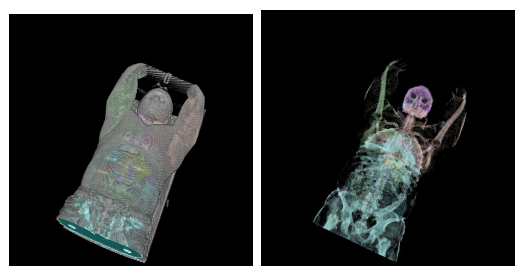

Fig. 4. The impact of adjusting transparency

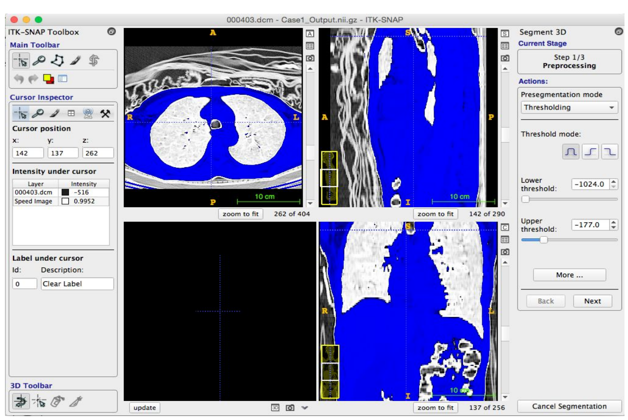

Fig. 5. Thresholding

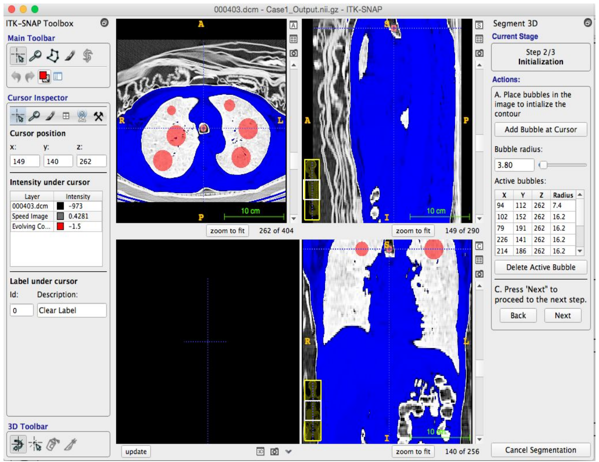

Fig. 6. Adding bubbles for region growing.

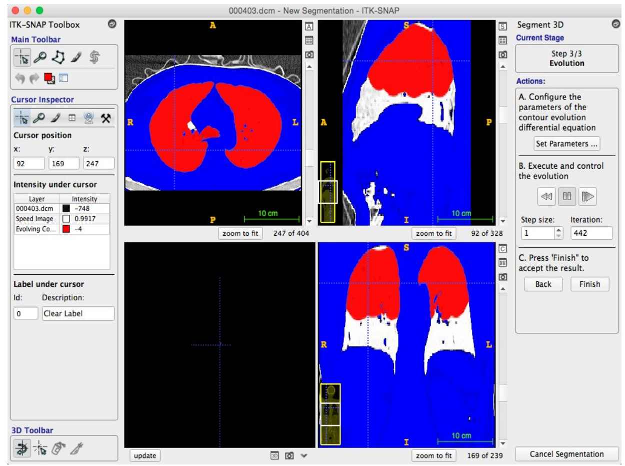

Fig. 7. Filling of seed points.

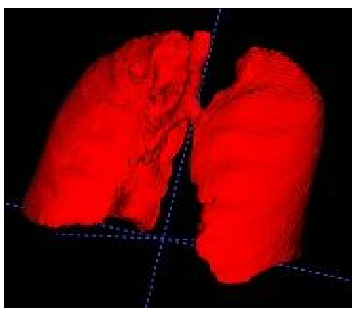

Fig. 8. 3D view of lungs segmented using ITK-Snap.

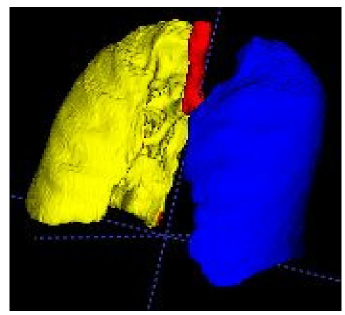

Fig. 9. Lungs further divided into left lung right lung and air pipe using the 3D scalpel tool in ITK-Snap.

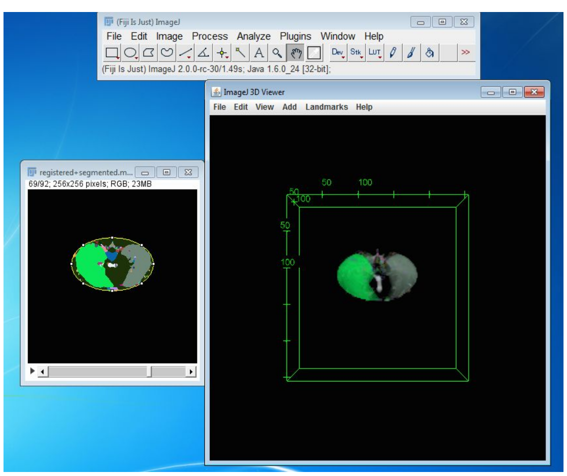

Fig. 10. 3D viewer in Fiji

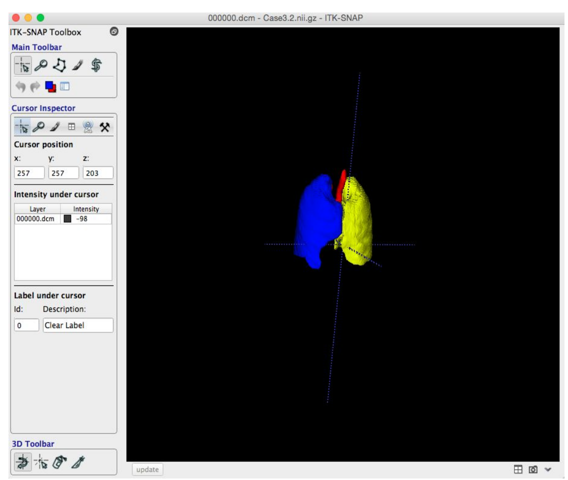

Fig. 11. 3D viewer in ITK-Snap

Table 1. Statistics obtained from Itk-Snap segmentation
Note: The total value indicate the sum of lungs and air pipe region
(ie: excluding Clear Label)

Case	Label Id	Label Name	No of Voxels	Volume (mm^3)	Image mean	Image Std Dev	Variance
1	0	Clear Label	104253951	2.38609e+08	-836.327	374.373	140155.143
	1	Air pipe	7677	17570.5	-636.258	403.284	162637.985
	2	Right lung	823765	1.88537e+06	-714.037	201.264	40507.198
	3	Left lung	820783	1.87855e+06	-730.226	205.589	42266.837
		Total	1652225	3781490.5	-2080.521	810.137	656321.959
2	0	Clear Label	104061453	2.38168e+08	-754.763	436.354	190404.813
	1	Air pipe	15463	35390.6	-647.007	376.896	142050.595
	2	Right lung	979323	2.2414e+06	-631.939	238.678	56967.188
	3	Left lung	849937	1.94527e+06	-631.139	243.665	59372.632
		Total	1844723	4222060.6	-1910.085	859.239	738291.659
3.1	0	Clear Label	105146642	2.40661e+08	-771.255	427.532	182783.611
	1	Air pipe	16409	37557.1	-818.594	240.955	58059.312
	2	Left lung	771055	1.7648e+06	-702.213	156.304	24430.940
	3	Right lung	496358	1.13607e+06	-644.237	167.048	27905.034
		Total	1283822	2938427.1	-2165.044	564.307	318442.390
3.2	0	Clear Label	104615997	2.39446e+08	-796.098	410.419	168443.756
	1	Air pipe	14554	33311.4	-812.199	249.262	62131.544
	2	Left lung	873120	1.99841e+06	-738.206	151.059	22818.821
	3	Right lung	664649	1.52126e+06	-719.543	162.036	26255.665
		Total	1552323	3552981.4	-2269.948	562.357	316245.395
4.1	0	Clear Label	104471570	2.39107e+08	-744.15	450.656	203090.830

	1	Air pipe	13586	31094.6	-755.781	286.448	82052.456
	2	Right lung	729913	1.67057e+06	-563.859	204.934	41997.944
	3	Left lung	691099	1.58174e+06	-581.544	203.473	41401.262
		Total	1434598	3283404.6	-1901.184	694.855	482823.471
4.2	0	Clear Label	104130731	2.38327e+08	-716.569	463.458	214793.318
	1	Air pipe	16609	38013.4	-771.676	287.68	82759.782
	2	Left lung	803825	1.83973e+06	-649.763	212.063	44970.715
	3	Right lung	955011	2.18576e+06	-668.738	198.447	39381.212
		Total	1775445	4063503.4	-2090.177	698.19	487469.276
4.3	0	Clear Label	104299223	2.38724e+08	-744.87	448.485	201138.795
	1	Air pipe	17326	39656.5	-732.311	306.343	93846.034
	2	Left lung	795650	1.82112e+06	-536.674	247.223	61119.212
	3	Right lung	793977	1.81729e+06	-564.793	216.354	46809.053
		Total	1606953	3678066.5	-1833.778	769.92	592776.806

Table 2. Morphological Segmentation: Values used

Image	Threshold	Gradient	Tolerance	Transparency
1.1	Otsu Threshold	5	50	77
2.1	Li Threshold	4	30	85
3.1	No Threshold	1	12	54
3.2	Intermode Threshold	5	48	61
4.1	Li Threshold	4	50	85
4.2	Li Threshold	4	50	84
4.3	Otsu Threshold	4	50	81

VI. Performance evaluation

The performance of the final output was analyzed using the following:

1. Reliability: Validation was done by comparing the results of automatically segmented image set (using GUI) with the result set obtained by using watershed segmentation algorithm. We could only compare the shape of results, actual quantification of image segmented using watershed algorithm may be considered for future work.
2. Accuracy: Analysed if reasonable degree of correctness was obtained or not. ITK-Snap resulted in proper segmentation of lungs.
3. User interface: Analysed how much user interaction is required for the system to work. Though both Fiji and ITK-Snap performs automatic segmentation, it does require user input for parameters like threshold, seed points, gradient, etc.

VII. Technical motivation and goal of the overall system

Comparison of images of same patient is handled by the registration subsystem. Among the different types of algorithms, deformable algorithm with maximum degree of freedom was found to be suitable for our project. Demons algorithm was used for registration. The segmentation subsystem's goal was to find the right parameters like threshold range and output scale level that will produce the best lung segmentation results. Watershed segmentation algorithm was used for segmentation. The quantification subsystem aimed to get the automatic segmentation results which will be comparable to the results obtained by the segmentation subsystem. Fiji and ITK-Snap were used for quantification and visualization.

The problem discussed here is how to segment lungs with reasonable degree of accuracy. The input is a set of abdominal CT scans and the expected output is a proper segmented lungs which must be quantified and visualized on a 3D viewer.

The whole system is simple and easy to understand especially since it is divided into three independent subsystems.

VIII. Design of the overall system

The integrated system mainly involved the following steps:

1. Selection of input datasets: First the abdomen CT scans were selected and used as input for registration, segmentation and quantification subsystems.
2. Algorithm analysis: Different algorithms were analyzed and compared to choose a suitable one for each subsystem. The limitations, ease of use, and relevance to our system's objectives were taken into consideration while selecting the algorithms.
3. Image pre-processing: Depending on the requirements of the subsystem, pre-processing like thresholding, edge-detection, filtering were done.
4. Applying algorithm or required method to process the datasets(registration, segmentation, quantification): Registration subsystem used Demons algorithm (Fig.12), Segmentation subsystem used watershed segmentation algorithm (Fig.13) and quantification subsystem used ITK-Snap and Fiji to automatically segment and quantify lungs from the datasets.
5. Visualize the results: The results from each of the subsystem's were finally rendered on the 3D viewer plugin of Fiji (Fig. 14) .

The final output is first registered, segmented and visualized in 3D viewer.

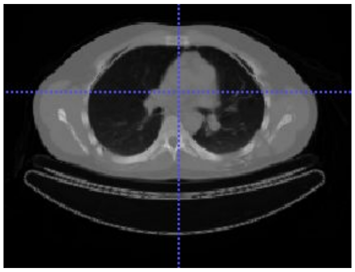

Fig. 12. Registration Result

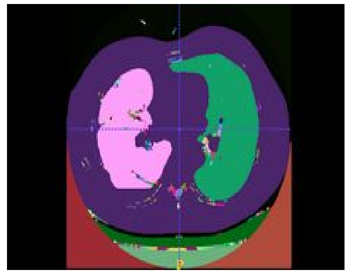

Fig. 13. Segmentation Result

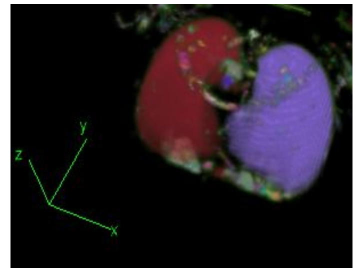

Fig. 14. 3D view of segmentation

IX. References

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