Medical Image Processing 67705

Homework 3: Liver Segmentation in CT Scans

Due date: 13.12.2020

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In the first part of this exercise you will continue your work on skeleton segmentation. This time, you will get more challenging cases. The proposed approach be to compute a Region of Interest (ROI) using anatomical knowledge and additional assumptions.

For the second part of the exercise you will implement Multiple Seeded region Growing (MSRG) segmentation of the liver in CT scans based on the ROI computed in the first part.

Part 1: find an ROI (40%)

The goal is to develop an algorithm to compute an ROI that is general and works for difficult cases. The difficulties include limited field of view, low-quality CT scan, no contrast agent and bones with various defects. The assumptions that were made for Homework 2 no longer apply..

Direct single-threshold segmentation for the new CT scans will result in the presence of unwanted objects, e.g. the scanner bed, and unwanted structures, e.g., other internal organs. An example of this:

For your solution, you may assume that the patient's lungs are healthy, and that the bones do not exhibit fractures, and that the spine does not show deviations (scoliosis).

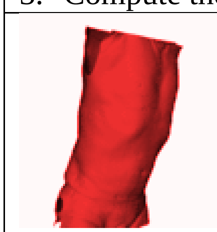
1. Compute the ROI for the chest bones (20%)

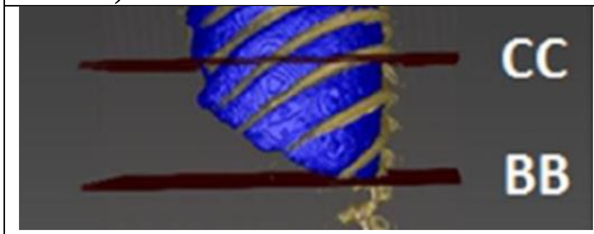
The first step is to find the ROI of the ribs and vertebrae around the lungs. These bone structures are located between the CC and BB planes:

We will compute the ROI in three stages:

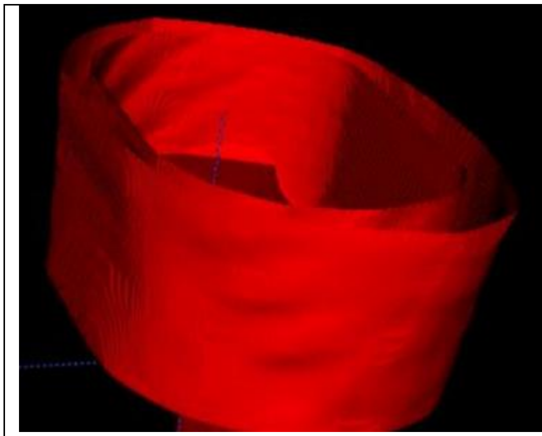
1. Isolate the patient's body from the bed and the surroundings
2. Isolate the lungs
3. Extract the area between the CC and BB planes

To achieve this, you are to implement the following functions:

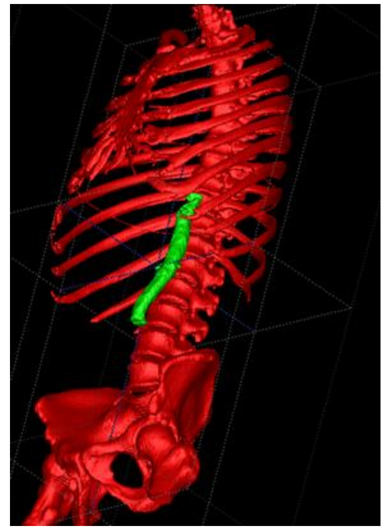
IsolateBody: Isolate the patient's body from the air and scan gantry
Input: CT Scan Output: Body segmentation Algorithm 1. Perform thresholding to remove all pixels with gray level (HU) below -500 and above 2000 (keep only those between -500 and 2000) 2. Filter out noise 3. Compute the largest connected component


IsolateBS: Isolate the lungs
Input: body segmentation from IsolateBody Output: (a) The lungs segmentation, **(b)** The BB and CC cross-sections slices Algorithm 1. Find the two large cavities inside the body segmentation which correspond to the lungs 2. Define two cross-sections above the lungs segmentation: the plane BB corresponds to the inferior slice of the lungs; the plane CC corresponds to the widest slice of the lungs (see Figure below) 3. The plane CC is the last slice/slice in which the lungs slice does not change much (or close to it).


ThreeDBand: 3D band around the lungs
Input: 1) Body segmentation from IsolateBody 2) Lungs segmentation from IsolateBS. 3) Planes BB and CC (slice indices) Output: 3D band around the lungs Algorithm: from slice BB to slice CC, extract the region confined between the body and the convex hull of the lungs (see fig below)



2. Compute an ROI for the vertebrae (20%)



Each CT scan includes an initial segmentation of the aorta (green structure on the figure on the right). In this section, you are to use this information to build a spine ROI (SpineROI).

The details of the algorithm and its implementation are up to you. You may use and combine tools that were discussed in class, including thresholding, region growing, graph cut, etc.

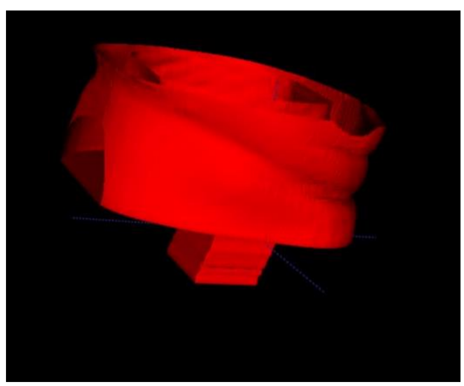
Compute a combined ROI

Write a function called 'MergedROI' that inputs a CT scan and returns an ROI.

The output of this function will be used for the third part. Save the output in a nifty file with the name format of <filename>_ROI.nii.gz

Submission

For the report, include the code and a 3D visualization of the ROIs of **all** the provided CT scans. Each ROI should contain the ribs and vertebra and a rectangular enclosing box around the skeleton. An example with expected result is:



The CT files found here:

[***https://drive.google.com/drive/folders/0B5wahAf6ThIuX2MxVnhYSW9faUk***](https://drive.google.com/drive/folders/0B5wahAf6ThIuX2MxVnhYSW9faUk)

The files for this project are:
Case{1-5}_CT.nii.gz
Case{1-5}_Aorta.nii.gz
HardCase{1-5}_CT.nii.gz
HardCase{1-5}_Aorta.nii.gz

Part 2: Region Growing Segmentation of the Liver in CT Scans (60%)

In this section you will implement MSRG (multiple seeded region growing) using connectivity and gray-level analysis from several seeds points, e.g. multiple seeded.

To initialize the algorithm, we need to have an area from which we sample seeds. As we mentioned before, simple thresholds will not be sufficient here. Instead, we want to find an ROI of the liver.

1. Liver ROI (10%)

Implement a method for finding an ROI in the liver from which you can sample seeds for the MSRG. You are provided with a segmentation of the aorta. Following is some relevant information:

1. Typically in CT scans, the liver tissue appears in the intensity range of $[-100, 200]$ HU
2. The liver is located to the right of the aorta, at approximately half its height

You might find it useful to use the IsolateBody function you implemented before.

2. Region Growing Algorithm (30%)

Implement the following functions:

findSeeds
Input: CT Scan and ROI Output: seeds list Algorithm: sample seeds from ROI

multipleSeedsRG
Input : 1) CT scan; 2) ROI Output: Liver segmentation Algorithm: 1. Extract N seeds points inside the ROI. 2. Perform Seeded Region Growing with *N* initial points

Note the following:

1. The MSRG should be performed in 3D, i.e., each voxel has 26 neighbors instead of 8 in 2D
2. Avoid using loops as much as possible. In the SRG iterations, use morphological operations
3. Seeds are voxels inside the ROI and are part of the liver
4. Start with ~200 seeds selected from you ROI
5. Implement your own MSRG: do not use resources such as libraries/packages from the Internet

3. Evaluation Metrics for the Segmentation (10%)

Use the following function to evaluate your results versus the GT segmentations:

evaluateSegmentation
Input: 1) Ground truth segmentation; 2) Estimated segmentation Output: Volume Overlap Difference and Dice Coefficient

4. MSRG Liver Segmentation (10%)

Finally, implement the following fully-automated function:

segmentLiver
Input: 1) CT nifti file name; 2) aorta segmentation nifti file name; 3) output file name Output: liver segmentation nifti file (to be saved under the given name)

For this part you can find the CT files here:

https://drive.google.com/drive/folders/0B5wahAf6ThIuX2MxVnhYSW9faUk

The relevant files for this exercise are:

Case{1-5}_CT.nii.gz
Case{1-5}_Aorta.nii.gz
Case1_liver_segmentation.nii.gz
HardCase{1-5}_CT.nii.gz
HardCase{1-5}_Aorta.nii.gz
HardCase1_liver_segmentation.nii.gz