

Sheep Lung Analysis Instructions

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January 23, 2006

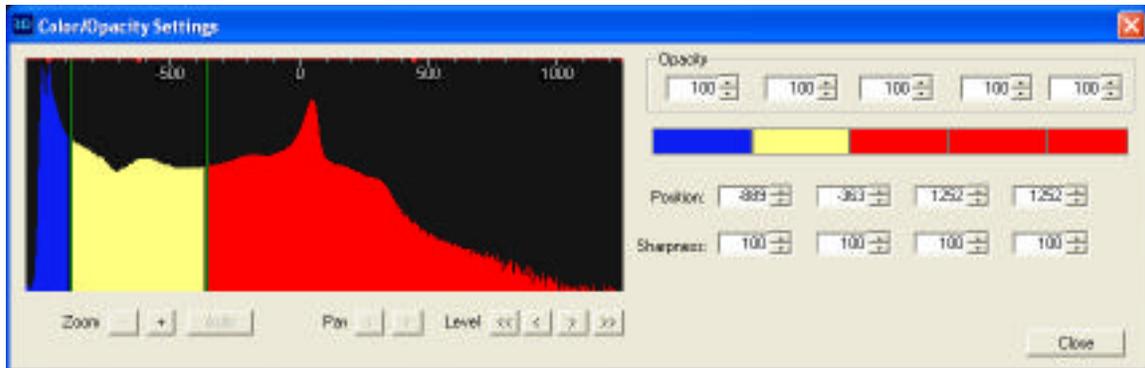
Algorithm Design

The analysis instructions provided in this document are derived from an algorithm designed to estimate the percentage of cancer burden in research sheep lungs from CT studies using the Voxar software application. The algorithm comprises two basic steps: 1) Segment or separate the voxels that correspond to lung volume from the total scan volume and 2) Segment or select voxels within the lung volume that correspond to disease.

The segmentation in this algorithm is accomplished by setting the opacity of voxels to specific values, based on the intensity of those voxels, and then selecting spatially connected voxels of like opacity. Opacity settings are determined by observing the total scan volume histogram, and specifying different values for certain ranges of intensities. After selections are made, morphologic operations (erosion, dilation, open, close) may be performed to refine the selection.

I. Lung Segmentation Instructions

The instructions in this step all derive from the use of the initial preset histogram-based segmentation settings. Those settings are shown below:



Please note the color settings as they will be consistent throughout the instruction set:

- Blue corresponds to large airway voxels and all non-signaling voxels outside the main volume of interest
- Yellow (pale yellow) corresponds to all voxels within the total lung volume
- Red corresponds to all non-lung volume structures and elements

Here are the step-by-step instructions for performing the lung segmentation:

Load Data Set

1. Click the Studies and DICOM button to invoke the data set window.
2. Click the desired series, then next to the lower right View box, click the 3D option. Now click View.
3. In the lower corner of the right hand panel, under Display Options, uncheck the “VOI outline”, if it is checked.

Histogram Adjustment

This step is intended to separate the scan volume into the regions identified above. We do this by adjusting the opacity and position settings of the Voxar histogram, starting with ballpark estimates stored in Voxar “Presets”. We will use the transverse MPR, with the histogram-based color coding overlay, to guide our adjustment.

4. In the right hand panel of the display window, under Preset, choose Sheep Lung Segment.
5. Click the Rotate button on the toolbar (to avoid unintended opacity adjustments).
6. Double-click the transverse MPR view in the left hand panel.
7. Scroll to a mid-volume slice, showing heart and lung.
8. In the right hand panel, click the MPR tab.
9. Click the “Use same Window, Level, ...” check box.
10. Click the histogram to invoke the histogram window.
11. In the histogram window, the threshold boundaries can be adjusted left to right by increasing or decreasing the first and/or second position values. **You can move the boundary markers with the left mouse button or click the position value box and use the mouse-wheel to increase or decrease.**
12. As you change the boundary position, examine the MPR views (scrolling through slices with the mouse wheel). You will be adjusting the upper boundary so that yellow fills toward the lung wall, while minimizing yellow-fill in the lung exterior. You will be adjusting the lower boundary so that blue fills the large airway, while minimizing non-airway blue-fill in the interior lung space. **Note, by checking and unchecking the “Use same Window, Level, ...” check box, you can examine the results of your adjustments.**

Remove Exterior Non-Lung Volume Voxels

We will now select those voxels that are both spatially connected *and* labeled by our histogram as exterior non-lung volume.

13. In the upper right hand panel, click Segmentation to set the program into this mode.
14. Choose the Region, Single Intensity tool.
15. In the MPR view, click on the region immediately exterior to the lung wall. Uncheck the MPR “Use same Window, Level, ...”, and scroll through the slices to examine your selection results. **On the toolbar, you may click the Select None and Redo Change Select to examine a slice with and without your selection.** Note that some large blood vessels may be selected.

16. To deselect or exclude “very small” interior lung-space elements that may have been selected, you can Refine the selection. On the toolbar, set the Refine modification size to 1 mm (or “very small”). Then choose the Refine, Open. As previous, scroll through to observe the result and adjust the modification size if necessary.
17. Now remove the selected voxels by clicking the Sculpt button. The result can only be observed in 3D mode.

Readjust Histogram

Now that exterior voxels are no longer available to the selection steps, we can readjust the histogram to maximally fill our interior lung space with our yellow label to include all “very small” voxel regions not removed above.

18. Click the histogram to invoke the histogram window.
19. Now move the upper boundary further to the right and in MPR view mode, with the “Use Same Window, Level...” checked, observe slices with “very small” interior red regions. Adjust the boundary until these begin to be filled. You do not have to be concerned with yellow fill exterior to the lung wall, because those voxels are no longer available to the selection process, having removed them in the previous step.

Select Lung Volume Voxels

From our remaining voxels, we will now select only those that are both spatially connected *and* labeled by our histogram as lung volume.

20. Choose the Region, Single Intensity tool.
21. Scroll to a mid-section transverse slice.
22. Click on an area labeled as lung volume.
23. Examine your selection result. If the selection includes any voxels exterior to the lung space, you will need to repeat the previous histogram adjustment and decrease (move left) the boundary, and then repeat this step.
24. To include interior lung space elements that have not been removed from our selection set, but may have not been selected, you can use the Refine tool. On the toolbar, set the Refine modification size to an approximation of the diameter of regions you are trying to include. Then choose the Refine, Close. Scroll through to observe the result and adjust the modification size if necessary.
25. Now under the Sculpt button, choose Sculpt All Except Selection.

Remove Remaining Airway and Stomach

To refine our lung-volume-voxels-only selection, we will remove any remaining airway and stomach (if present) voxels.

26. Switch to 3D viewing mode.
27. Invoke the histogram window and set the opacity value to zero for all positions except the first.
28. Under the Region select button, set the Minimum Volume to 1 sample.
29. Under the Region select, choose Select All Visible.
30. Now choose Sculpt to remove.

Remove Remaining Non-Lung Space Voxels

At this point it may be necessary to manually select regions of voxels to remove.

31. Invoke the histogram window and reset all opacity values to 100.
32. Under the Region select, choose Select All Visible.
33. Switch to MPR view and examine all slices, looking for unwanted selections, particularly in the diaphragm region.
34. Use the Shape tool to trace the unwanted regions. **Note, unfortunately, when the Shape tool is chosen, your current selection is deselected, so you will have to rely on your knowledge of the region to be traced (and eventually removed). Also, you must click Select None before beginning your Shape tool selection, otherwise it will be included as part of the total selection to be removed.**
35. Use the Sculpt tool to remove your selection(s).

Calculate the Total Lung Volume

36. Again, under Region select, choose Select All Visible.
37. Now click the Measure Select Volume.
38. Click the Capture:Capture All Visible Views to save the volume measurement. Note the current date, and the position (first, second, third... in gallery window) of the thumbnail corresponding to this capture for future reference.

II. Cancer Segmentation/Selection Instructions

The instructions in this step describe how to separate “disease” voxels from the lung volume voxels extracted in the previous step. The process is based on a simple binary threshold designed to separate the remaining visible voxels based on their intensities. The user will be provided an initial threshold preset and will then be required to adjust it based on a visual inspection of the data in 3D and 2D.

Here are the step-by-step instructions for performing the disease segmentation:

1. Load the Sheep Cancer Select preset.
2. Set the Region select Minimum Volume to 1 sample.
3. Invoke the histogram window and adjust the first position. Note, if required, move all other position markers beyond the maximum intensity.
4. Observe the 3D view and make adjustments to eliminate obvious non-disease voxels.
5. To inspect the results of the current threshold in 2D, first, under the Region Select tool, choose Select All Visible.
6. Now switch to MPR and scroll through the slices to observe your selection.
7. Click the MPR tab, and check the “Use same Window, Level...”.
8. Adjust the histogram threshold and observe the yellow fill. To observe the result for a new threshold, click Select None, then again, Region:Select All Visible. Uncheck the MPR “Use same Window, Level...” box and inspect.
9. You may want to experiment with the Refine morphologic operators to include or exclude voxels.
10. Once you are satisfied with the observed selection, click the Measure Select Volume to compute the disease burden.

11. Click the Capture:Capture All Visible Views to save the volume measurement. Note the current date, and the position (first, second, third... in gallery window) of the thumbnail corresponding to this capture for future reference.