

# Appendix A

## Airway Segmenter & Analyzer - User Manual


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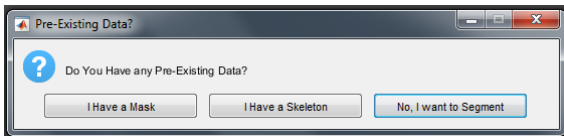
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## Loading Images


The first step of the Airway Segmenter & Analyzer (ASA) program is to load the desired MicroCT Scan. Next, a question dialog  will appear asking if there is any pre-existing data.



1. **I Have a Mask** - If loading with its mask, the user can add to/edit the existing mask or jump to skeletonizing the mask.
2. **I Have a Skeleton** – If loading with its skeleton, the user can jump straight to analyzing airways.
3. **No, I want to Segment** – If loading just the MicroCT scan, segmentation will need to occur (see workflow in appendix).

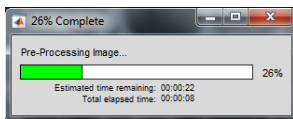
Due to the size of the scans, this will take some time. An icon  will appear letting the user know that the images are being loaded. Once loaded, the stack of images can be scrolled through. The contrast of the image can be manipulated by toggling  Adjust Contrast and then clicking and dragging around on the image. If a mask is loaded, it can be overlayed on top the MicroCT scan and viewed simultaneously.

# Pre-Processing Images

The next step involves pre-processing the image stack\*. Upon pressing, a slider  will appear in the bottom of the screen which is used to adjust certain filtering and thresholding values that require human judgement.

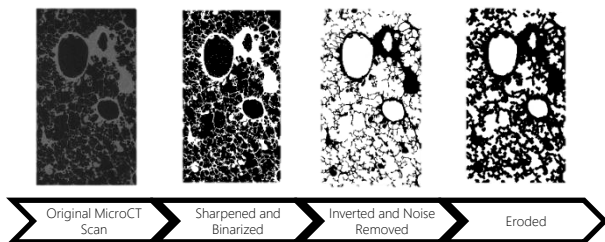
Clicking 'View Original' brings up the original image that can be used for comparison. Once the ideal values are set, pressing 'Confirm Filter & Threshold' will use those settings across the entire stack of images and pre-process them.

A progress bar with time estimations will appear.



[1] \*Be sure to have the desired frame visible before pressing pre-processing as it gives preview to only the visible frame on the screen (stack cannot be scrolled through during)

## Pre-Processing Algorithm

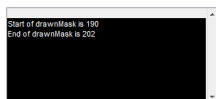


## How to Select/Segment Airways

To start selected airways and begin segmenting, simply press hover the mouse over the image and press the [x] key to place a green marker x onto the slice where the mouse is hovered. The X Y and Z location of the markers get tracked and will be linearly interpolated.

### Drawing Boundaries (drawnMask)



Often times while clicking through images (pressing [x]), there will be walls that do not connect due to weak contrasting. The solution to this is to press the [d] key on the keyboard, and manually draw a boundary that *acts* as a wall. From here, scrolling through the slices keeps the boundary on, until the user presses [shift-d]. The line will disappear, which means it has been recognized and will be used for the segmenting step. The Activity Log will keep track of the range of slices this covers.



Be sure to make frequent use of

the ☐ Filtered Preview [ F ] which in addition to ☐ Zoom can be used to see the fine details of the segmentation.

## Segmenting

Once all the points of the desired airway are selected, clicking the 'Segment' button will linearly interpolate the points and locate the airway mask. Once completed, the  Overlay Mask [ O ] will be checked and the stack of images can be scrolled through with the newly segmented airway in red. From here, the slider located underneath Overlay Mask  can be used to adjust the transparency of the segmented airway mask. Be sure to carefully look through the overlayed images paying close attention to any explosions. To deal with explosions a 'Spilt Segment' will be required.

### Split Segment (Re-segmenting)

If any explosions appear, simply press the [d] key on the keyboard and *split* the image from its exploded counterpart, scrolling though and pressing [shift-d] when finished. After each explosion is fixed, press the 'Split Segment' button and those certain slices will be fixed.

Note\* you can only have 1 drawnMask [d] boundary per slice so be sure to use it to cover all possible leakage areas.

## Adding Mask

If you are happy with the segmented airway mask, simply press 'Add Mask' button to add the red segmented airway to the set and have it change colors to green indicating its success. From here, either continue working on a new airway or save the mask.


## Removing Mask

1. If wanting to remove a red airway, simply press the [backspace] key and enter the range you wish to remove
2. If wanting to remove everything, red and green, press [shift-backspace] to select the range of removal.


## Available Segmentation Tools


The toolbar can be displayed by pressing [t] and disabled by pressing [shift-t]. In order of appearance, tools are as followed:


**User Manual**  Displays the path of the user manual (this).

**Paint Brush**  Toggles on a 'paintbrush' which when clicked, draws in red a circled region onto mask. Double click and drag to continuously paint mask. Pressing [page up] increases the brush size and [page down] decreases the brush size. Toggling off the Paint Brush applies the painted area, (red → green).

Pressing [shift-page up] or [shift-page down] gets rid of brush size indicator. Otherwise right click and selected delete has the same functionality.

**Manual Adding**  Toggles on the manual adding of an airway. After clicking, draw a region onto the image. Afterwards, pressing the [a] key will *add* this and turn the inside of the drawn shape to green.



**Connecting Airways**  Toggles on a connecting airways tool which draws on a small dot that can be used to connect two airways that are obstructed in the MicroCT scan. To use, simply click onto the image where the connected airway should be and a red dot will be generated. These do not get interpolated so be sure to click on every slice between airways. Toggling off applies the connected region, (red → green).

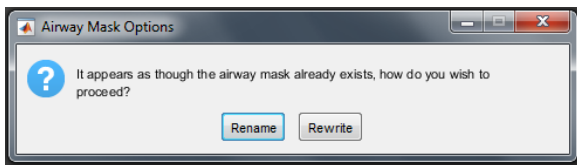
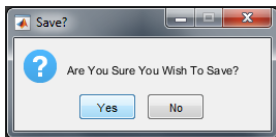
**Re-Processing Images**  Clicking this brings back the buttons and sliders from the 'Pre-Process Images' step and is used to re-process the filtered stack. This will ask for the range of images to re-process so make sure to have that in mind.\*

\*This tool only gets enabled after the original stack has already been initially pre-processed.




## Saving Mask


Pressing the 'Save Mask' button will bring up a confirmation question  on if you are sure you have selected all the desired airways. If you click 'no', you can further continue selecting and segmenting airways until ready to save. If 'yes' is selected, the program will save the masks into the directory  of the MicroCT scan with the extension '.airway.mask'.



If the file had been previously saved, you are given two options, either renaming the file, or to rewrite the file. If selected 'Rename', an input dialog box will ask the user on what to save the file. Anything inputted into the dialog box will be added after '.airway.mask'. An example would be typing in "2" and having the file be named 'C://path/filename.airway.mask\_2.img'. Rewriting obviously replaces the previous mask with the new one.

## Skeletonizing Mask

Clicking the 'Skeletonize Mask' button will bring up a question  on if you wish to *skeletonize now* or *later* since this process can be lengthy.

Clicking *later* will write the pathname into the *SkeletonQueue.txt* file in the program directory.  This file can then be loaded into *SkeletonQueueText.m* file also in the program directory and it will read through the paths and create a skeleton for every mask loaded into it.

Clicking *now* will launch ImageJ and send the mask and preform *Gaussian Blur 3D...* and then *Skeletonize (2D/3D)*. It is then returned into MATLAB and gets saved with the extension *.airway.mask.skeleton* (renamed or rewritten following same convention as earlier discussed if already skeleton already exists).

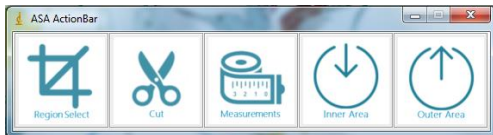
Afterwards, the skeleton will then get displayed in 3D, its branch points will be gathered, and the stack will be scrollable in 3D (the Z-axis).

From here, the user can click on the green ROIs and select starting (circle) and ending [square] branch points to be used for the generating cross sections step.

## Generating Cross Sections


Clicking on 'Generate Cross Sections' will send the X Y and Z coordinates of the starting and ending ROI to get analyzed in ImageJ. It will also prompt a name for the selected branch used for identification. After executing, the branch length will be returned, the targeted airway will be colored, 10 cross sectional images will be created and an ImageJ ActionBar will be brought up enabling analysis of the cross sections.



### ImageJ ActionBar <sup>[2]</sup>



- **Region Select** – Creates a 160x160<sub>px</sub> square region in the center of the image. This can be adjusted and need not be a perfect square – albeit ideally it is.
- **Cut** – Cuts the cross sections to fit that of the region select.
- **Measurements** – Performs wall calculations and displays ROIs for inner and outer areas of the cross sectional lumen.
- **Inner Area** - Creates a 1<sub>px</sub> ROI in the center of the image (used to represent obstructed inner airways)
- **Outer Area** - Creates a 9<sub>px</sub> ROI in the center of the image (used to represent obstructed outer airways)



## Extracting Data

Clicking on 'Extract Data' will save the ImageJ ROIs into a folder  called 'SubStacks\_and\_Rois' in the MicroCT folder directory. As well, it saved the 10 cross sectional images in the same folder. These are saved with the branch name appended to the back.


 20160511\_uCT\_7287\_6492\_res2x\_NameOfBranch\_ROI.zip  
 20160511\_uCT\_7287\_6492\_res2x\_NameOfBranch\_substack.tif


This also grabs the 10 cross sections and their respective ROIs into MATLAB for Alveolar Attachment Counting. Additionally, all the raw measurements are stored.

## Alveolar Attachment Counting

Clicking on 'Alveolar Attachment' toggles on crosshairs. Left clicking  the mouse places green markers x and increase the alveolar attachment count per slice. If a mistake is made, pressing [backspace] decreases the counter and removes the last added marker. To move onto the next slice, simply right click  the image. After counting all 10 slices, the data is ready to be exported.

## Exporting Data

Clicking 'Export Data' will ask the user if they wish to continue onto a new airway or not.  If clicking yes, the program jumps to the 'Generate Cross Sections' stage and a new starting and ending branch point can be selected.

Whether hitting yes, or no, the airway data gets calculated and formatted and saved into an excel spreadsheet in the MicroCT directory folder  with the extension '.measurements.xlsx'.

# Toggles


The seven toggles to the Airway Segmenter program are as shown:


**Adjust Contrast** – allows the images to be clicked and dragged on to adjust contrast levels.


**Contrast View** – toggled on displays the contrast stack; toggled off displays the original image.

**Filtered Preview** – turns on the ‘filtered preview’. In essence, this is what the program sees as what are unique objects. This mode is extremely helpful while clicking for segmentations as it shows the user what the program will be able to recognize.

**Overlay Images** – displays the overlays of the mask onto the image. These will appear as green airways. This mode illustrates what airway has been segmented, and can be used to find explosions that will need to be reprocessed.

**Zoom**  – allows the image to be zoomed in or out. This is helpful for zooming close during segmenting to see the image on a pixel by pixel level.

**Rotate**  – allows the image to be rotated in the 3D space. This is helpful for viewing the 3D skeleton from other angles.

**Pan**  – allows the images to be panned around. This is helpful for moving to a different view in the image if zoomed in closely.

# Programmer

Airway Segmenter & Analyzer was programmed by University of Victoria Software Engineering Coop Student Sukhdip Sandhu. 4/28/2017.

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## Sources

[1] Waitbar with time estimation is courtesy of Andrew, file is downloadable at <https://www.mathworks.com/matlabcentral/fileexchange/22161-waitbar-with-time-estimation>

[2] ActionBar ImageJ Plugin courtesy of Jerome Mutterer, available at [http://imagejdocu.tudor.lu/doku.php?id=plugin:utilities:action\\_bar:start](http://imagejdocu.tudor.lu/doku.php?id=plugin:utilities:action_bar:start)