

Retinal Video Analysis Suite (ReVAS) Tutorial

Sight Enhancement Laboratory at Berkeley, School of Optometry.
University of California, Berkeley, USA.

Contents

1 ReVAS Tutorial and Purpose of Tutorial	3
2 Downloading / Setup	4
3 Starting up / Running ReVAS	5
4 GUI Overview	6
5 Workflow	8
6 Module Overview	15
7 Module Configurations	19
8 Description of Feature Implementations	30
9 Troubleshooting	31
10 Acknowledgements	32

1 ReVAS Tutorial and Purpose of Tutorial

Welcome to the Retinal Video Analysis Suite (ReVAS)! ReVAS is an analytical tool for retinal videos, used for processing and extracting useful eye position data from them. This tutorial will go over how to use the ReVAS built-in graphical user interface from start to finish, as well as take an in-depth look at all of the features included in ReVAS. For instructions on how to setup and run the ReVAS tool, go to Sections 2-3.

For instructions on the basic functionalities of the ReVAS tool and a step-by-step tutorial on how to use it, go to Sections 4-6.

For more advanced configurations and information about the ReVAS tool, go to Sections 7-8.

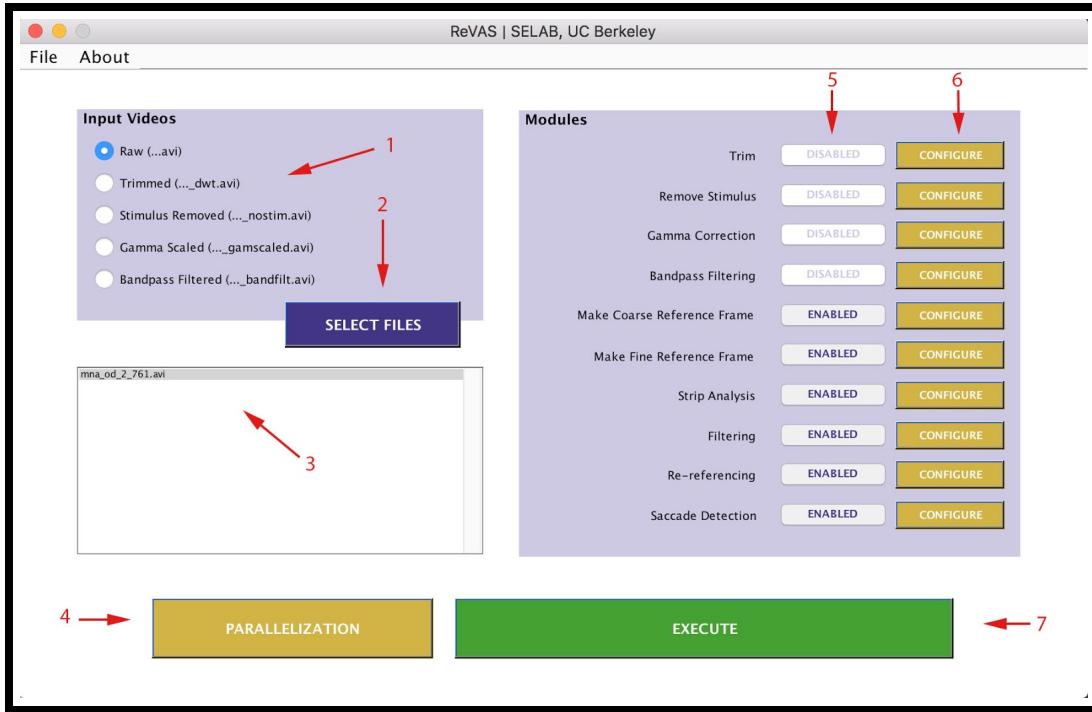
For a troubleshooting guide, go to Section 9.

2 Downloading / Setup

3 Starting up / Running ReVAS

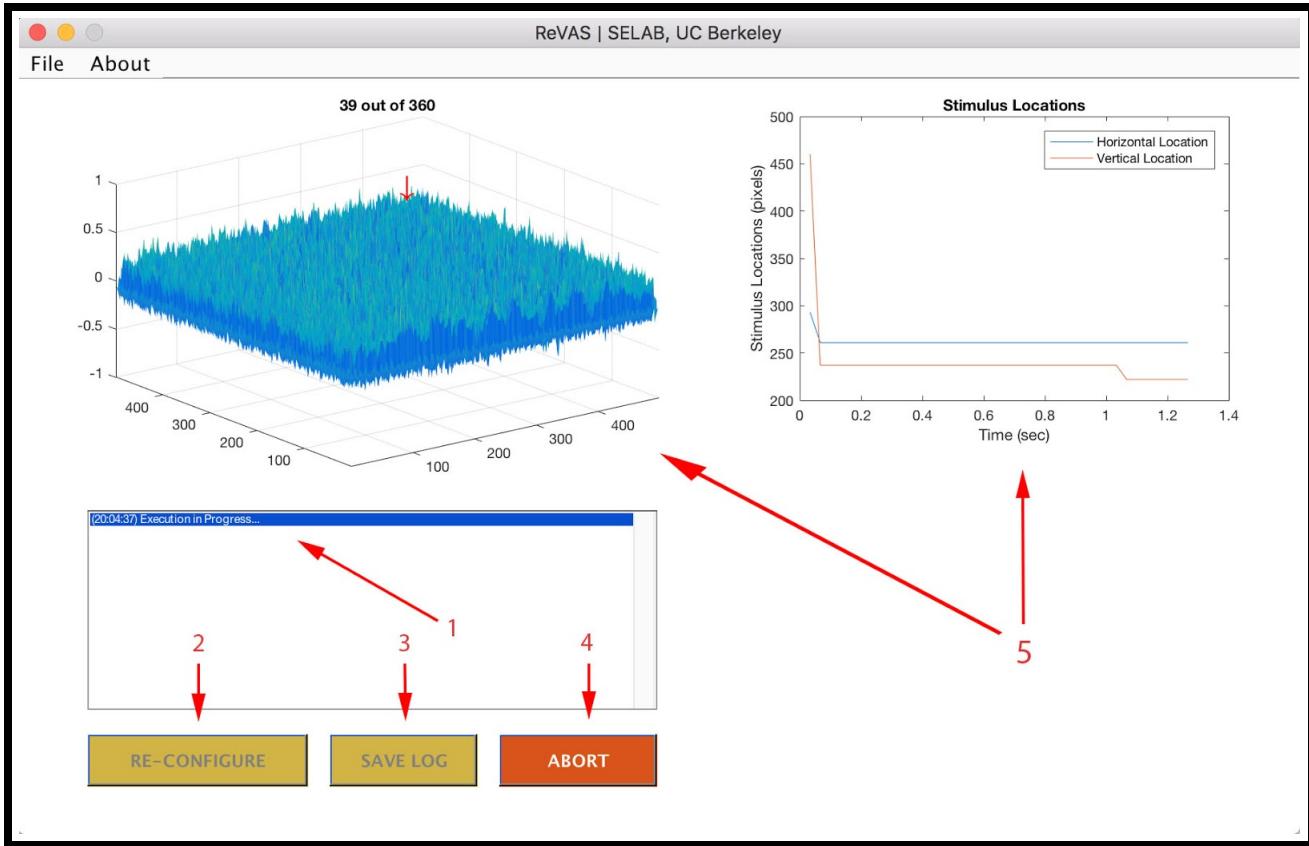
4 GUI Overview

Configuration Overview



1. Input Videos: Options for the type of input video.
 - (a) Raw
 - (b) Trimmed
 - (c) Stimulus Removed
 - (d) Gamma Scaled
 - (e) Bandpass Filtered
2. Select Files: Opens a menu to select the input video. Overwrites previously selected videos (if another video has already been selected).
3. Display Window: Displays the name of the selected input video.
4. Parallelization: Opens menu for parallelization options.
5. Enable / Disable Modules: Options to enable or disable modules (click button to enable or disable).
6. Configure Modules: Press to configure values for particular feature.
7. Execute: Press to execute video analysis.

Execute Overview



1. Message Window: Messages are displayed here. During execution, this screen should output Execution in Progress Other messages should be displayed as well when appropriate, such as end of execution or any errors.
2. Re-Configure: Press RE-CONFIGURE to go back to configuration screen and change configurations. This cannot be pressed during execution.
3. Save Log: Press SAVE LOG to save log file. This cannot be pressed during execution. Option is disabled during parallelization.
4. Abort: Press ABORT to abort execution. Option is disabled during parallelization.
5. Graph Window: Graph construction should be displayed in these two locations, if verbosity is enabled for a particular module.

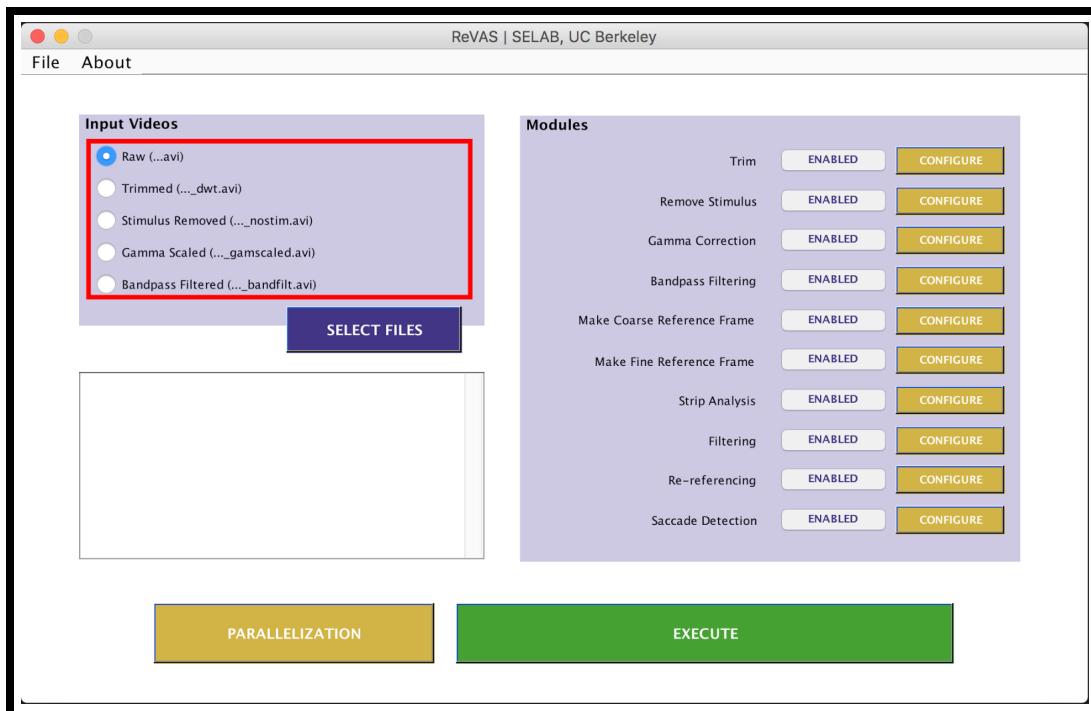
5 Workflow

This section will go through the entire process of using the ReVAS toolbox, after starting it up, to analyze retinal videos.

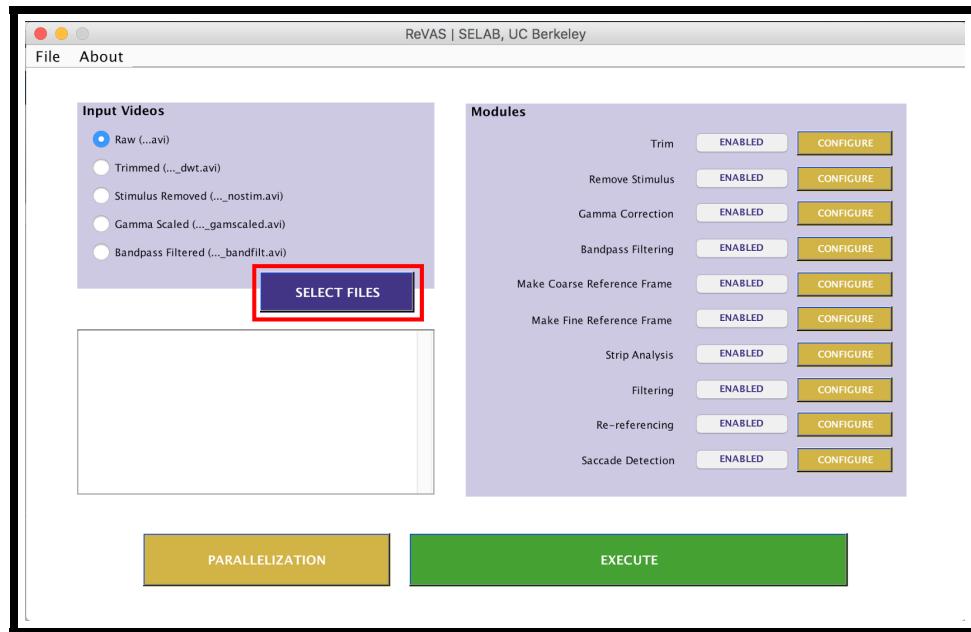
1) Selecting videos to process

The first step is to select what type of input video that will be used. Selection depends on which step of the analysis that you will begin on:

- Raw videos have a .avi extension. Use this option for videos that have not been analyzed at all.
- Trimmed videos have a “_dwt.avi” extension. Selecting this option automatically disables the Trim Module. Use this option for videos that have already been trimmed by the Trim Module.
- Stimulus Removed videos have a “_nostim.avi” extension. Selecting this option automatically disables the Remove Stimulus Module as well as any preceding modules. Use this option for videos that have already had their stimulus removed by the Remove Stimulus Module.
- Gamma Scaled videos have a “_gamscaled.avi” extension. Selecting this option automatically disables the Gamma Correction Module as well as any preceding modules. Use this option for videos that have already been gamma-corrected by the Gamma Correction Module.
- Bandpass Filtered videos have a “_bandfilt.avi” extension. Selecting this option automatically disables the Bandpass Filtering Module as well as any preceding modules. Use this option for videos that have already been through bandpass filtering by the Bandpass Filtering Module.

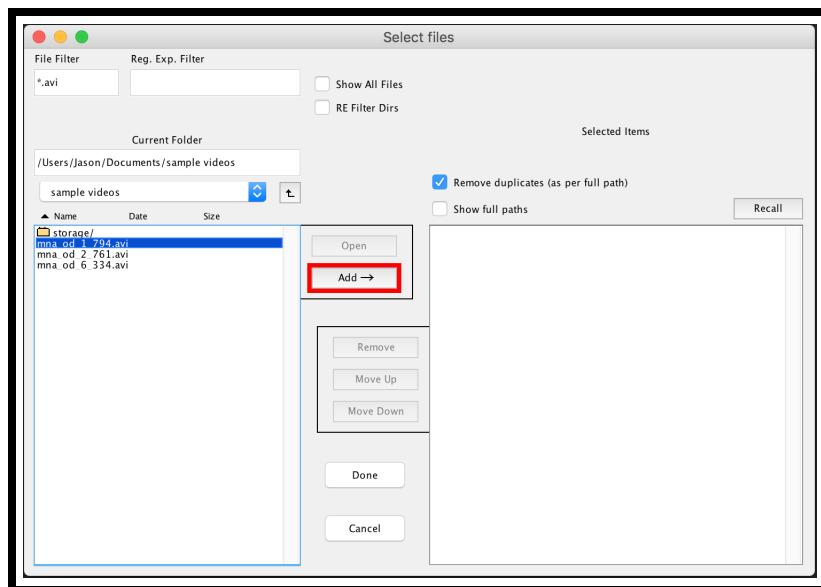


Then, select the videos that will be analyzed. To do this, click on the SELECT FILES button on the Configuration screen.

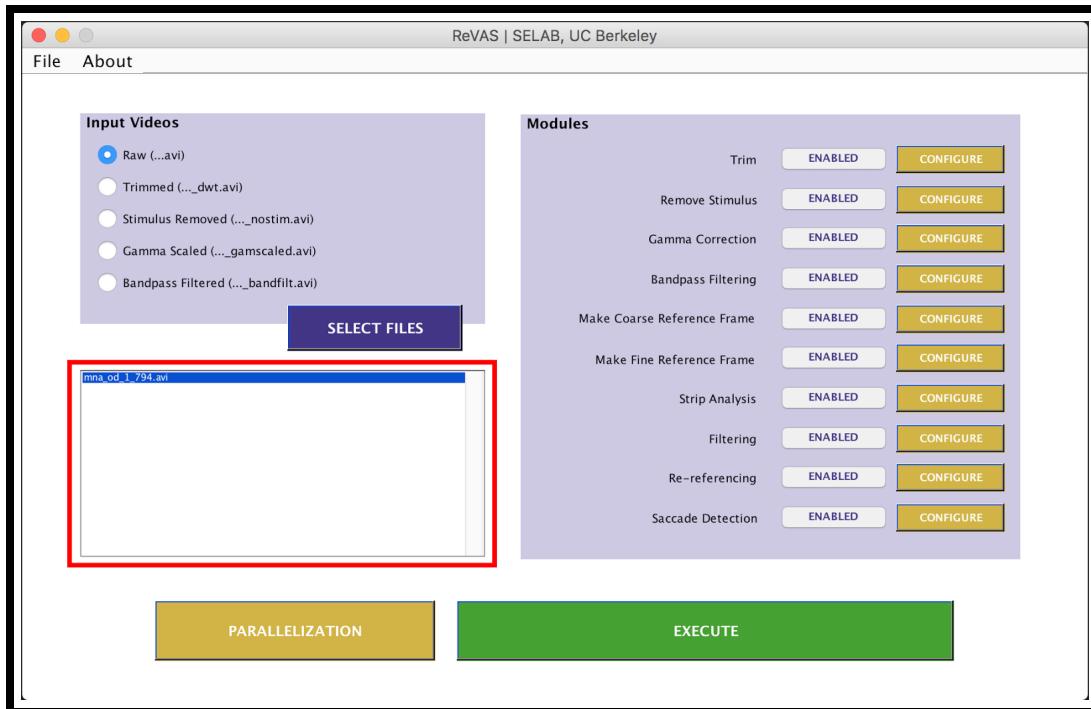
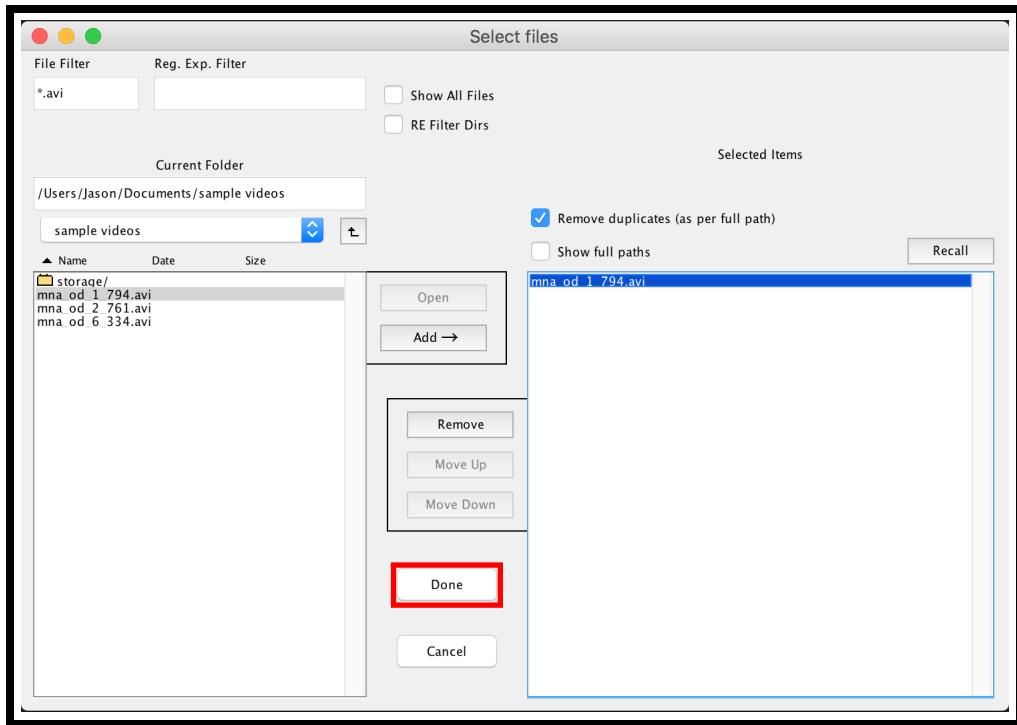


A new window should pop up prompting the user to select files. By default, the file filter should be set to “*.avi”, which means that only .avi files should display in the left-hand window.

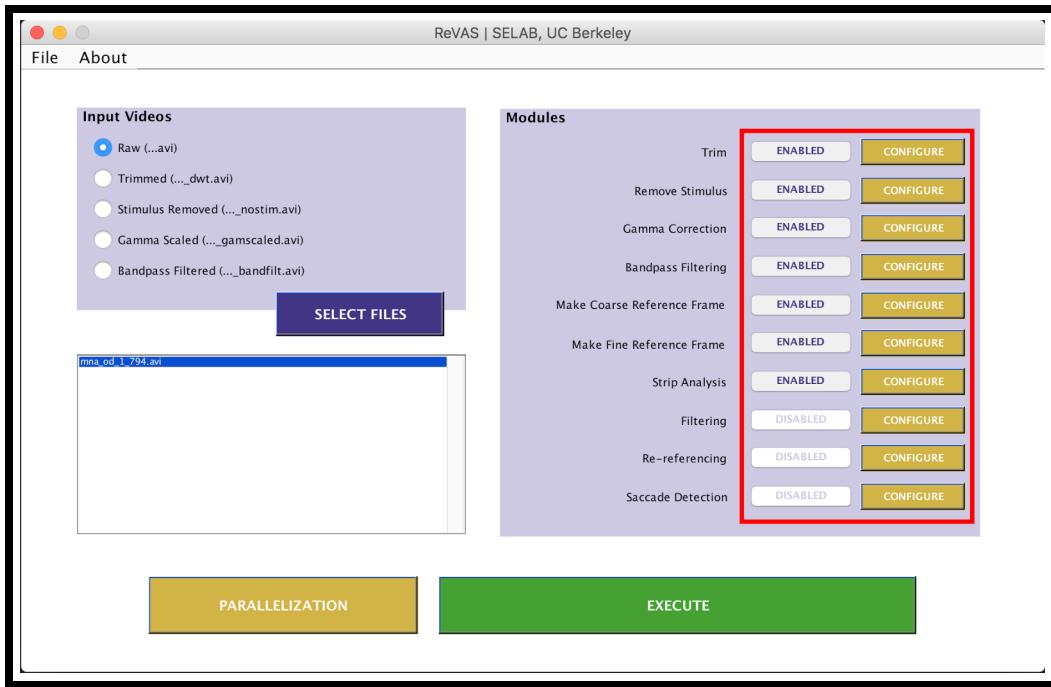
To select videos to be analyzed, navigate to the current folder where the videos are stored using the left window. Select the videos, then click “Add”. You should see the added videos appear on the right window.



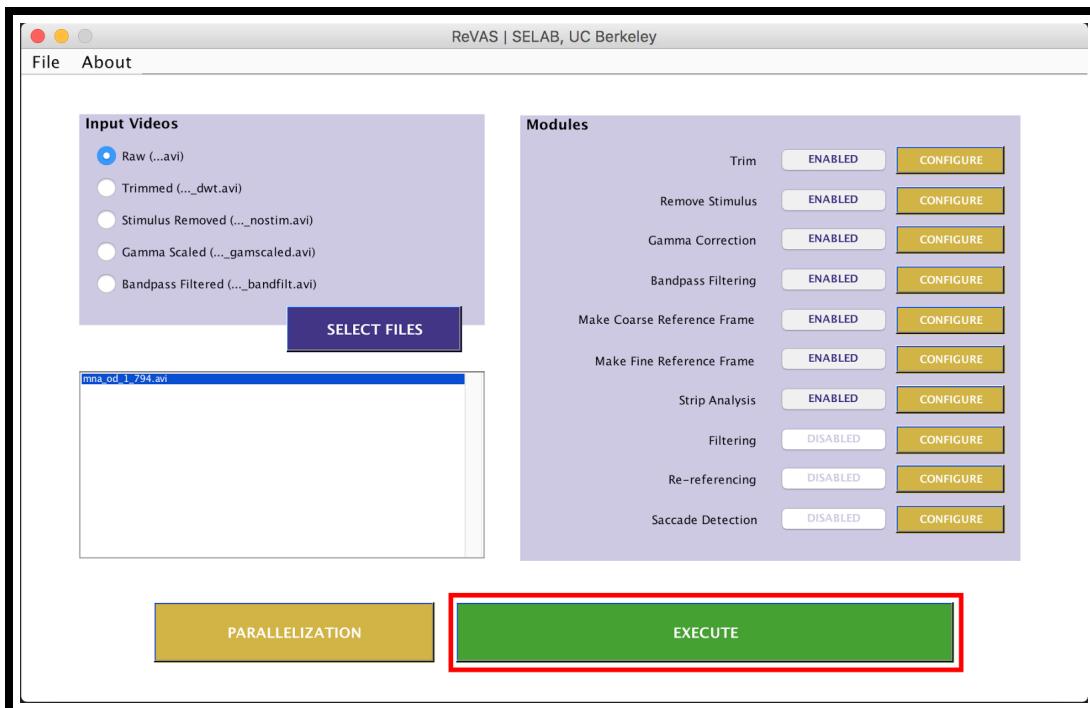
To remove selected videos, highlight the videos you want removed, then click the “Remove” button. When you are finished with your selection(s), click “Done”. Your selected videos should appear in the display window of the Configuration Screen.

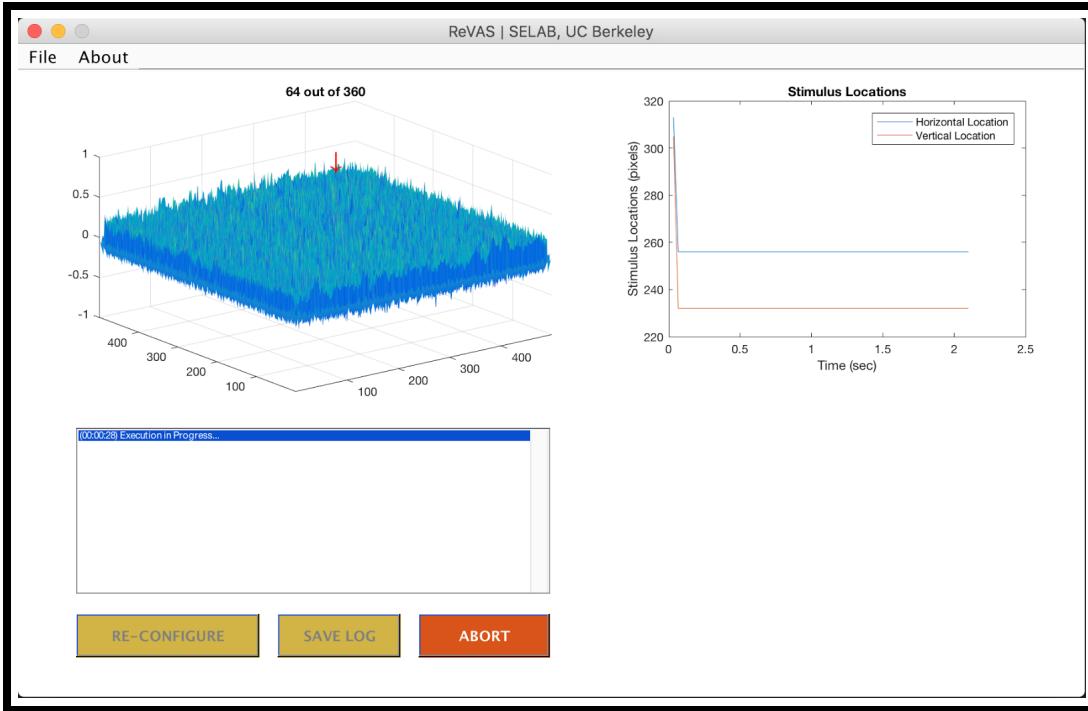


- 2) Enabling/Disabling Modules** The next step is to choose which modules you want to apply to the selected videos. Choose the modules by clicking on their respective toggle buttons to enable or disable them. If you want to adjust the parameters of each module, click on the CONFIGURE button next to that module. For a full list of what each module does, refer to Section 7: Module Configurations.

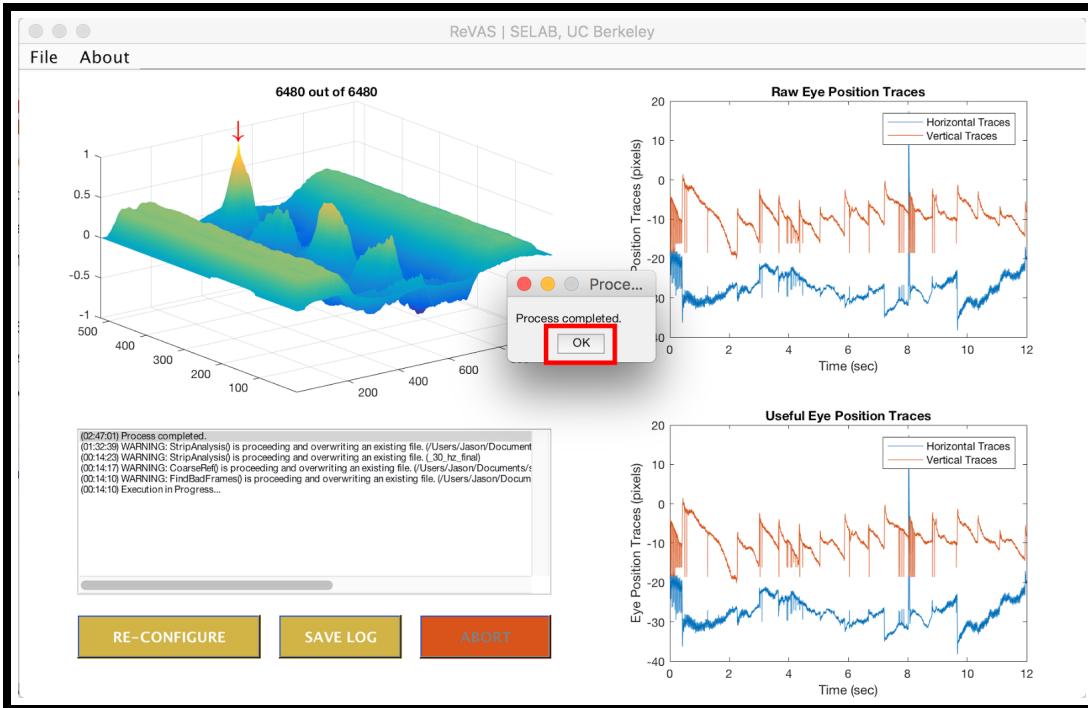


- 3) Execution** Once everything has been configured to your preferences, press the EXECUTE button. The GUI's main screen should transition to the Execute Screen and the analysis process should automatically begin.



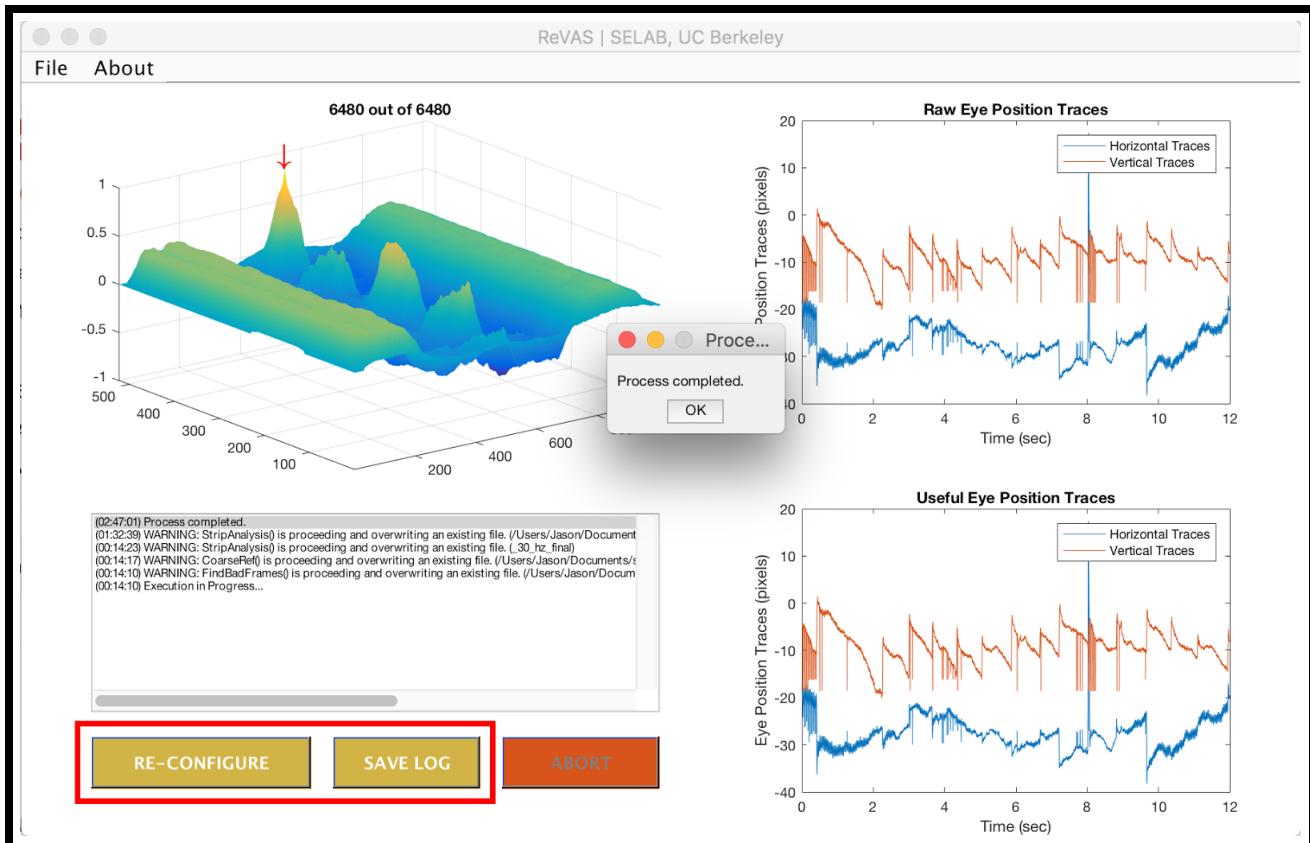


- 4) Finishing Execution/Aborting Early** Once execution has finished, a message should appear both as a pop-up and in the message window. Press OK to confirm and to close the pop-up.

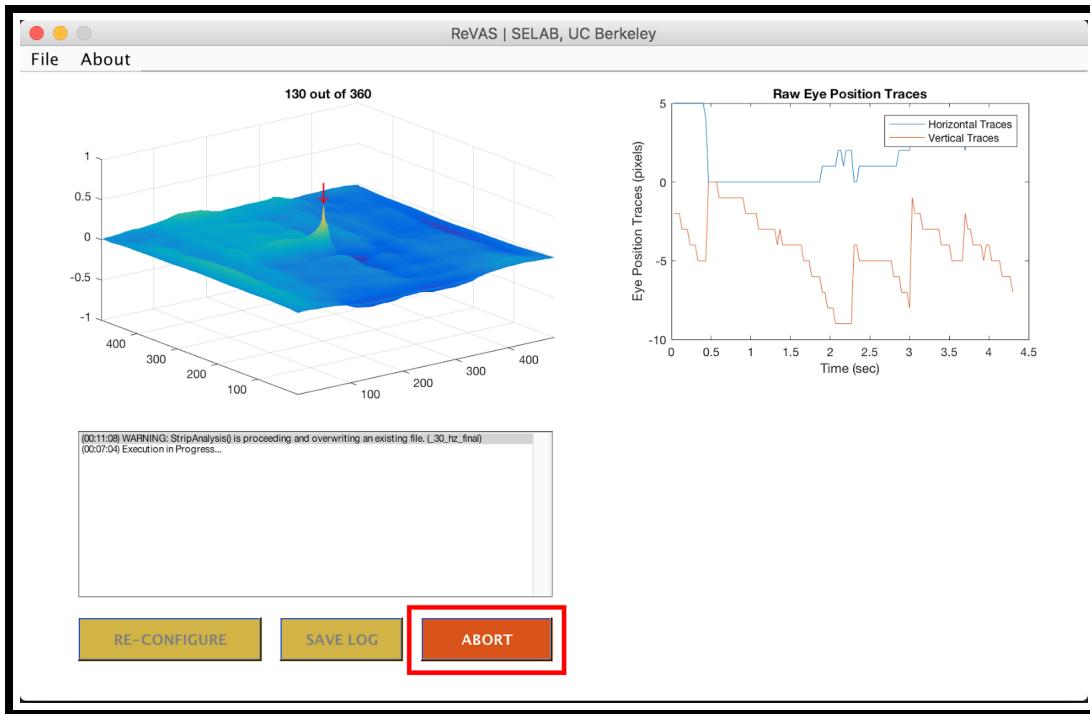


At this point, you have a couple of options:

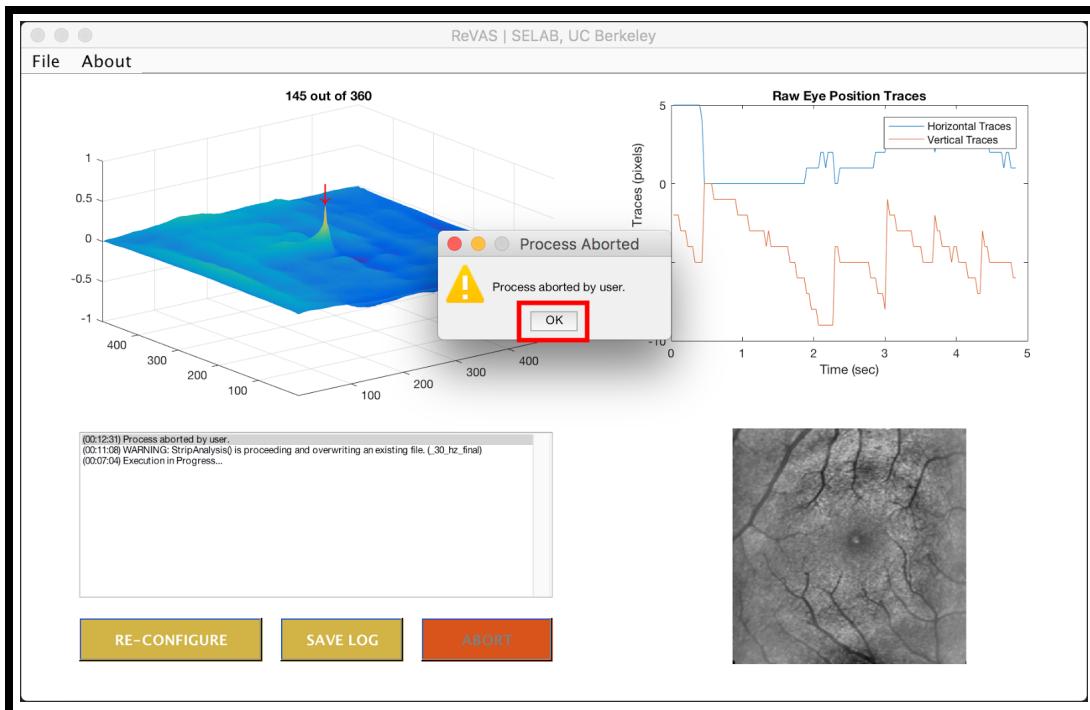
- Pressing the SAVE LOG button will save the outputs recorded in the message display box during execution. This option will not appear if you are using the “Parallelization” option (see Section 6: Features).
- Pressing the RE-CONFIGURE button will send you back to the Configure Screen, where you are able to change the configurations for your analysis.



If you want to stop the analysis process during its execution, press the ABORT button (will not appear if using the Parallelization option). Execution will stop as soon as it is able to, and a message should appear both as a pop-up and in the message window.



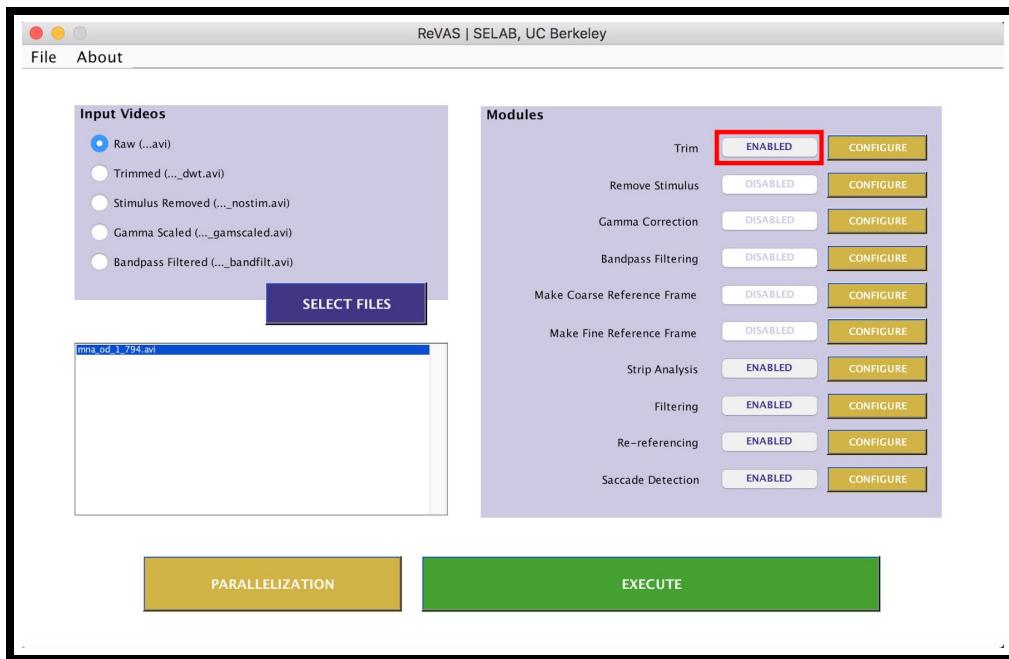
Press OK to confirm and to close the pop-up. From there, you are free to either save the log or re-configure.



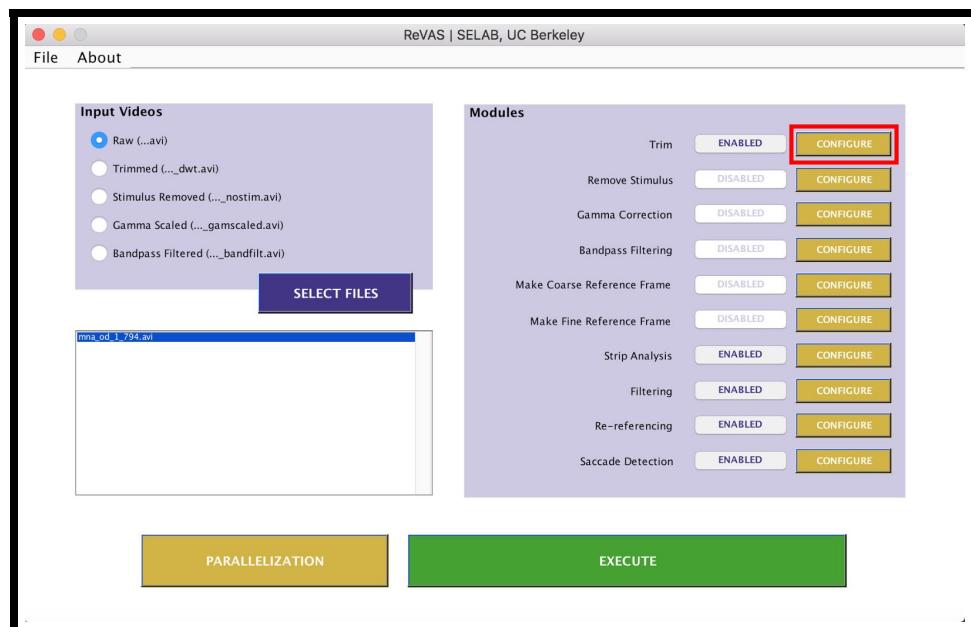
6 Module Overview

- 1) Loading and saving configurations** The following steps will demonstrate how to load and save configurations. (The trim configuration will be used as an example. These steps can be applied to the other configurations as well.)

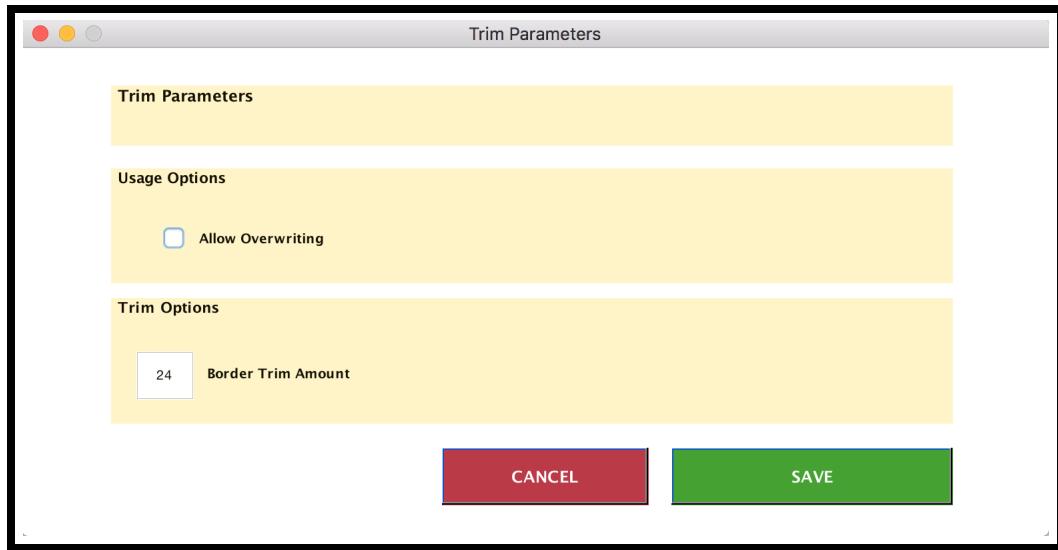
To save a configuration, first make sure it is enabled. To do this, simply press the button to the right of the modules name to toggle between ENABLED and DISABLED.



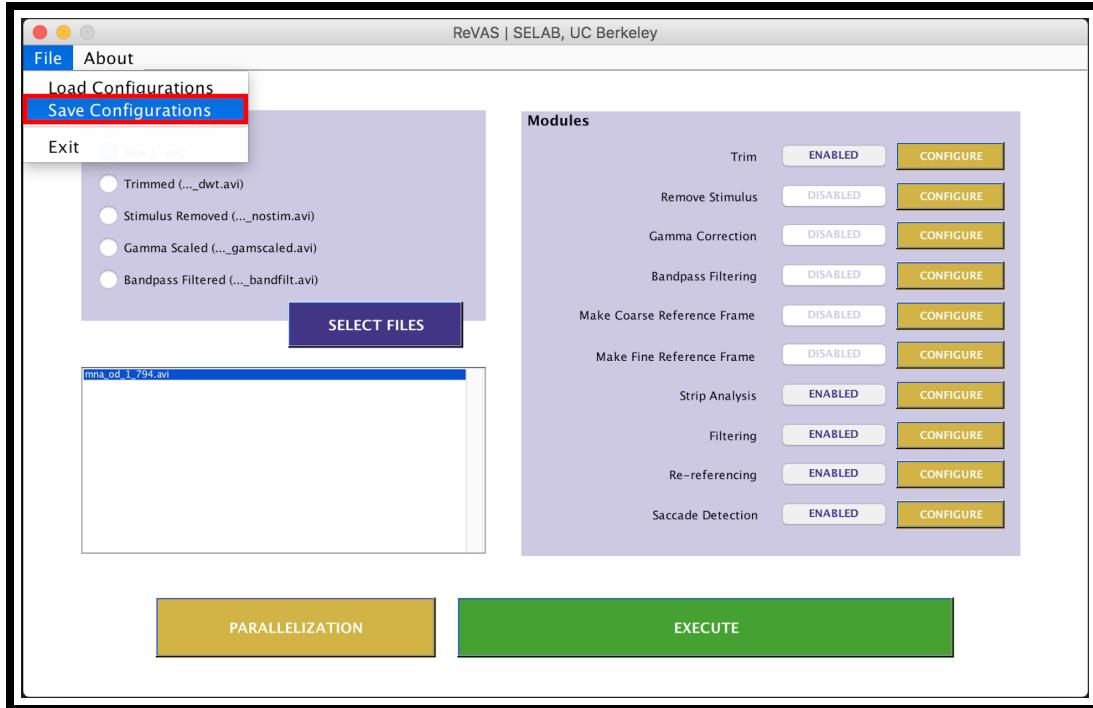
Once the module is set to ENABLED, select the CONFIGURE button immediately to the right of the ENABLED button.



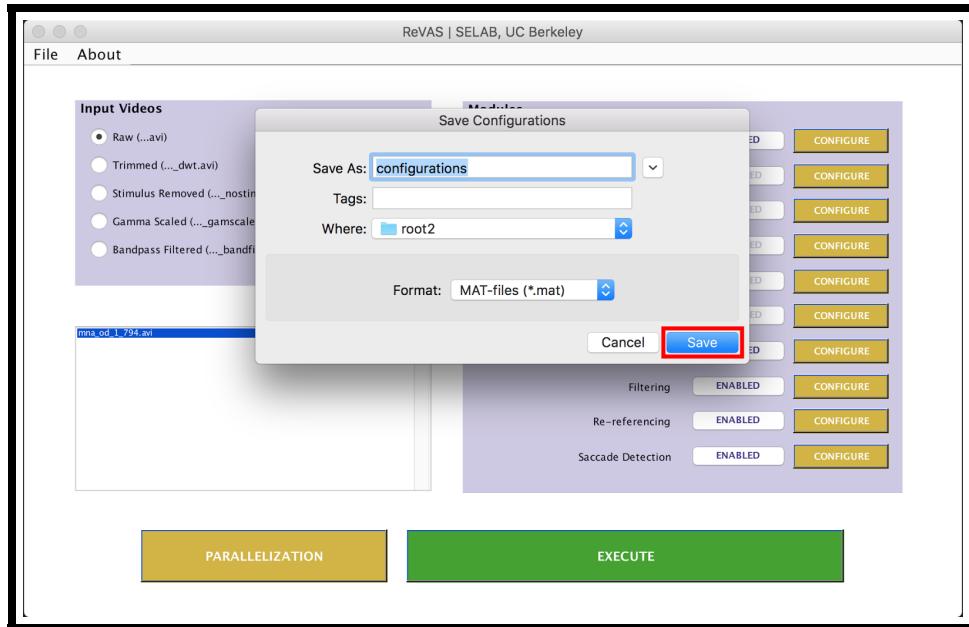
The screen below should pop up in a new window. Change the parameters of the selected module to your preferences (for information on what each configuration does, see Section 7: Module Configurations). To save these parameters, press the green SAVE button. Otherwise, press CANCEL.



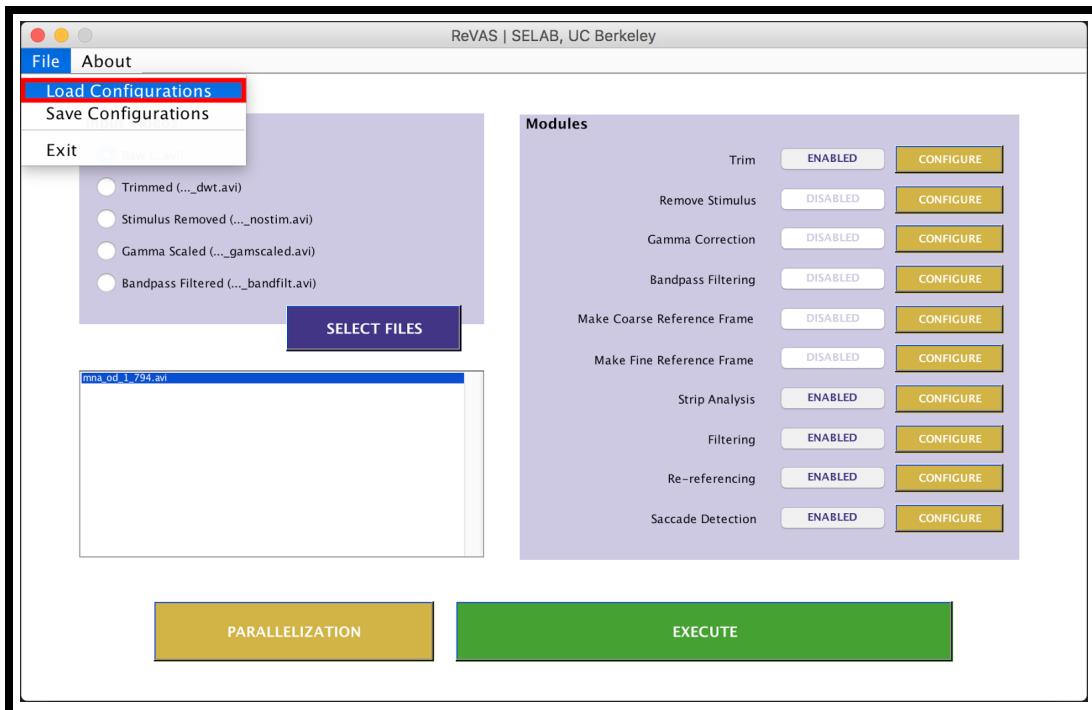
After making all the necessary changes to each configuration, go to the Toolbar at the top of the Configuration Screen and select File → Save Configurations.



Select a location to save your configurations. The default name will be set to “configurations.mat”; you may change the name if you wish. Press “Save” to save your configurations.

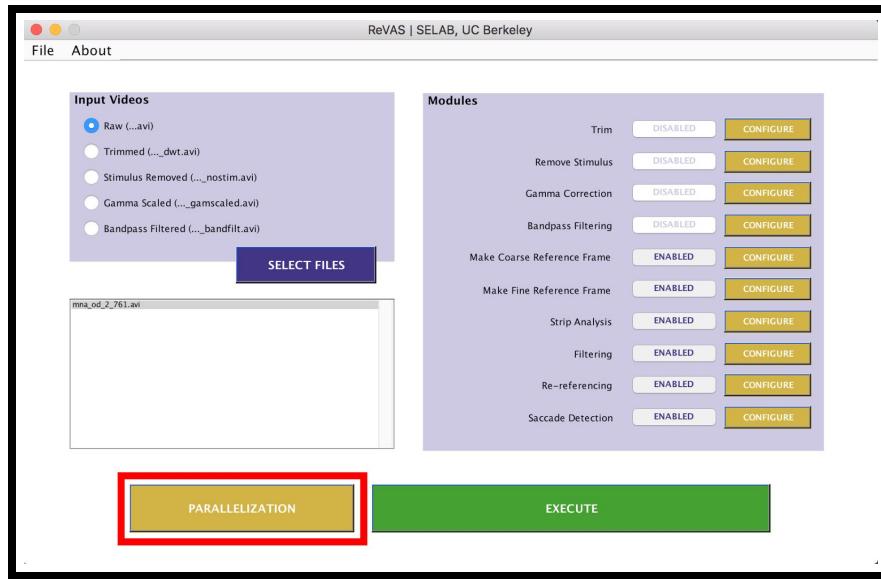


To load configurations, go to the Toolbar at the top of the Configuration Screen and select File → Load Configurations.



Select the “.mat” file that corresponds to the configuration file that was saved before, and press “Open”. The configurations should be loaded.

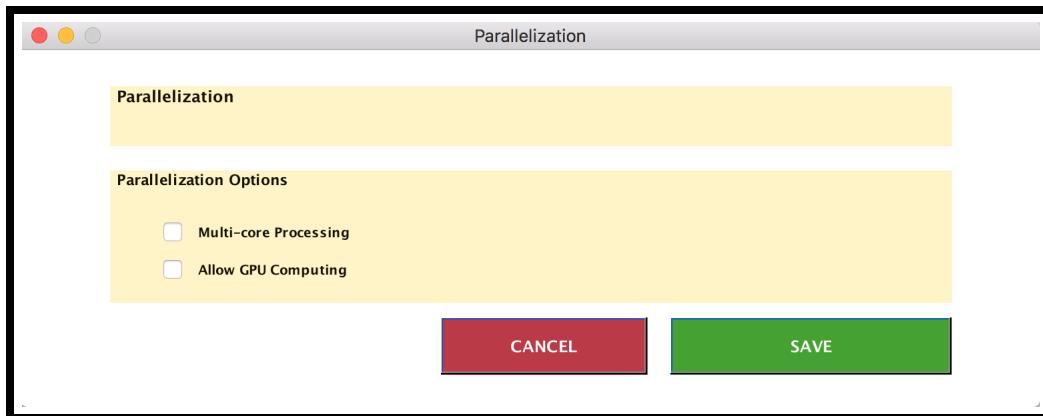
- 2) Parallelization option Before execution, you may choose to use the parallelization option to help speed up computation, if applicable to your device. To use the parallelization option, after selecting the input file, click on the yellow PARALLELIZATION button.



The Parallelization Options screen should pop up in a new window. There are two options: Multi-core Processing and GPU Computing. (**NOTE: These options should only be selected if the computer has the capacity for them.)

- Multi-core Processing: Utilizes multiple cores in your CPU to speed up computation. Only certain modules have the capacity for parallel computing.
- Allow GPU Computing: For certain modules, if a Graphical Processing Unit is available, enabling this option transfers data to and performs computation on the GPU, which can result in faster computation.

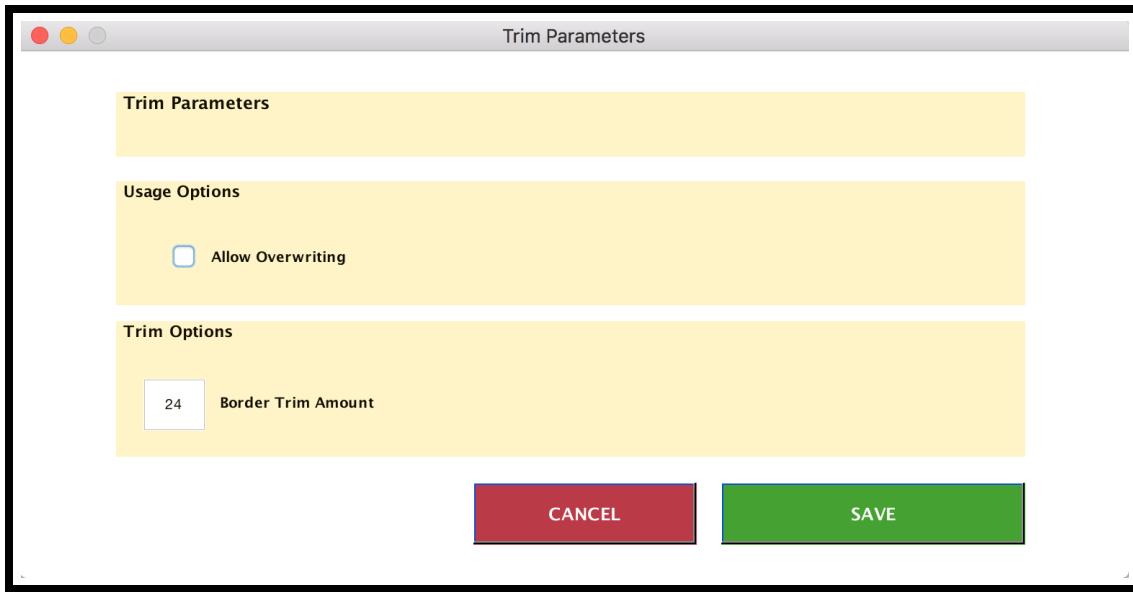
To select either option, simply check the box next to it. Press SAVE to confirm these changes, or press CANCEL to go back.



After selecting these options, press EXECUTE to begin the analysis with Parallelization.

7 Module Configurations

1) Trim

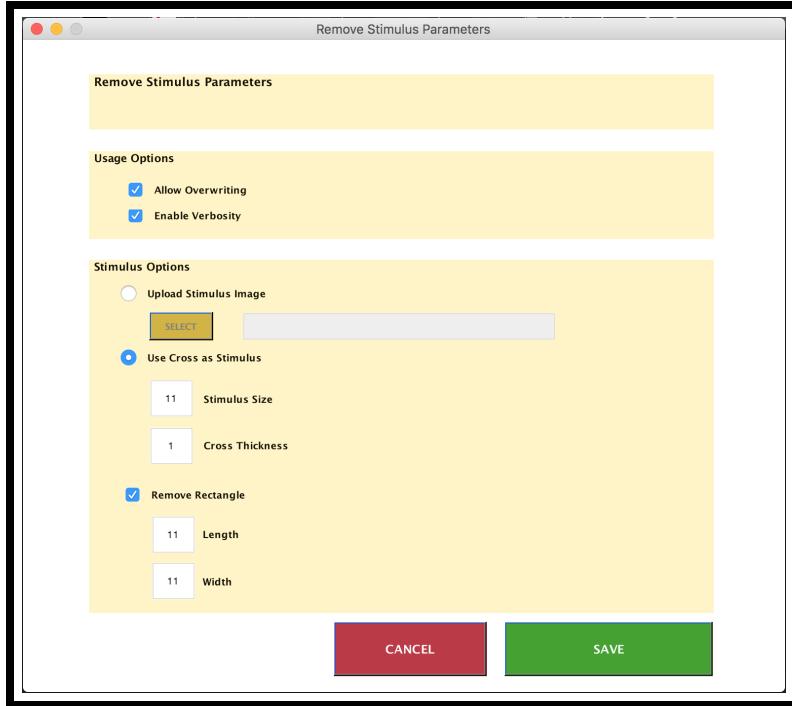


The Trim Module trims the video's upper and right edges. It then produces a trimmed version of the video, stored in the same location as the original video, but with “_dwt” appended to the original file name.

Parameters:

- Usage Options
 - (a) Allow Overwriting: If this box is checked, any file with the same name as the output will be overwritten. If this box is not checked and a file with the same name as the output exists in the same folder, the module will not execute. Default value = Checked.
- Trim Options
 - (a) Border Trim Amount: This is the number of rows/columns (in pixels) that will be removed from the upper/right edges of the video. Default value = 24 px.

2) Remove Stimulus

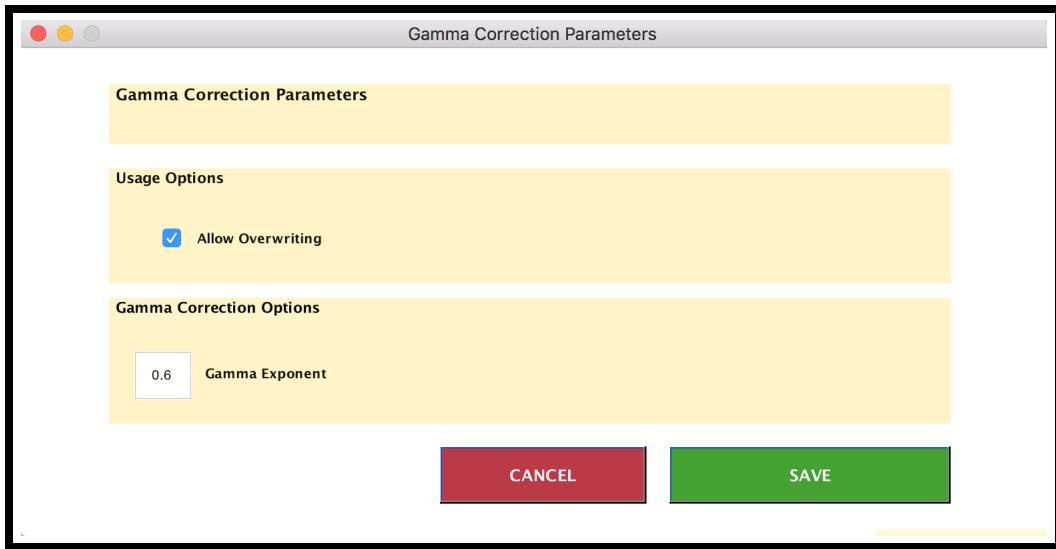


The Remove Stimulus Module first finds the location of the chosen stimulus at each video frame and stores them in a .mat file. Then, it removes an area around the stimulus from each video frame, producing a new version of the video with a “_nostim” extension. The new video is stored in the same location as the original video.

Parameters:

- Usage Options
 - (a) Allow Overwriting: If this box is checked, any file with the same name as the output will be overwritten. If this box is not checked and a file with the same name as the output exists in the same folder, the module will not execute. Default value = Checked.
 - (b) Enable Verbosity: If this box is checked, graphs will be displayed on the Graph Window of the Execute Screen during execution to monitor progress. Default value = Checked.
- Stimulus Options
 - (a) Upload Stimulus Image: If this option is chosen, you can choose an image from your files to represent as your stimulus. The module will use this image when it searches for the stimulus in each video frame. Press the SELECT button to browse and select the stimulus image. Default value = Not Selected.
 - (b) Use Cross as Stimulus: If this option is chosen, the module will assume that you are using a standard white fixation cross as the stimulus. Default value = Selected.
 - i. Stimulus Size: The pixel size of the stimulus cross. Default value = 11 px.
 - ii. Cross Thickness: How thick the stimulus cross will be. Default value = 1 px.
 - (c) Remove Rectangle: Check this option if you want to remove an area around the stimulus different from the size of the stimulus. Default value = Checked.
 - i. Length: The pixel size of the removal rectangle's length (in the x-direction). Default value = 11 px.
 - ii. Width: The pixel size of the removal rectangle's width (in the y-direction). Default value = 11 px.

3) Gamma Correction



The Gamma Correction Module applies gamma correction to the video to adjust the intensity of each frame. It produces a gamma-corrected version of the input video stored in the same location, but with “_gamscaled” appended to the original file name.

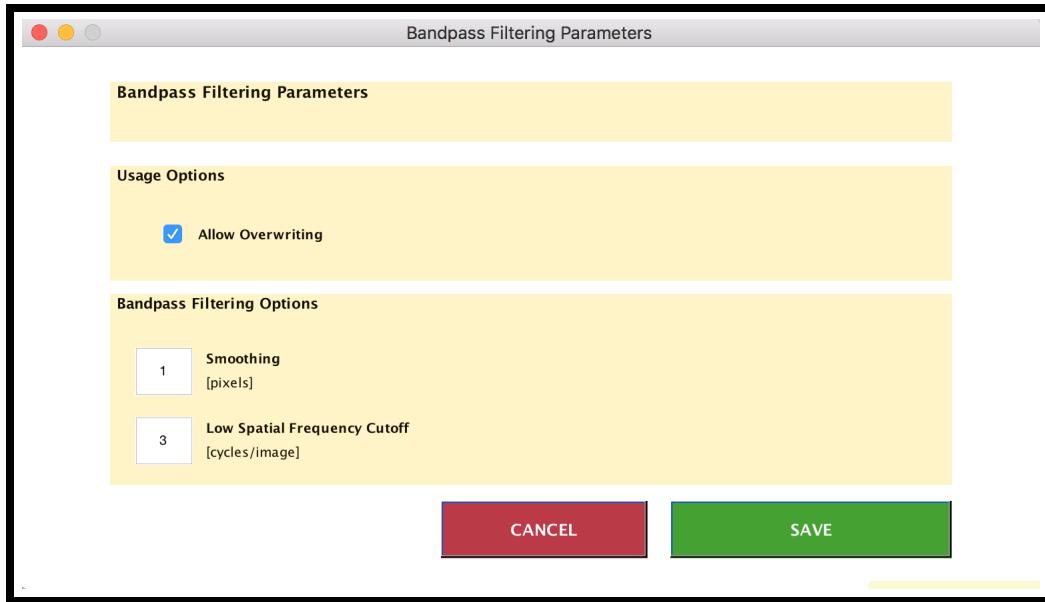
(a) Usage Options:

- Allow Overwriting: If this box is checked, any file with the same name as the output will be overwritten. If this box is not checked and a file with the same name as the output exists in the same folder, the module will not execute. Default value = Checked

(b) Gamma Correction Options:

- Gamma Exponent: Scales the intensity mapping applied to the video. Values less than 1 will brighten the video, while values greater than 1 will darken the video. Default value = 0.6.

4) Bandpass Filtering



The Bandpass Filtering Module smoothes, filters, and normalizes the video to remove high-frequency or low-frequency noise that could otherwise interfere with the analysis. It produces a bandpass-filtered version of the input video in the same location as the original, with “_bandfilt” appended to the original file name.

Parameters:

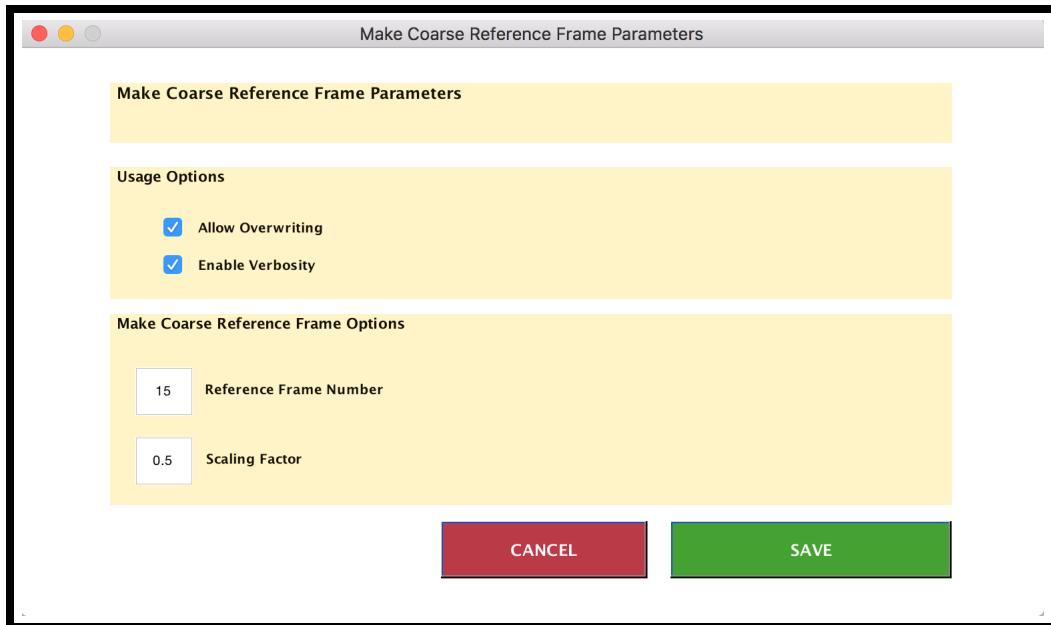
(a) Usage Options:

- i. Allow Overwriting: If this box is checked, any file with the same name as the output will be overwritten. If this box is not checked and a file with the same name as the output exists in the same folder, the module will not execute. Default value = Checked

(b) Bandpass Filtering Options:

- i. Smoothing: Used for filtering out high-frequency noise in the frames. The input value represents the standard deviation of the Gaussian smoothing kernel (in pixels); higher values increase the smoothing effect. Default value = 1 px.
- ii. Low Spatial Frequency Cutoff: Used for removing low-frequency fluctuations in the video that may result due to brightness gradients. Increasing the cutoff value increases the range of low-spatial frequencies to be removed. Default value = 3 cycles/image.

5) Make Coarse Reference Frame

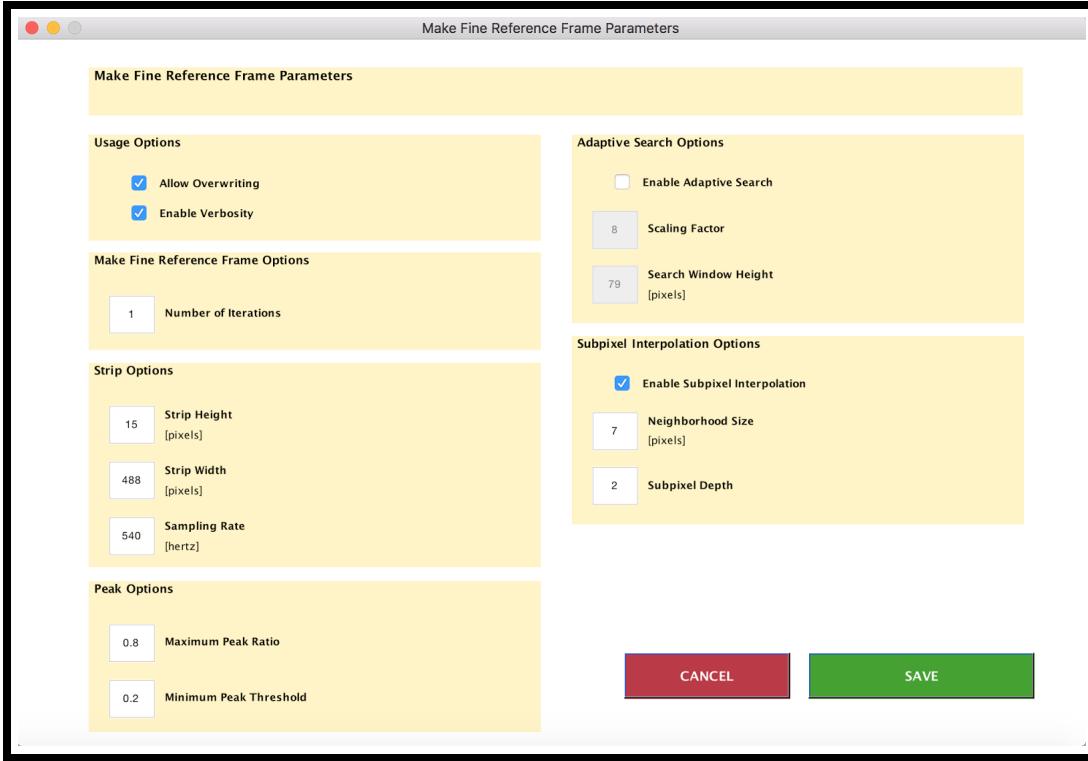


The Make Coarse Reference Frame Module creates a retinal montage using whole video frames and makes a “rough” reference frame, to be used as the starting reference frame in our analysis of eye position traces. This frame will later be refined in the Make Fine Reference Frame Module (if enabled). This module creates two .mat files: one that stores the rough frame movements in the video necessary to make the reference frame (titled “framePositions.mat”) and another that stores the actual coarse reference frame (using the same title as the original video, but with “_coarseref.mat” appended).

Parameters:

- (a) Usage Options:
 - i. Allow Overwriting: If this box is checked, any file with the same name as the output will be overwritten. If this box is not checked and a file with the same name as the output exists in the same folder, the module will not execute. Default value = Checked.
 - ii. Enable Verbosity: If this box is checked, graphs will be displayed on the Graph Window of the Execute Screen during execution to monitor progress. Default value = Checked.
- (b) Make Coarse Reference Frame Options:
 - i. Reference Frame Number: Determines the frame number of the video that will be used as the initial reference frame for the analysis. Because this module only generates a coarse reference frame, the initial reference frame should not affect computation too much, provided that the initial frame is fairly representative of the video as a whole. Default value = 15
 - ii. Scaling Factor: To speed up computation, this module scales down each frame by some factor before performing cross-correlation with the initial reference frame. Changing this number will change the magnitude of how much each frame is scaled (the closer the fraction is to 0, the more each frame shrinks). Default value = 0.5

6) Make Fine Reference Frame



The Make Fine Reference Frame creates a more precise retinal montage using horizontal strips of the coarse reference frame (generated from the Make Coarse Reference Frame), and uses those improved eye movement estimates to generate a refined reference frame. The reference frame generated through this step will be the actual one used in the analysis of eye position traces. Two separate .mat files are created: one that stores the final “useful” eye position traces generated through the analysis of the coarse reference frame (with the same title as the original video, but with the extension “.hz_final.mat”), and another that stores the actual refined reference frame (same title as original video, but with the extension “_refframe.mat”). (**NOTE: If the Strip Analysis Module is also enabled, the “.hz_final.mat” file will be overwritten by it.)

Parameters:

(a) Usage Options:

- Allow Overwriting: If this box is checked, any file with the same name as the output will be overwritten. If this box is not checked and a file with the same name as the output exists in the same folder, the module will not execute. Default value = Checked
- Enable Verbosity: If this box is checked, graphs will be displayed on the Graph Window of the Execute Screen during execution to monitor progress. Default value = Checked

(b) Make Fine Reference Frame Options:

- Number of Iterations: This is how many times this module is executed; the more times it is executed, the more refined the reference frame can get, but the longer the process will take. Default value = 1

(c) Strip Options:

- i. Strip Height: The height of each strip when performing the strip analysis using the coarse reference frame. Default value = 15 px
- ii. Strip Width: The width of each strip when performing the strip analysis using the coarse reference frame. Default value = 488 px
- iii. Sampling Rate: The frequency at which strips are taken during the strip analysis using the coarse reference frame. The number of strips equals the Sampling Rate divided by the Strip Height; therefore, increasing this quantity increases the number of strips used. Default value = 540 Hz

(d) Peak Options:

- i. Maximum Peak Ratio: When strip analysis using the coarse reference frame is performed, usually the highest peak of the correlation map determines the location of best fit for a particular strip on the reference frame. However, there may be instances where multiple “highest” peaks have similar values, which may have an adverse effect when trying to match the strip to the reference frame. To remedy this problem, the correlation value at the highest peak is compared to the correlation value of the second highest peak, and the ratio between the two is known as the Peak Ratio. The Maximum Peak Ratio determines the maximum allowed peak ratio for each strip. If the Peak Ratio is lower than the Maximum Peak Ratio, that strip is considered a “useful” eye position trace. Default value = 0.8
- ii. Minimum Peak Threshold: During strip analysis with the coarse reference frame, if a particular correlation map for a strip has overall low correlation values, it means that the strip does not fit well with the reference frame. The Minimum Peak Threshold determines the minimum allowed peak correlation value for each correlation map. If the peak value for a particular strip is higher than this quantity, that strip is considered a “useful” eye position trace. Default value = 0.2

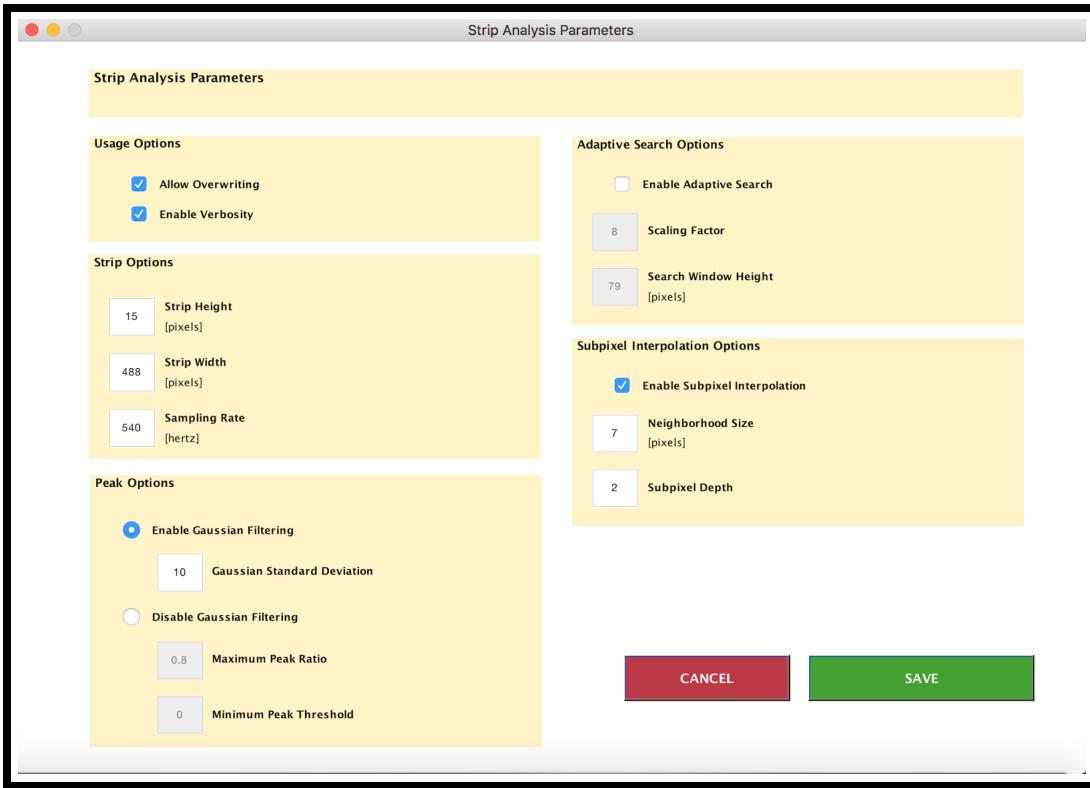
(e) Adaptive Search Options:

- i. Enable Adaptive Search: If this box is checked, the module will perform Adaptive Search when performing strip analysis of the coarse reference frame. Adaptive Search decreases the search window for finding peaks on correlation maps, which can reduce the overall running time of the analysis, but at the risk of slightly lower accuracy during correlation. Default value = Unchecked
 - A. Scaling Factor: This is the number of times to temporarily scale down the coarse reference frame to perform preliminary eye position estimates, if Adaptive Search is enabled. The higher this number, the more the reference frame will be scaled down. Default value = 8
 - B. Search Window Height: The size of the search window, if Adaptive Search is enabled. This search window will be centered around the preliminary eye position estimates obtained from the analysis of the scaled down reference frame. Default value = 79 px

(f) Subpixel Interpolation Options:

- i. Enable Subpixel Interpolation: If this box is checked, the module will apply Subpixel Interpolation to the correlation maps during strip analysis of the coarse reference frame. It will fit a continuous interpolation function over the discrete values obtained during correlation, resulting in a smoother correlation map. Default value = Checked
 - A. Neighborhood Size: The window size centered around the peak value of the correlation map. It determines the size of the meshgrid applied at the center of the peak during interpolation. Default value = 7 px
 - B. Subpixel Depth: The grid spacing of the meshgrid applied to the correlation map (divided by 100). The smaller this value is, the finer the correlation map will be after interpolation. Default value = 2

7) Strip Analysis



The Strip Analysis Module uses horizontal strips from a pre-defined reference frame to extract eye position traces from the video. This is the main module that does most of the analytical work on the video. A single output with the same name as the video but with “.hz_final.mat” appended to it is generated, containing the “useful” eye position traces, time array, parameters structure, and reference frame path used in the analysis.

Parameters:

(a) Usage Options:

- i. Allow Overwriting: If this box is checked, any file with the same name as the output will be overwritten. If this box is not checked and a file with the same name as the output exists in the same folder, the module will not execute. Default value = Checked
- ii. Enable Verbosity: If this box is checked, graphs will be displayed on the Graph Window of the Execute Screen during execution to monitor progress. Default value = Checked

(b) Strip Options:

- i. Strip Height: The height of each strip when performing the strip analysis. Default value = 15 px
- ii. Strip Width: The width of each strip when performing the strip analysis. Default value = 488 px
- iii. Sampling Rate: The frequency at which strips are taken. The number of strips equals the Sampling Rate divided by the Strip Height; therefore, increasing this quantity increases the number of strips used. Default value = 540 Hz

(c) Peak Options:

- i. Enable Gaussian Filtering: If enabled, the module will use a Gaussian Filtering method to determine “useful” peaks on the correlation map (which corresponds to “useful” eye position traces). Default value = Selected
 - A. Gaussian Standard Deviation: The standard deviation for the Gaussian filter. Default value = 10
- ii. Disable Gaussian Filtering: This option disables Gaussian Filtering as the method to determine “useful” eye position traces, and instead uses an alternate method using Peak Ratios and Peak Thresholds.
 - A. Maximum Peak Ratio: Usually the highest peak of the correlation map determines the location of best fit for a particular strip on the reference frame. However, there may be instances where multiple “highest” peaks have similar values, which may have an adverse effect when trying to match the strip to the reference frame. To remedy this problem, the correlation value at the highest peak is compared to the correlation value of the second highest peak, and the ratio between the two is known as the Peak Ratio. The Maximum Peak Ratio determines the maximum allowed peak ratio for each strip. If the Peak Ratio is lower than the Maximum Peak Ratio, that strip is considered a “useful” eye position trace. Default value = 0.8
 - B. Minimum Peak Threshold: If a particular correlation map for a strip has overall low correlation values, it means that the strip does not fit well with the reference frame. The Minimum Peak Threshold determines the minimum allowed peak correlation value for each correlation map. If the peak value for a particular strip is higher than this quantity, that strip is considered a “useful” eye position trace. Default value = 0
- iii. Adaptive Search Options
 - A. Enable Adaptive Search: If this box is checked, the module will perform Adaptive Search when performing the strip analysis. Adaptive Search decreases the search window for finding peaks on correlation maps, which can reduce the overall running time of the analysis, but at the risk of slightly lower accuracy during correlation. Default value = Unchecked
 - Scaling Factor: This is the number of times to temporarily scale down the pre-defined reference frame to perform preliminary eye position estimates, if Adaptive Search is enabled. The higher this number, the more the reference frame will be scaled down. Default value = 8
 - Search Window Height: The size of the search window, if Adaptive Search is enabled. This search window will be centered around the preliminary eye position estimates obtained from the analysis of the scaled down reference frame. Default value = 79 px

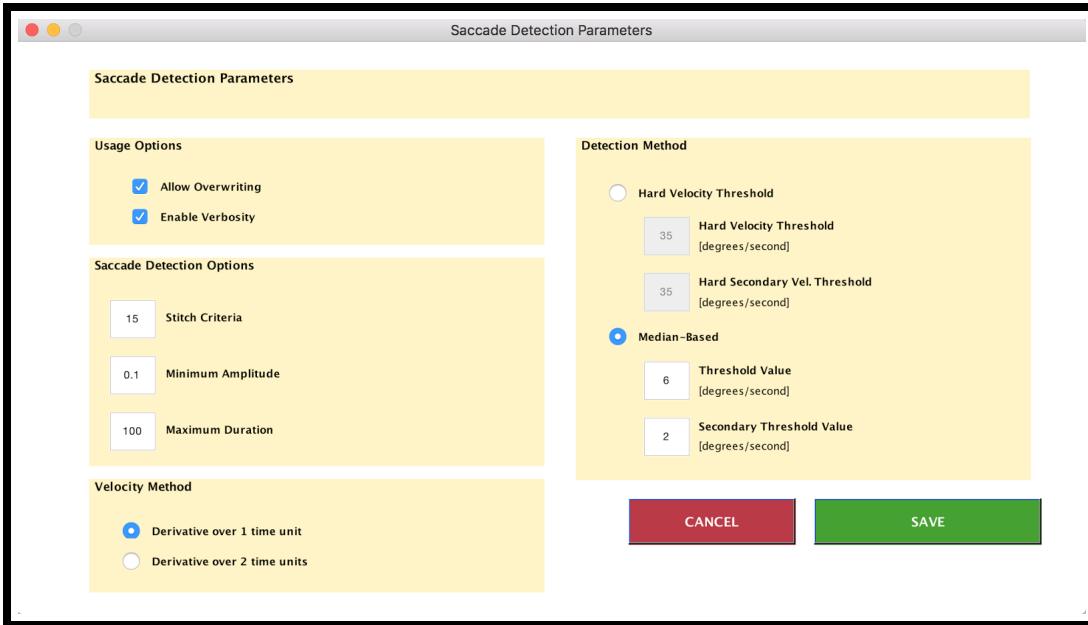
(d) Subpixel Interpolation Options:

- i. Enable Subpixel Interpolation: If this box is checked, the module will apply Subpixel Interpolation to the correlation maps. It will fit a continuous interpolation function over the discrete values obtained during correlation, resulting in a smoother correlation map. Default value = Checked
 - A. Neighborhood Size: The window size centered around the peak value of the correlation map. It determines the size of the meshgrid applied at the center of the peak during interpolation. Default value = 7 px
 - B. Subpixel Depth: The grid spacing of the meshgrid applied to the correlation map (divided by 100). The smaller this value is, the finer the correlation map will be after interpolation. Default value = 2

8) Filtering

9) Re-Referencing

10) Saccade Detection



The Saccade Detection Module searches through the video to detect saccades and drifts in eye movement. It does this through a detection of frames with exceptional differences in velocity. This module produces a .mat file with the same name as the original video but with “_sacsdrift” appended to it, containing information about the saccades and drifts.

Parameters:

(a) Usage Options:

- i. Allow Overwriting: If this box is checked, any file with the same name as the output will be overwritten. If this box is not checked and a file with the same name as the output exists in the same folder, the module will not execute. Default value = Checked
- ii. Enable Verbosity: If this box is checked, graphs will be displayed on the Graph Window of the Execute Screen during execution to monitor progress. Default value = Checked

(b) Saccade Detection Options:

- i. Stitch Criteria: Determines whether or not to lump together two different saccades that were detected. If the difference between any two marked saccades is less than this number (in milliseconds), then the two saccades are lumped together as microsaccades. Default value = 15 ms
- ii. Minimum Amplitude: The cutoff to determine which saccades have a great enough amplitude to be counted by the module. Default value = 0.1
- iii. Maximum Duration: The cutoff to determine which saccades are too long in duration to be counted by the module. Default value = 100 ms

(c) Velocity Method:

- i. Derivative over 1 time unit: If this option is selected, the formula used to calculate velocity will be: $v_x(t) = [x(t + \Delta t) - x(t)] / [\Delta t]$. Default value = Selected
- ii. Derivative over 2 time units: If this option is selected, the formula used to calculate velocity will be: $v_x(t) = [x(t + \Delta t) - x(t - \Delta t)] / [2\Delta t]$. Default value = Not Selected

(d) Detection Method:

- i. Hard Velocity Threshold: Select this option if you want saccades to be detected when the velocity of some eye movement exceeds a fixed value. Default Value = Not Selected

- A. Hard Velocity Threshold: The fixed threshold for detecting saccades. If a velocity exceeds this threshold, it is counted as a saccade. Default value = 35 degrees/second
- B. Hard Secondary Velocity Threshold: The fixed secondary threshold used to capture the entire peak of a saccade detected by the first velocity threshold. Default value = 35 degrees / second
- ii. Median-Based: Select this option if you want saccades to be detected through an analysis of the median of velocity differences. Default Value = Selected
 - A. Threshold Value: The tolerance threshold that dictates the cutoff for what velocity differences are considered saccades, according to the following formula: $\text{threshold} = \text{median} \pm \text{thresholdValue} * \text{standardDeviation}$.Default value = 6 degrees/second
 - B. Secondary Threshold Value: The secondary threshold used to capture the entire peak of a saccade detected by the first threshold value. Default Value = 2 degrees / second

8 Description of Feature Implementations

9 Troubleshooting

10 Acknowledgements

Retinal Video Analysis Suite (ReVAS) Copyright ©August 2017. Sight Enhancement Laboratory at Berkeley. School of Optometry. University of California, Berkeley, USA.

Mehmet N. Agaoglu, PhD. mna@berkeley.edu, mnagaoglu@gmail.com

Matthew T. Sit. msit@berkeley.edu

Derek Wan. derek.wan11@berkeley.edu

Susana T. L. Chung, OD, PhD. s.chung@berkeley.edu

Tutorial Authors

Jason Chen. jbchen120@berkeley.edu

Alex Yeo. alexsyeo@berkeley.edu