

Appendix A

ECG DIGITIZATION APPLICATION

VERSION 1 MANUAL

Designed on MATLAB 2019a

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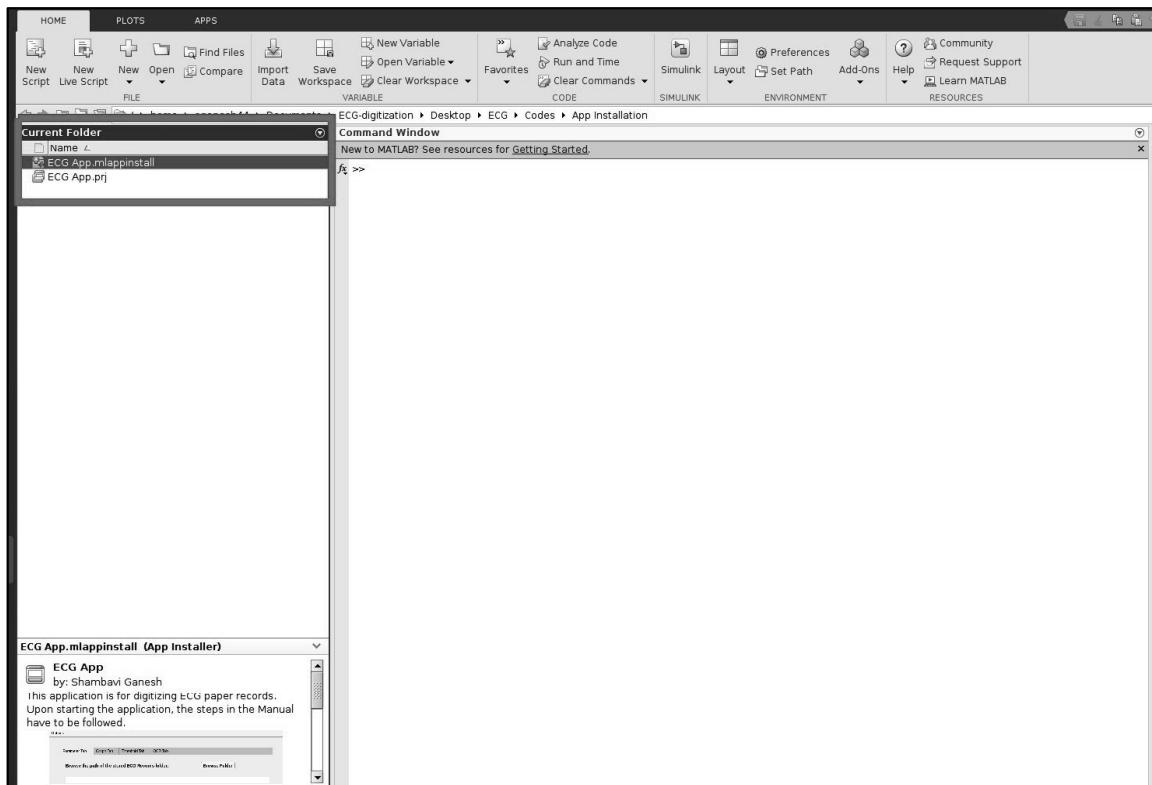
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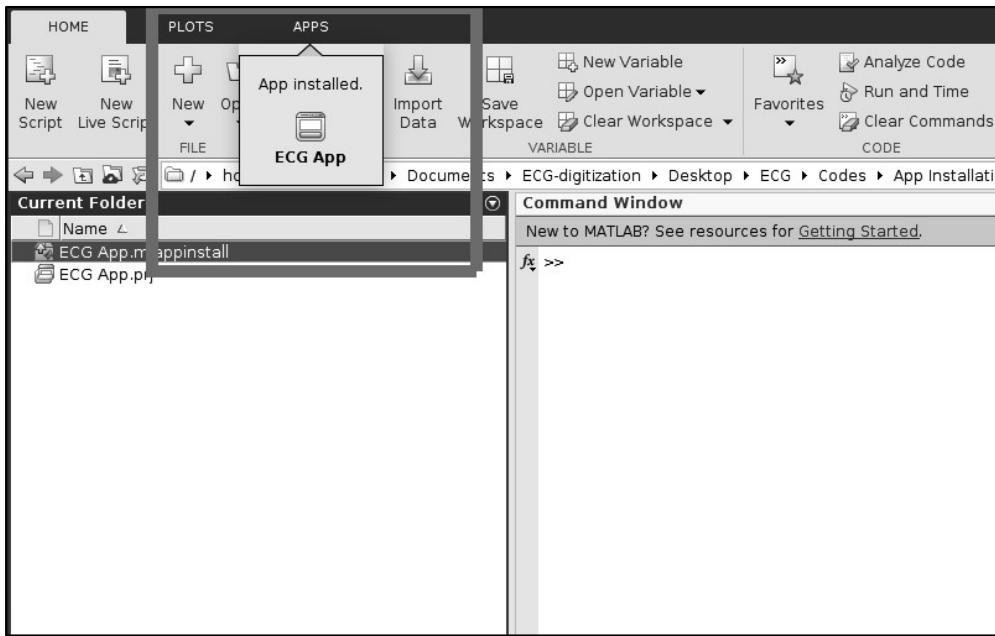
Section 1: Installation of ECG App

This is a manual for the ECG app, which is primarily for the digitization of the paper scanned records. The ECG contours will be extracted, and the demographic information of each record will be stored as well. The application is designed on **App Designer** on MATLAB 2019a. For further details about the software, code, and examples, please visit <https://github.com/ECG-Digitization-Project>.

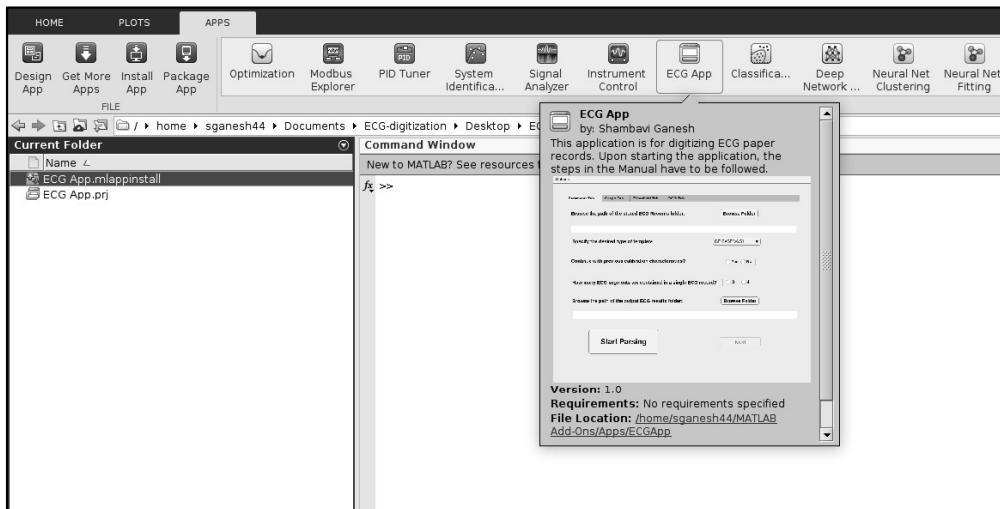
- a) The application can be opened by first extracting the zip file **ECG APP** into a folder. The file runs on MATLAB, so it is necessary to have MATLAB (preferably 2014a or above) open. In MATLAB, navigate to the **ECG APP** folder, in the current folder window. Double click on **ECG App.mlappinstall** to install it.



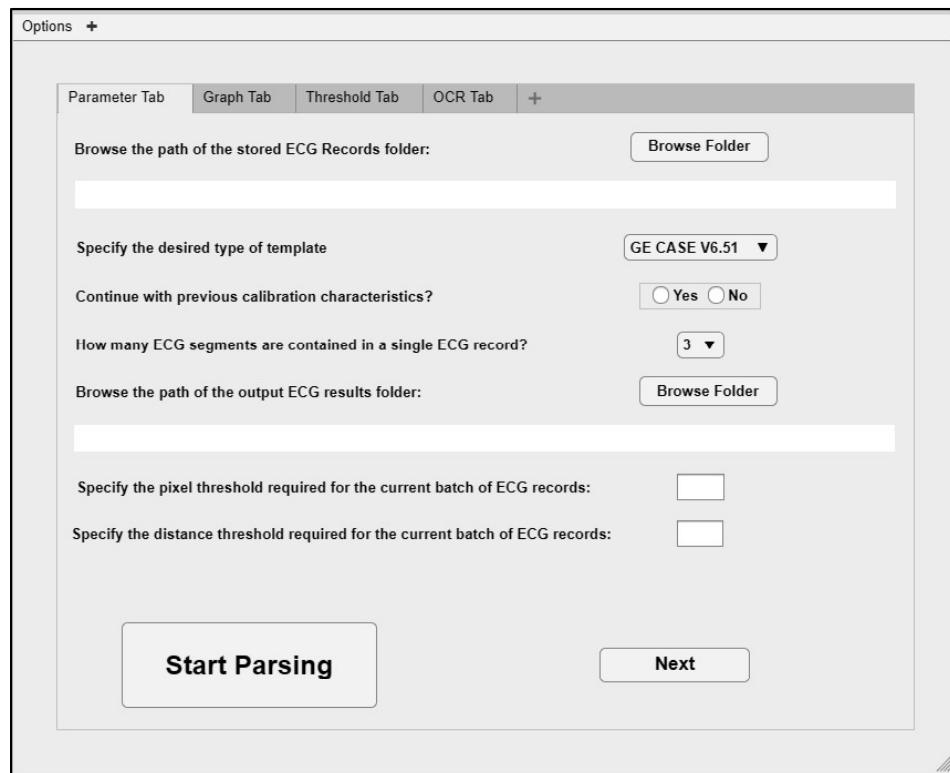
- b) Once the app is installed, it will be clearly indicated in the **APPS** tab of MATLAB, with **App installed** being displayed.



- c) Click on the **APPS** tab, after which the **ECG App** icon should be visible under the **APPS** tab. Double click on the **ECG APP** icon



- d) The **ECG App** will open, and the application will be displayed as follows:



Section 2: Brief Introduction to the Tab Groups

There are 4 tab groups totally in the ECG APP, which are the Parameter Tab, Graph Tab, Threshold Tab and OCR Tab. There is no need to navigate between the tabs, as there are “Next” buttons in each Tab which takes the user to the appropriate next step.

Parameter Tab: This tab requires information about where files are stored, and the type of ECG record being processed.

Graph Tab: This tab needs to be accessed to provide further information about the template and parameter information in case the user desires it. This Tab need not be accessed during all instances of ECG digitization.

Threshold Tab: This tab lets the user decide the appropriate threshold value for a particular set of ECG records.

OCR Tab: This tab merely asks the user whether character removal from the records is desired.

The figure in the next page displays the Tabs.

Options +

Parameter Tab Graph Tab Threshold Tab OCR Tab +

Browse the path of the stored ECG Records folder:

Specify the desired type of template

Continue with previous calibration characteristics? Yes No

How many ECG segments are contained in a single ECG record?

Browse the path of the output ECG results folder:

Specify the pixel threshold required for the current batch of ECG records:

Specify the distance threshold required for the current batch of ECG records:

Start Parsing

Next

Section 3: Navigating the Tabs Parameter Tabs

- a) The folder path to the stored ECG scanned files must be specified, by pressing the **Browse Folder** in the Parameter Tab.

Options +

Parameter Tab Graph Tab Threshold Tab OCR Tab +

Browse the path of the stored ECG Records folder:

Specify the desired type of template

Continue with previous calibration characteristics? Yes No

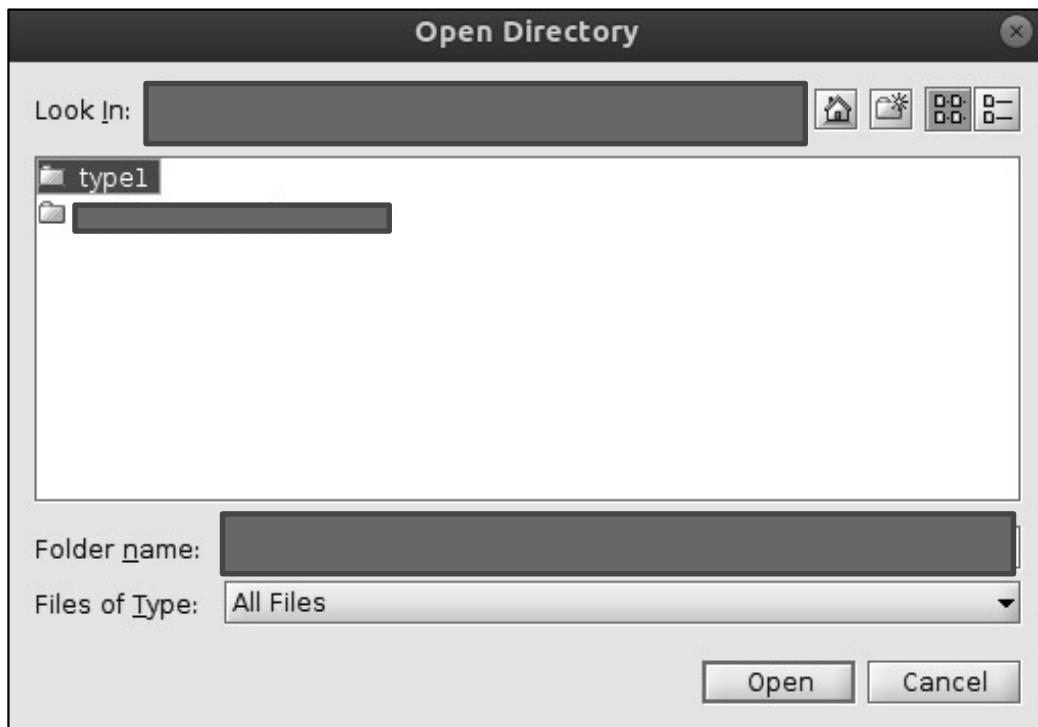
How many ECG segments are contained in a single ECG record?

Browse the path of the output ECG results folder:

Specify the pixel threshold required for the current batch of ECG records:

Specify the distance threshold required for the current batch of ECG records:

b) A pop-up dialogue box appears. The folder in which the scanned ECG records are stored, must be selected. Please make sure only the images (of any valid format) exist in this folder and nothing else.



- c) The path of the folder selected will appear in the space below, which the user can cross verify.

Options +

Parameter Tab Graph Tab Threshold Tab OCR Tab +

Browse the path of the stored ECG Records folder:

Specify the desired type of template

Continue with previous calibration characteristics? Yes No

How many ECG segments are contained in a single ECG record?

Browse the path of the output ECG results folder:

Specify the pixel threshold required for the current batch of ECG records:

Specify the distance threshold required for the current batch of ECG records:

d) The template of the ECG record needs to be selected, corresponding to a particular ECG vendor and make. If the present ECG records do not match available options (GE CASE V6.51 or MAC500K 003A), then the user can store the new parameters by selecting (1) New Template 1 or (2) New Template 2, which appears in the drop down menu.

Options +

Parameter Tab Graph Tab Threshold Tab OCR Tab +

Browse the path of the stored ECG Records folder:

Specify the desired type of template

Continue with previous calibration characteristics? Yes No

How many ECG segments are contained in a single ECG record?

Browse the path of the output ECG results folder:

Specify the pixel threshold required for the current batch of ECG records:

Specify the distance threshold required for the current batch of ECG records:

e) Calibration parameters can be loaded by selecting **YES**, or the user can choose **NO** to create new calibration parameters. If the user is selecting **New Template 1** or **New Template 2**, please make sure to choose **NO** so that the new parameters of the template can be stored. It is recommended that when the user is using the set of records for the first time, option **NO** should be chosen. Depending on the option selected, slightly different steps are required to be taken after this section is completed, detailed on **Pg 19**.

Options +

Parameter Tab Graph Tab Threshold Tab OCR Tab +

Browse the path of the stored ECG Records folder:

Specify the desired type of template: GE CASE V6.51 ▾

Continue with previous calibration characteristics? Yes No

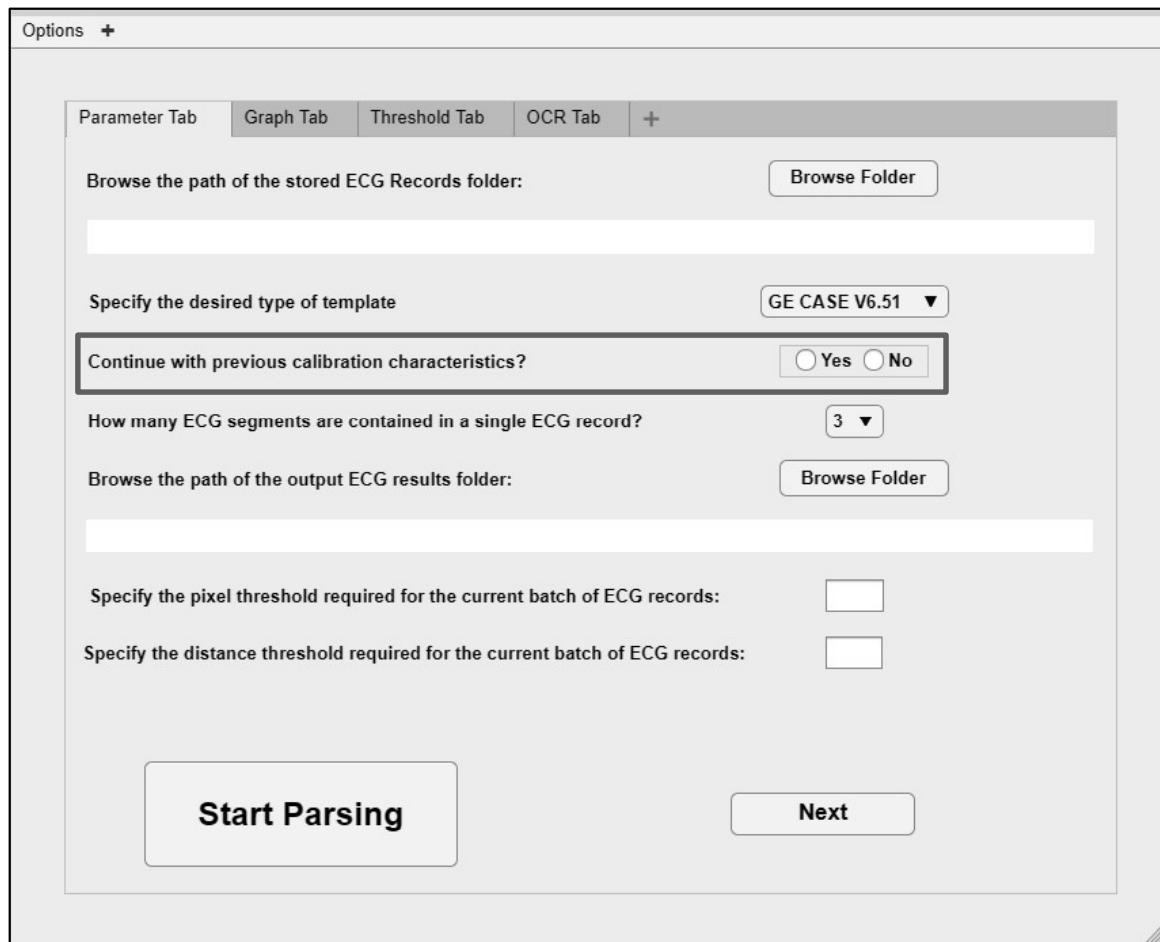
How many ECG segments are contained in a single ECG record? 3 ▾

Browse the path of the output ECG results folder:

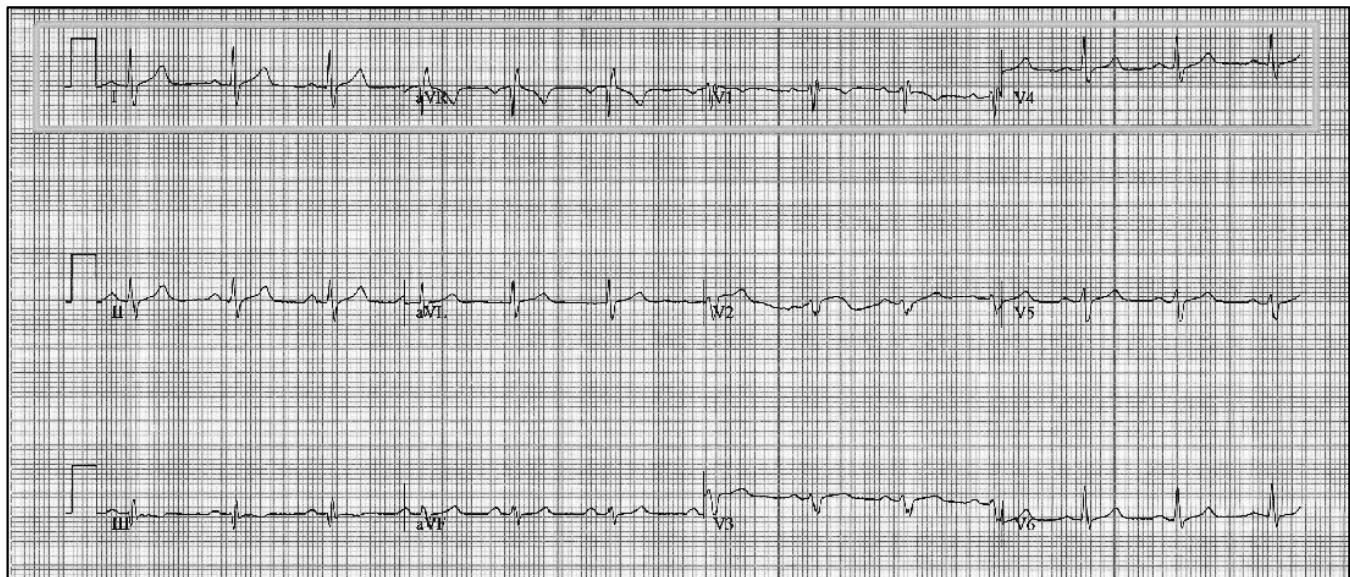
Specify the pixel threshold required for the current batch of ECG records:

Specify the distance threshold required for the current batch of ECG records:

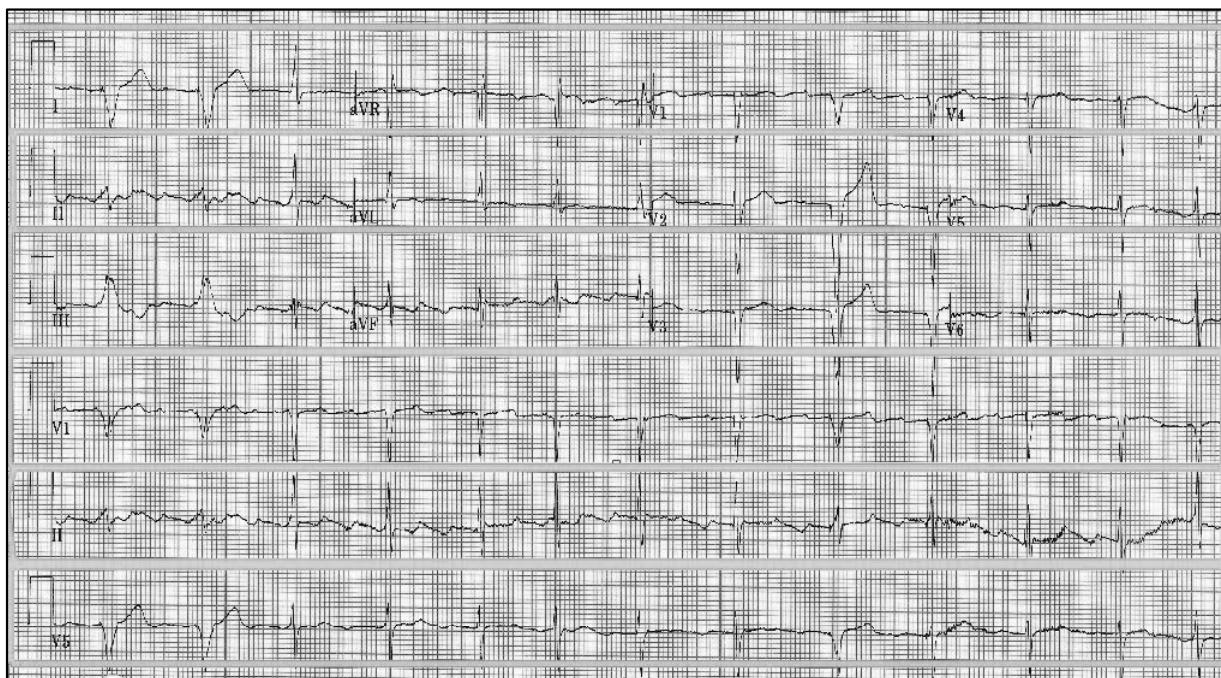
Start Parsing **Next**



f) The user is required to specify the number of ECG segments. A segment is defined as follows:



The user will be provided an option to crop and choose 4 segments from a record, in the Graph Tab (Section 4). An example of an ECG segment with more than 4 segments is provided below.



Options +

Parameter Tab Graph Tab Threshold Tab OCR Tab +

Browse the path of the stored ECG Records folder:

Specify the desired type of template GE CASE V6.51 ▾

Continue with previous calibration characteristics? Yes No

How many ECG segments are contained in a single ECG record? 3 ▾

Browse the path of the output ECG results folder:

Specify the pixel threshold required for the current batch of ECG records:

Specify the distance threshold required for the current batch of ECG records:

Start Parsing **Next**

This screenshot shows the configuration interface for parsing ECG records. It includes tabs for Parameter, Graph, Threshold, and OCR. The main area has fields for the input folder (with a 'Browse Folder' button), template type (GE CASE V6.51 dropdown), calibration continuation (radio buttons for Yes or No), and the number of segments per record (a dropdown set to 3). There are also fields for output folder, pixel threshold, and distance threshold. At the bottom are 'Start Parsing' and 'Next' buttons.

i) Then, select the browse option to store the results in the output folder.”

Options +

Parameter Tab Graph Tab Threshold Tab OCR Tab +

Browse the path of the stored ECG Records folder:

Specify the desired type of template GE CASE V6.51 ▾

Continue with previous calibration characteristics? Yes No

How many ECG segments are contained in a single ECG record? 3 ▾

Browse the path of the output ECG results folder:

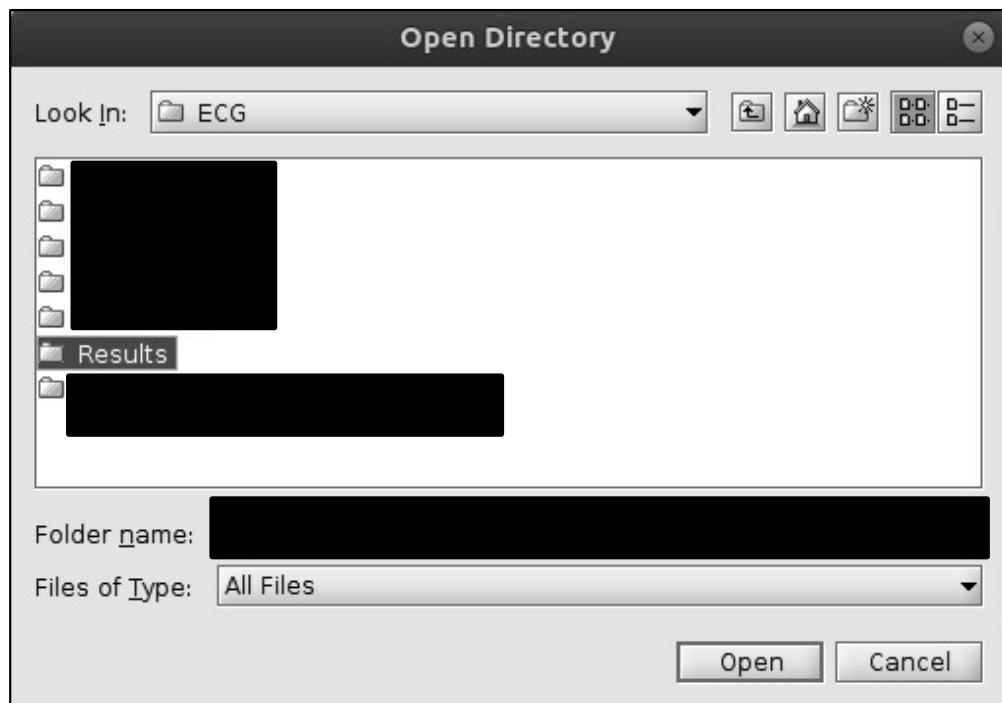
Specify the pixel threshold required for the current batch of ECG records:

Specify the distance threshold required for the current batch of ECG records:

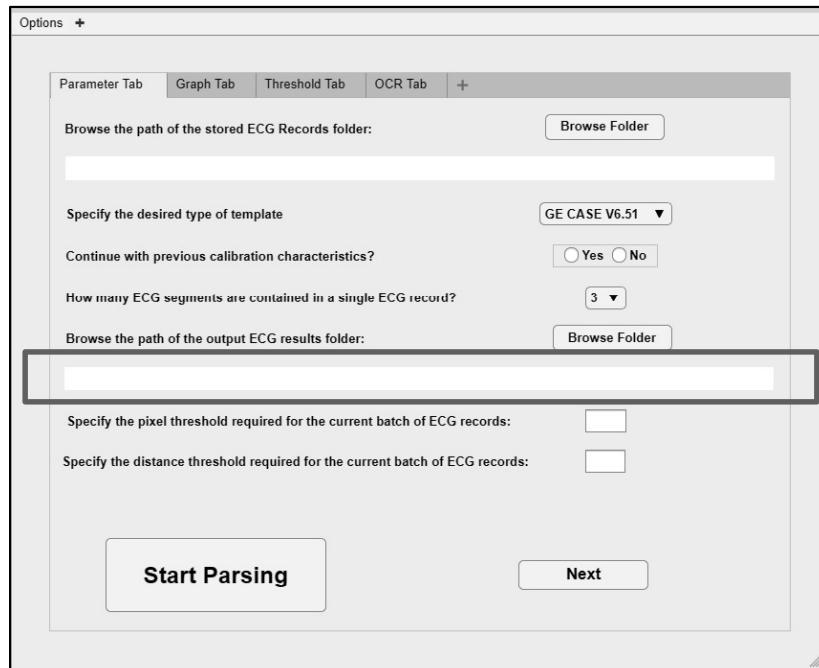
Start Parsing **Next**

This screenshot is identical to the one above, showing the configuration interface for ECG parsing. The 'Browse the path of the output ECG results folder:' field is highlighted with a red rectangle, indicating it is the next step to be selected. All other fields and buttons are visible as described in the first screenshot.

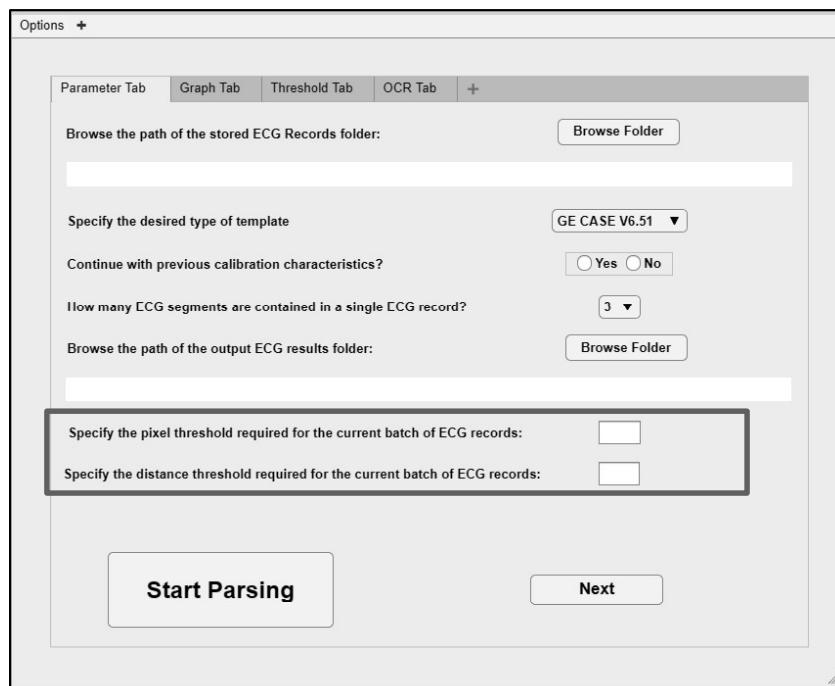
A pop-up dialogue box will appear:



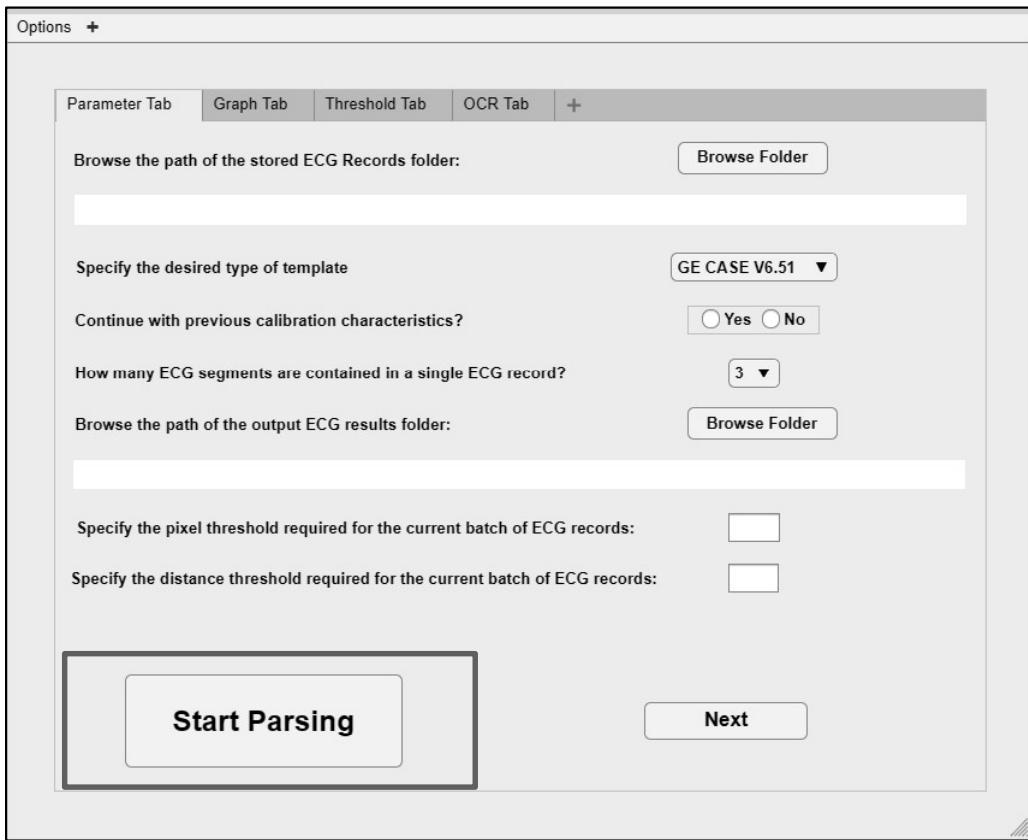
The user can verify the path of the Results Folder in the below space.



- j) The user can then input values for the minimum pixel and distance threshold, as highlighted in the figure.



k) The user can then choose the “Start Parsing” Button, in order to start calibration.



A pop-up dialogue will denote progress:

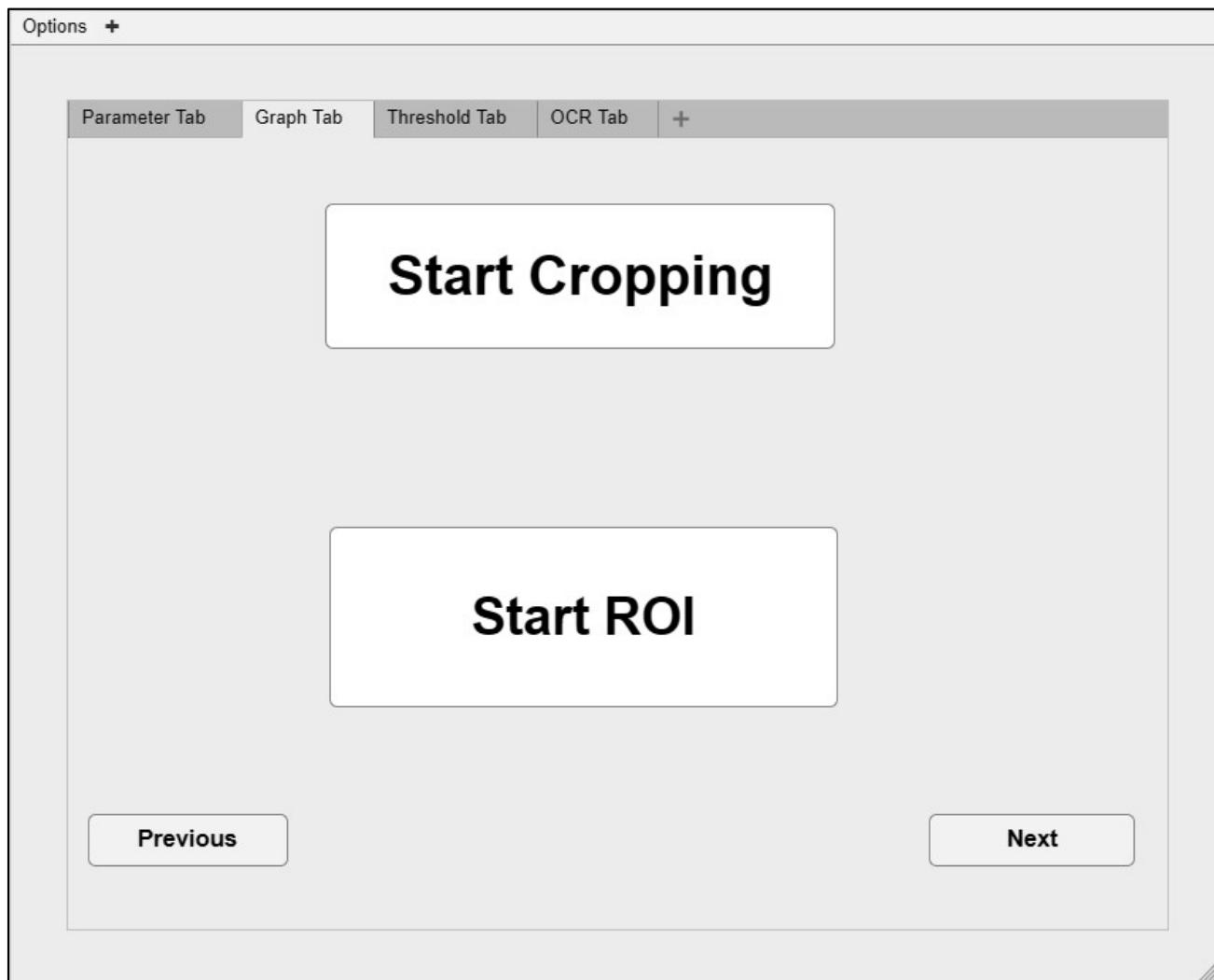


After this is completed, the user can select the **next** button. For the users who want the previous calibration parameters, and chose **YES**, are directed to the **Threshold Tab**, in which the user can select thresholding parameters. **Please go to Section 5: Navigating the Threshold Tab on Pg.26.** The rest of this section will contain instructions on what to do if the user chooses option **NO** in the calibration parameters question in e).

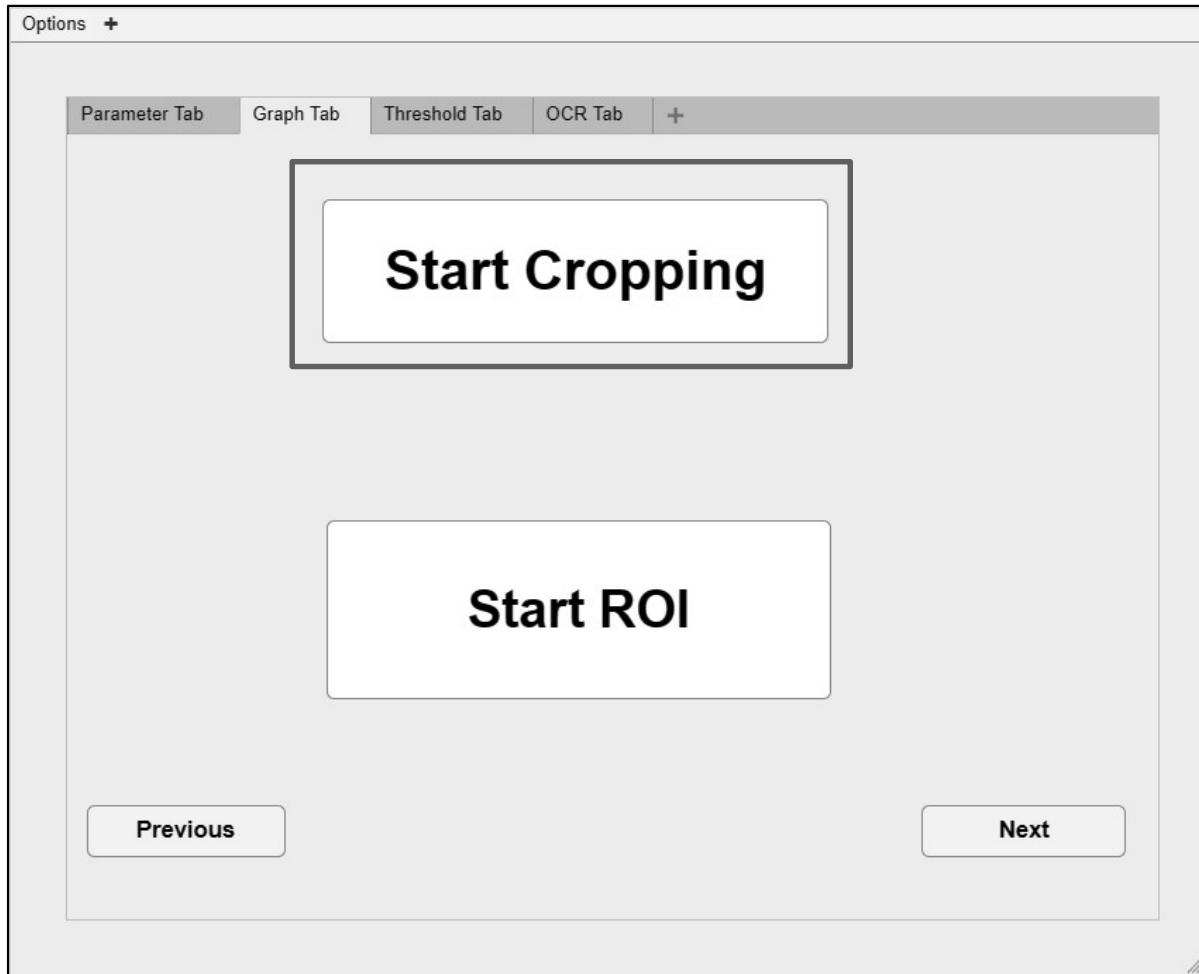
- 1) If the user chose **NO** and calibrate the parameters of the template instead, the following instructions would be helpful. It's more or less the same as the **YES** case, with subtle differences as outlined below. The user is required to specify the number of ECG segments, this is like what was previously explained. Then, browse the output folder in which the results are to be stored. After the rest of the parameters have been filled out, the user can then press **next** button which will take them to **Graph Tab on Pg. 20.**

Section 4: Navigating the Graph Tabs

- a) Only if the user chooses **NO** as the calibration option, will they be redirected to the **Graph Tab** to first crop, and then parse the images. The user does not need to come here otherwise.

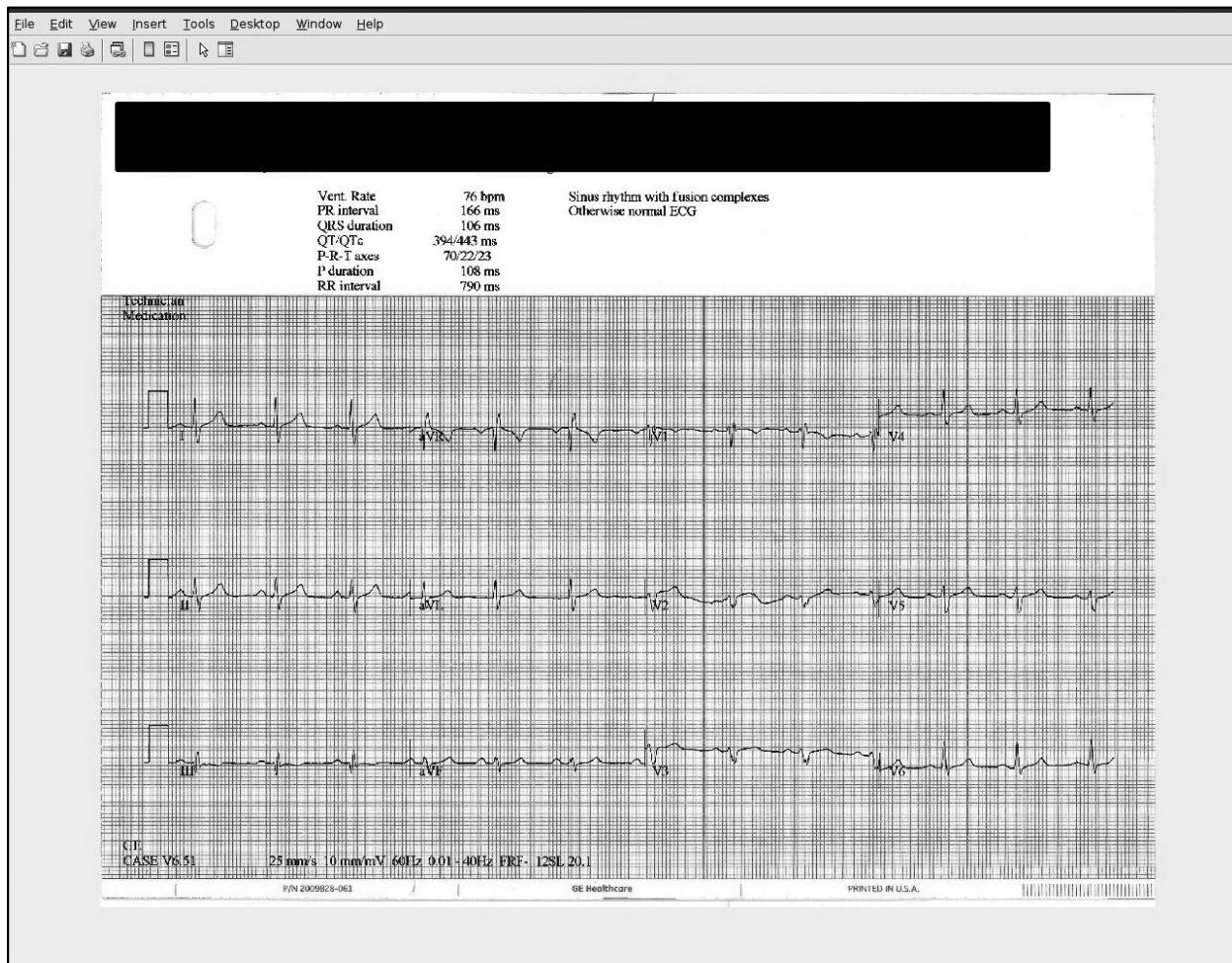


b) Upon choosing the **Start Cropping** button:



The following dialogue box will pop-up. The user will be required to draw a window around the ECG segments.

The GUI will then proceed to look like this:



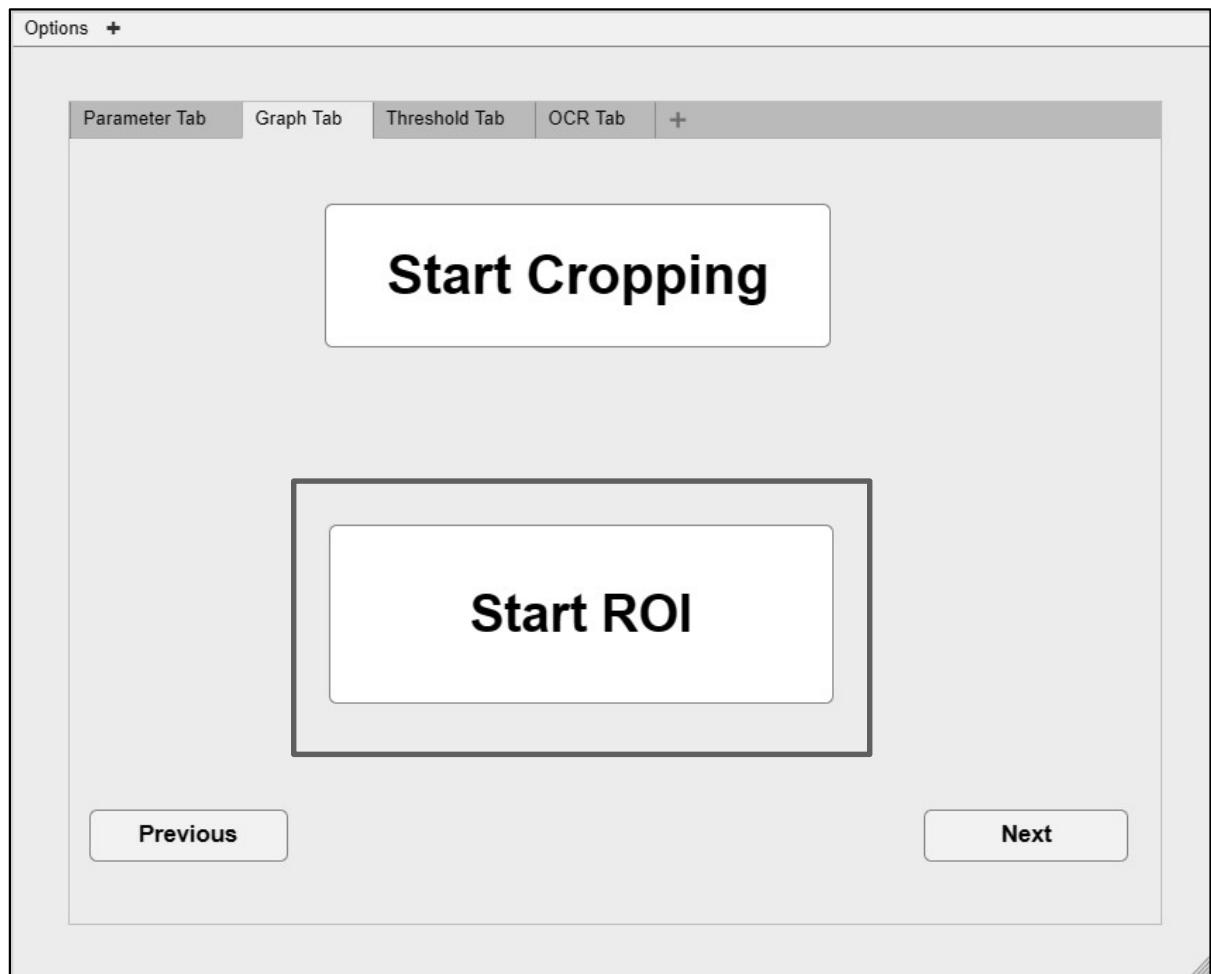
Draw a rectangle (denoted by a thin blue square) around the segments, which will look something like the following:



The **blue line** encapsulating the Segments is the cropping line, in the above picture. Once the cropping rectangle is drawn, please **right click on the mouse → select Crop Image**.

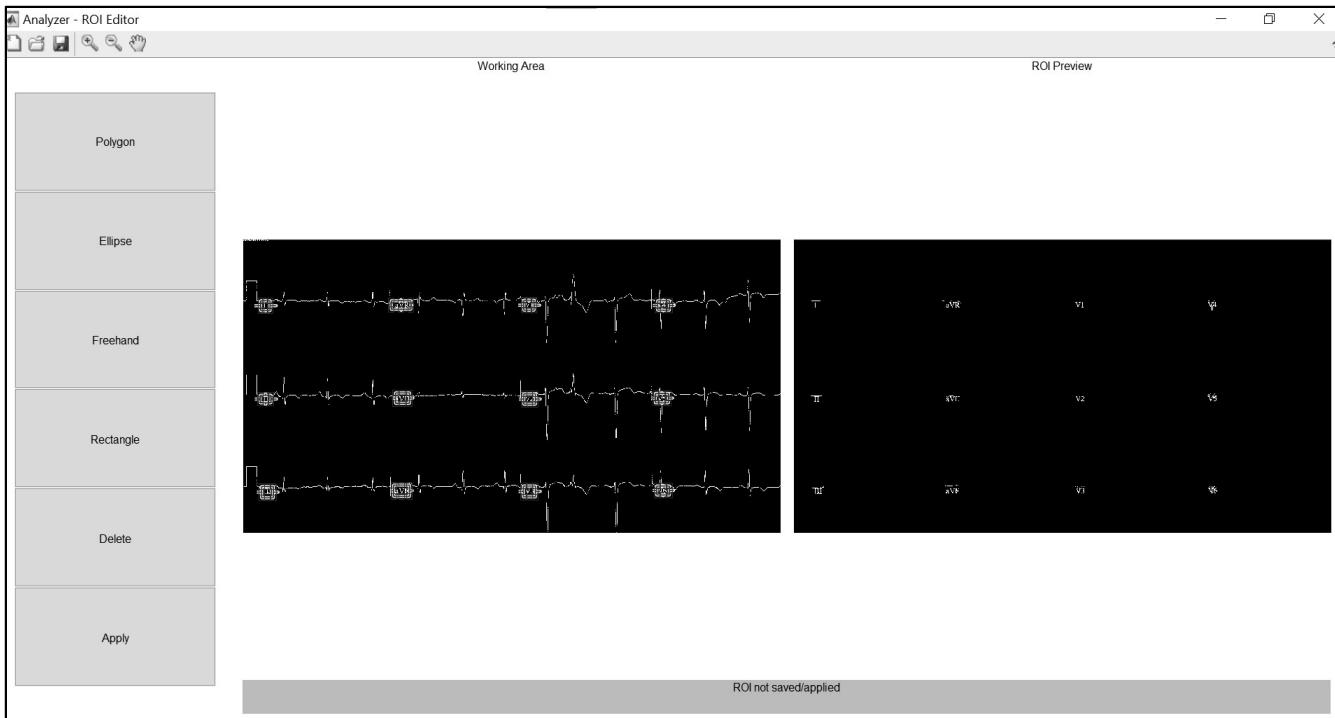
Once the image is cropped the user needs to highlight some salient points on the cropped image, which will appear in another pop-up dialogue box.

- c) After the ECG wave forms are cropped, select the **Start ROI** button.

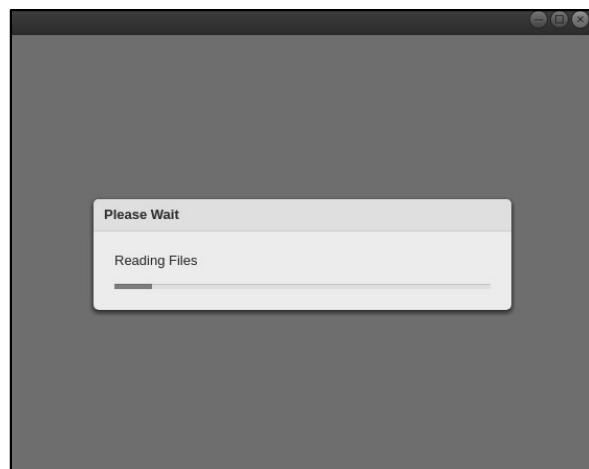


The user is required to specify a few regions in an ordered manner. The salient region in question, are the positions of the ECG lead characters.

Select the **Rectangle** option in the pop-up ROI editor. Draw rectangles around the ECG lead characters found in the record. Once completed, please select **Apply**.

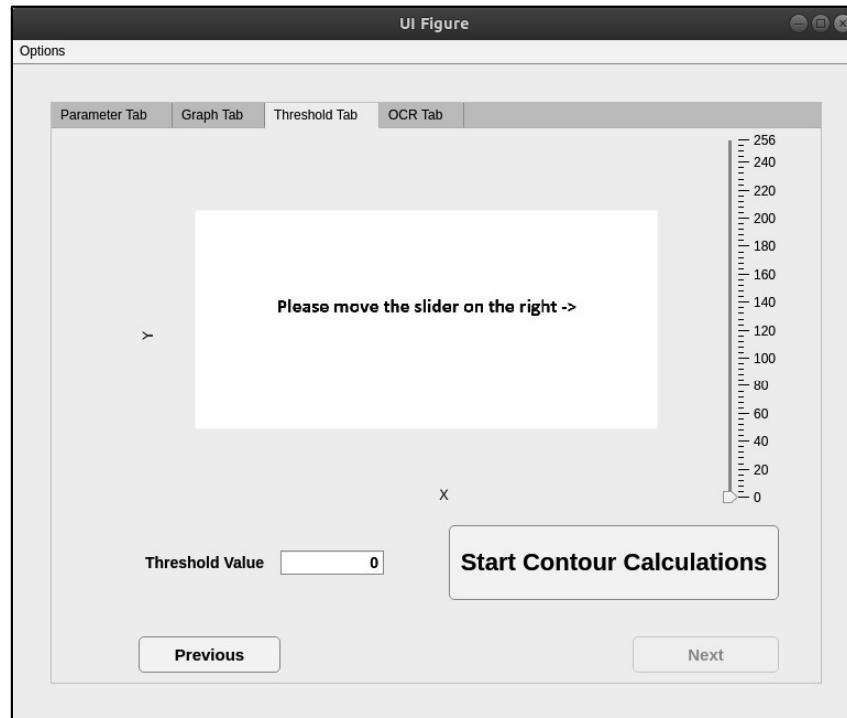


A pop-up dialogue box then will be visible, after which the user can select the next button to go to the Threshold Tab on Pg 26.

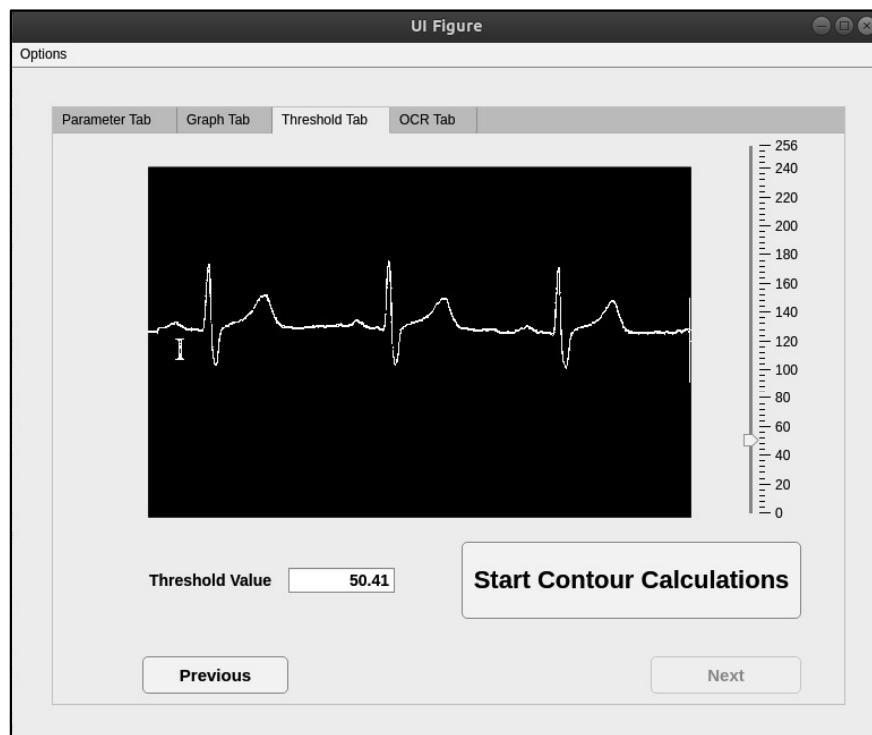


Section 5: Navigating the Threshold tab

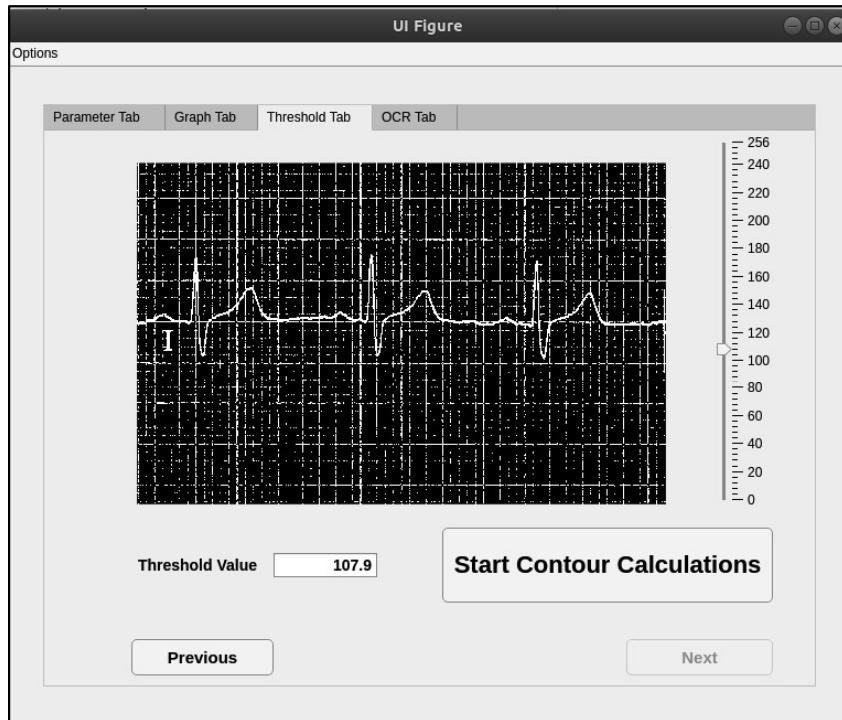
- a) The threshold can be navigated by using the slider on the right.



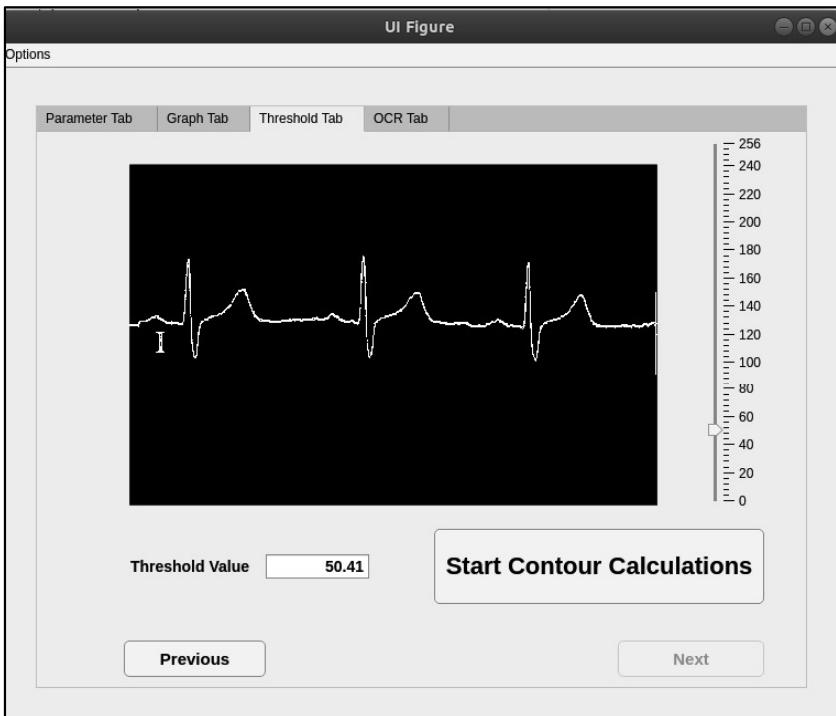
- b) Once the slider button is moved, the thresholded image appears in the tab.



c) It is important to note the method in which the threshold must be selected. The threshold must not be too large, for the following will happen:



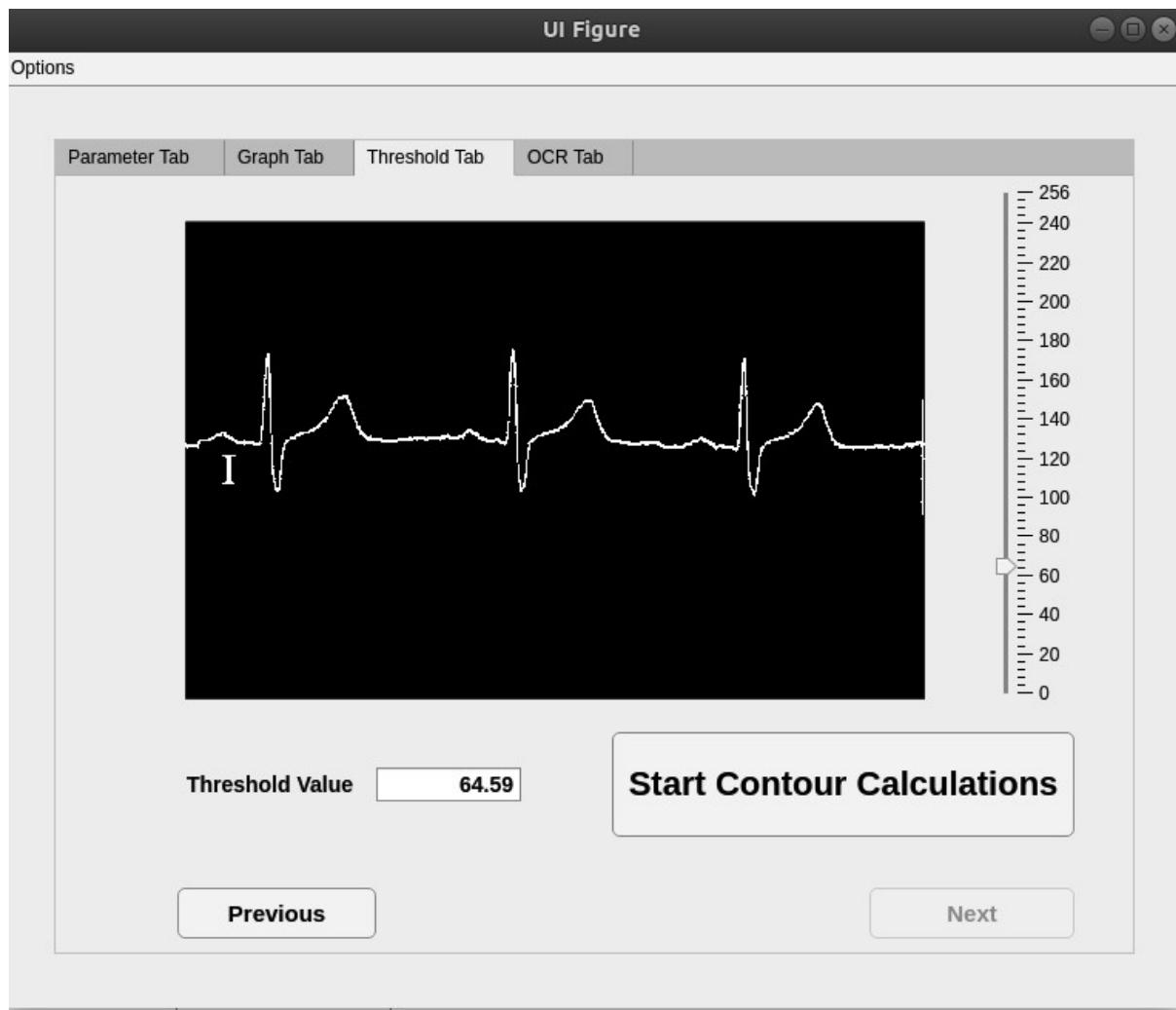
d) If the threshold is less than the optimal value, the image may look smooth, but the signal strength of the ECG decreases.



The optimal value of threshold would be that value beyond which you see noise infiltrating

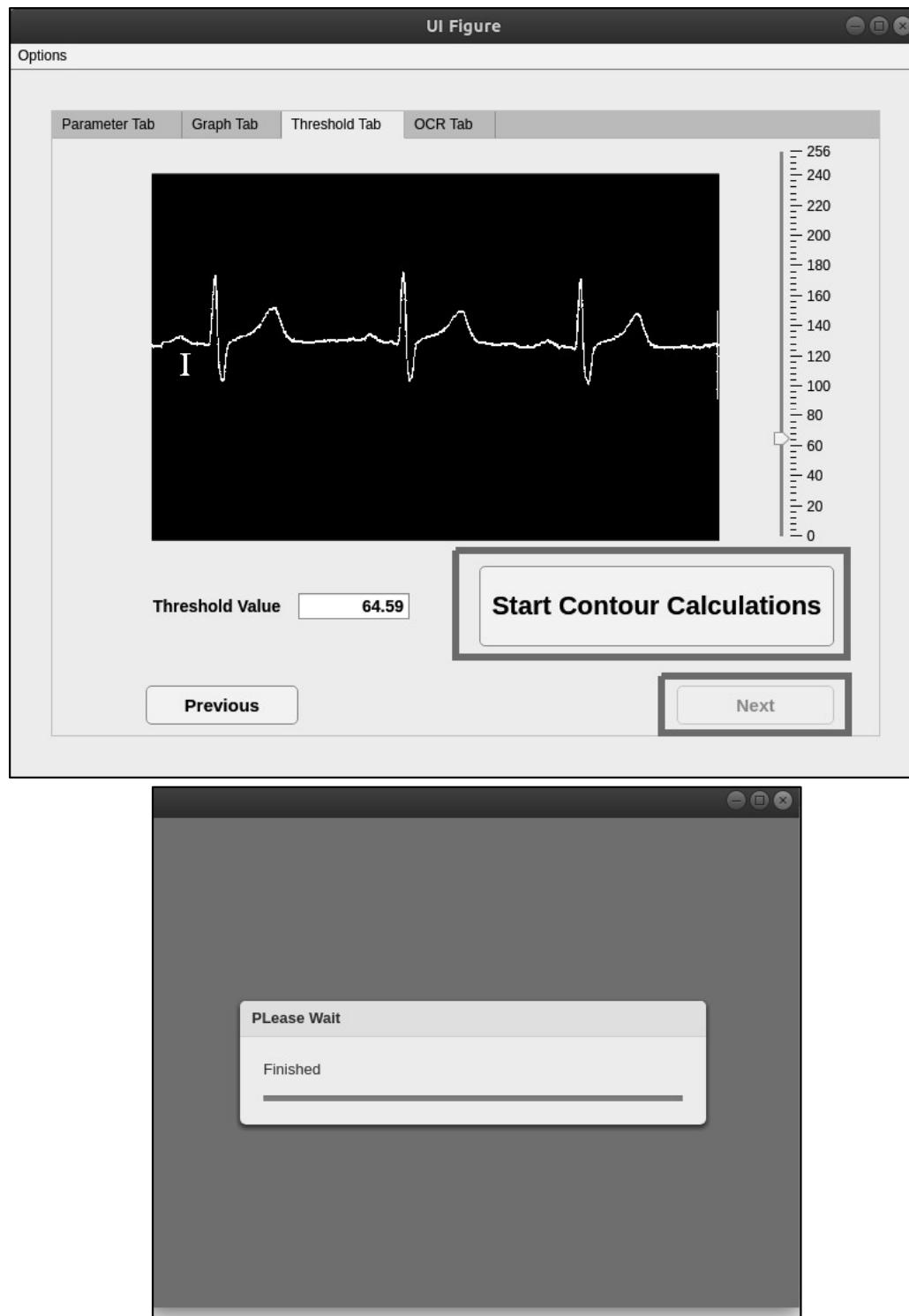
the image, and the beginnings of the salt and pepper noise. The signal needs to be at its strongest while the noise has to be minimum, and a delicate balance between the 2 has to be struck.

An example of this would be:



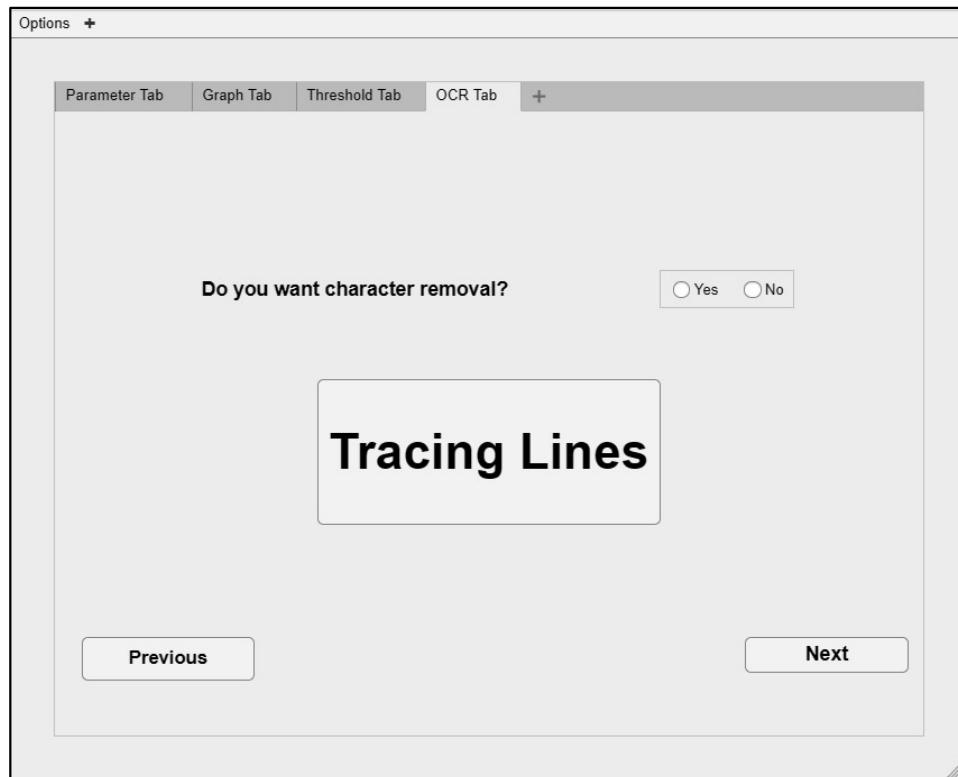
e) Press **Start Contour Calculations** Button once the user is satisfied with the threshold.

A pop-up dialogue box will appear. The **Next** button can be pressed to go to the next OCR tab.



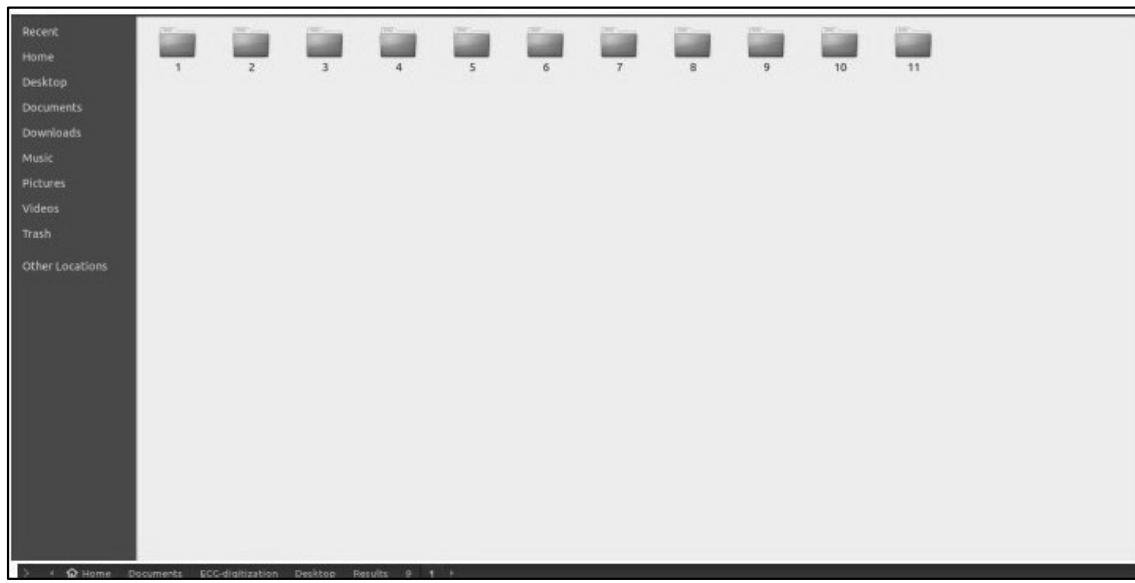
Section 6: Navigating the OCR tab

a) Finally, in the OCR tab, Character removal can be selected if required. Then **Final Processing** must be selected, and the results will be stored in the earlier specified folder.



Section 7: Understanding the Results Organization

- a) Each ECG paper record will have its own folder, in which the digitized ECG records, along with the extracted patient demographic information are stored.



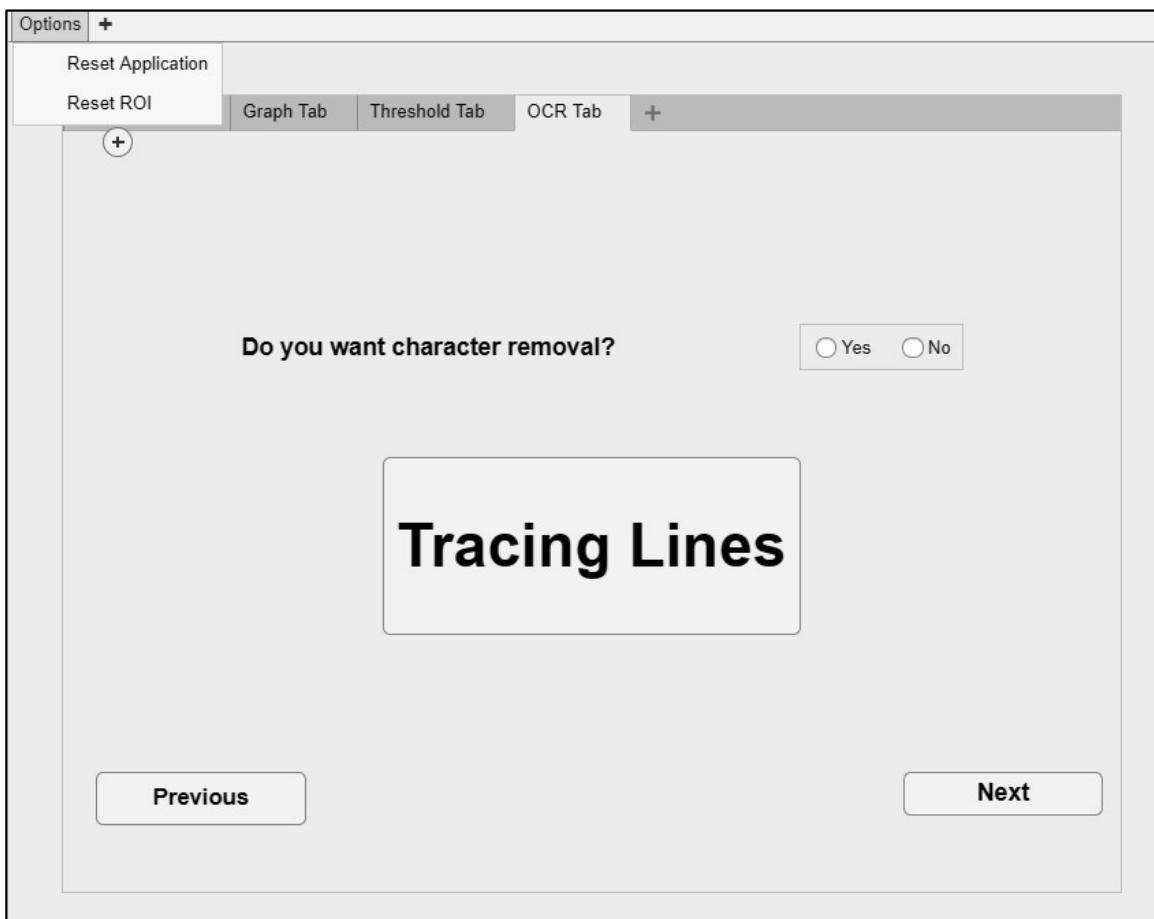
Inside each folder, demographic text information, and the digitized segments.



The order in which the segments are saved as follows. For example, **Segment_11** refers to the first segment, next to DC pulse 1. **Segment_12** refers to the one directly beneath it. **Segment_21** refers to the segment adjacent to the **Segment_11**.

Section 8: Reset Button

- a) The reset button is located as follows on the top of the GUI. Select the Option button, and then select **Reset Application**. All the fields should be wiped out and the GUI should return to the parameter Tab.



Appendix B

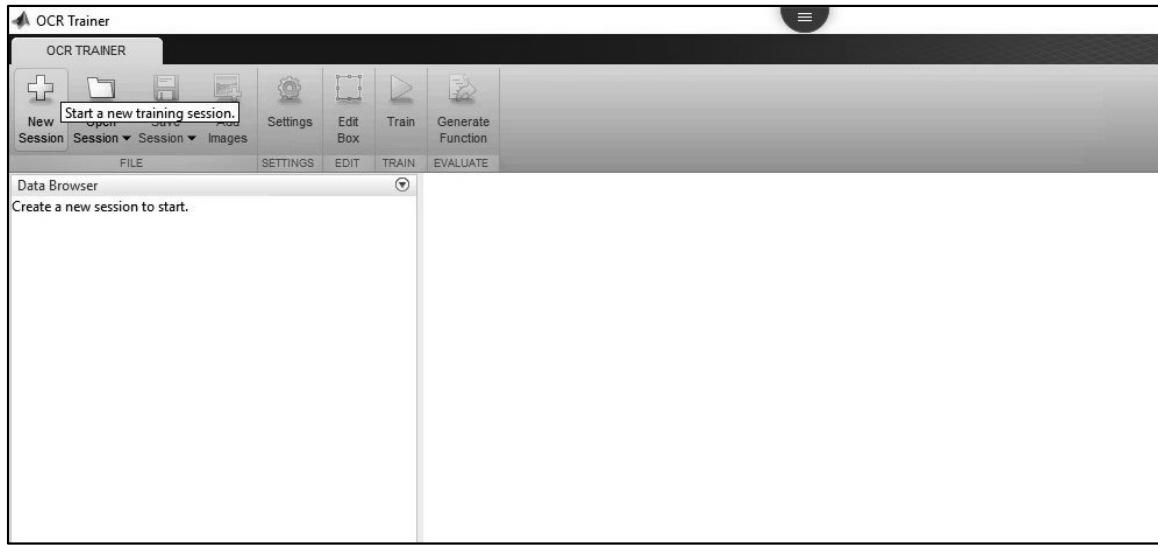
OCR MANUAL

This file contains steps to carry out training of characters found in the ECG scans, in order to create a library of training data using **OCRtrainer**, in MATLAB.

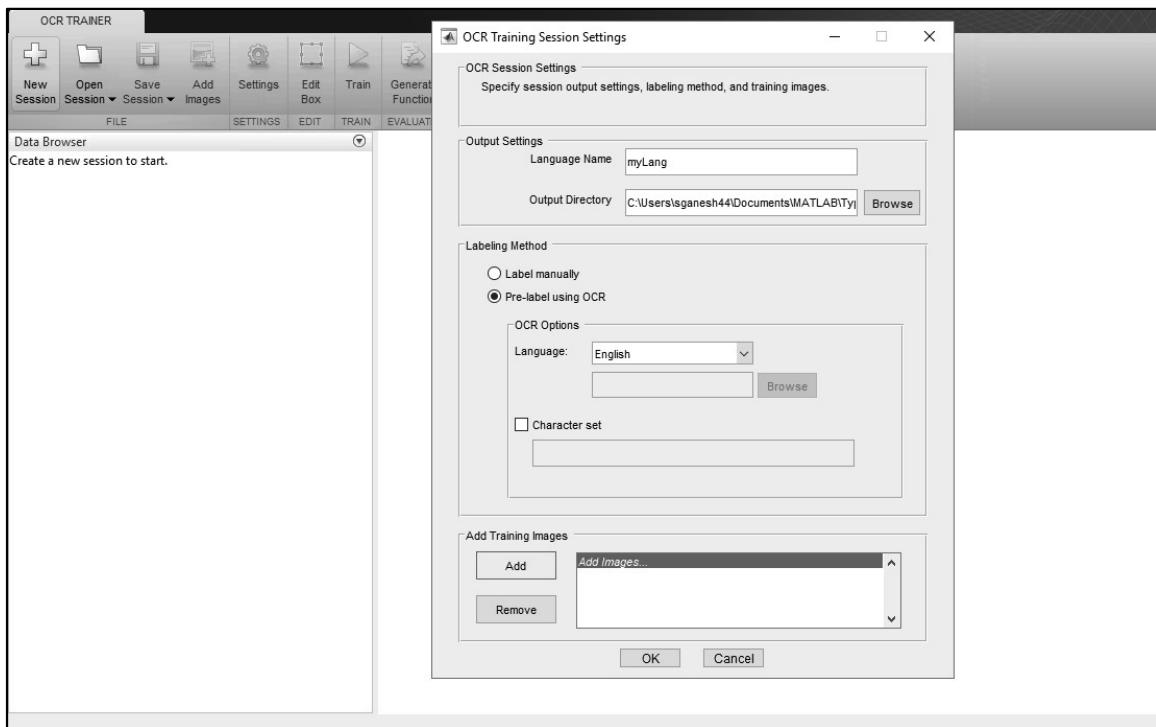
- 1) In MATLAB, the user is required to go to APPS > OCR Trainer .



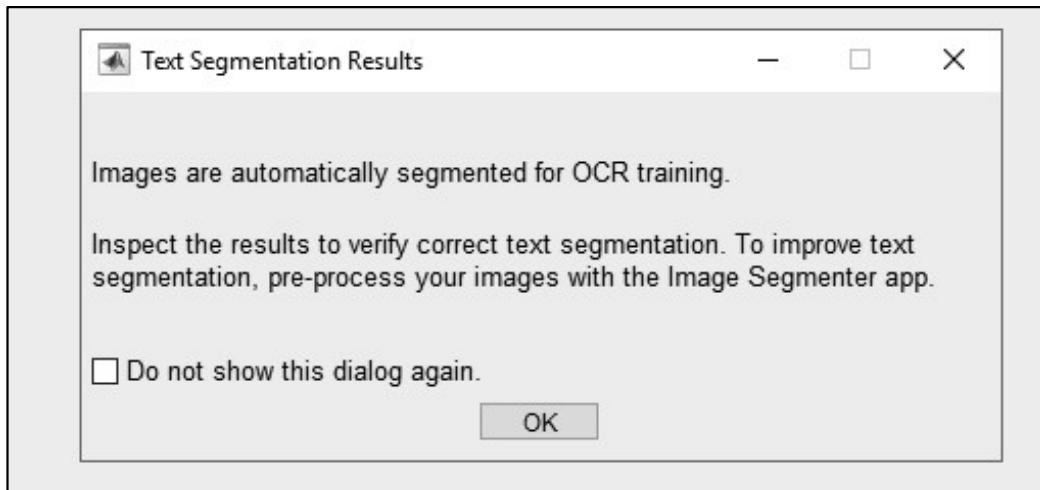
- 2) The following window opens, and the user has to click New Session.



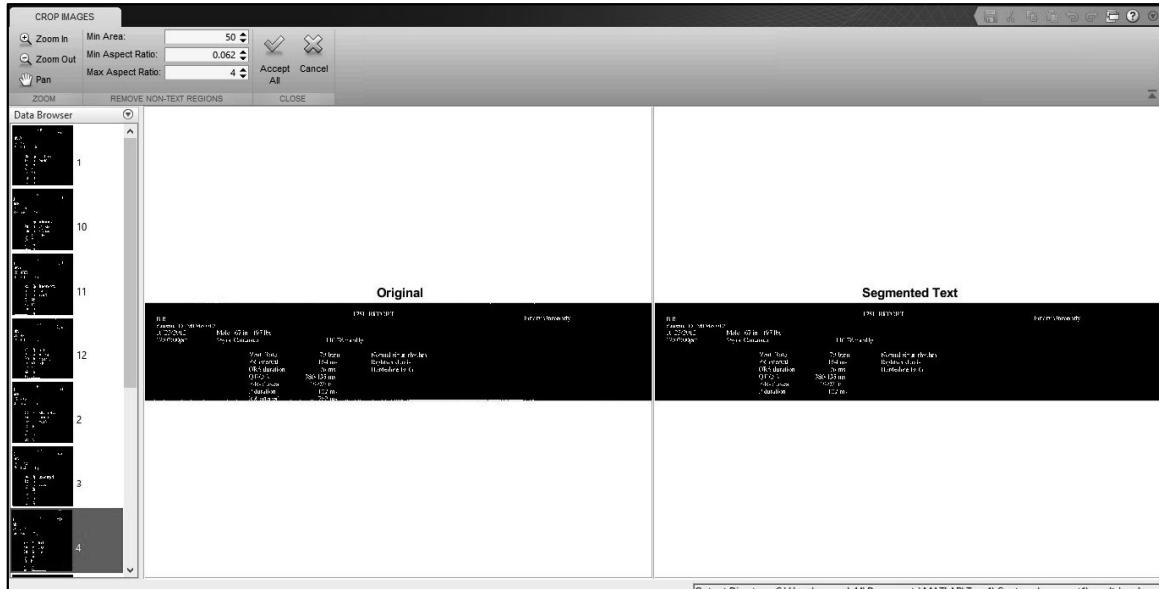
- 3) The user can modify parameters like where the language library file must be stored, whether the letters have to be segmented manually/or using **OCRtrainer** etc. The user is also required to add images at this step.



- 4) This dialogue box will then pop-up indicating images are going to be segmented.



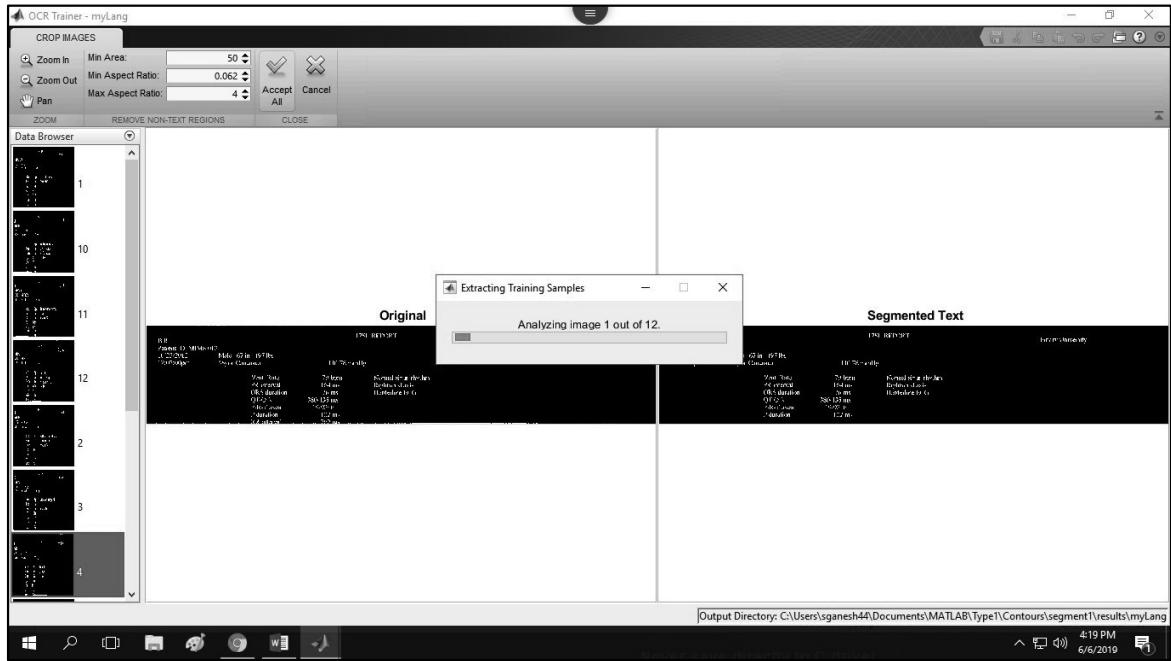
- 5) The software then requires the user to look at the images and decide if the desired text is being segmented.



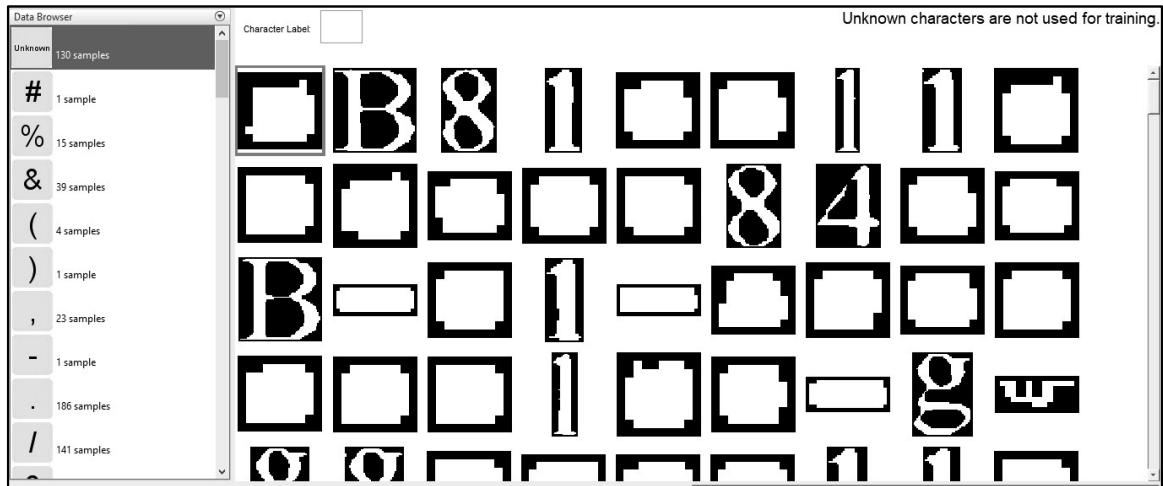
- 6) Sometimes the text is not recognized, like in the following case. The user must correct such cases.



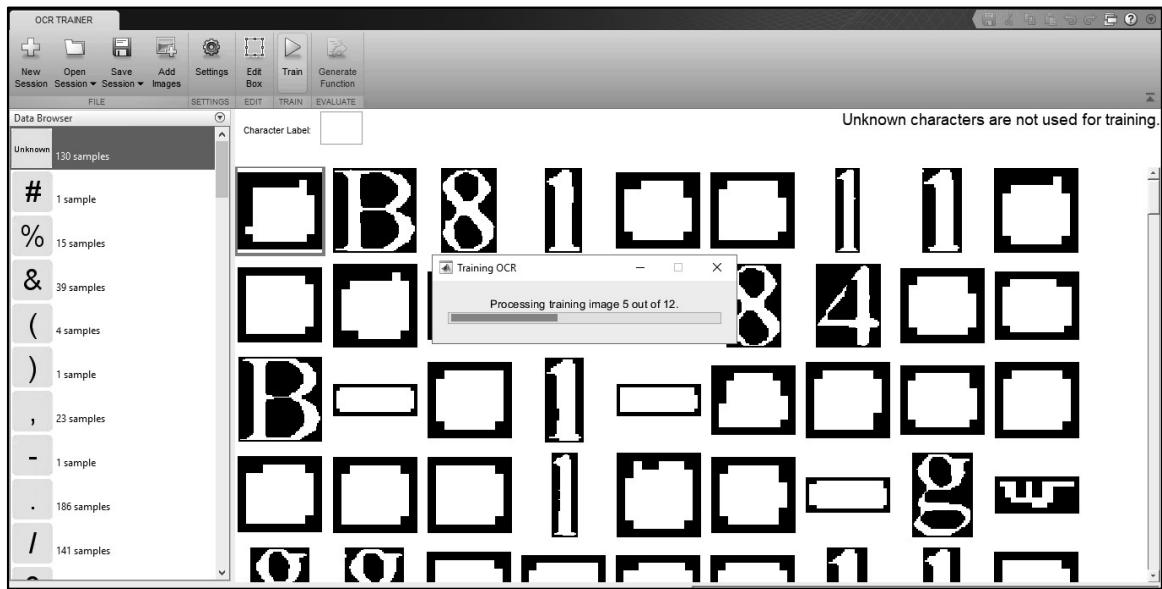
7) The **OCRtrainer** then extracts and recognizes the characters.



8) The user is required to relabel some characters which are mislabeled.



9) Then the user can click the **TRAIN** button, and training will take place.



10) This window indicates that the training is complete.

