User Guide

Questions, feedback or requirement can be sent to

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We are glad for collaboration to explore the clinical application of super-resolution ultrasound imaging.

This User Guide was written based on the SRUS version 2.0.

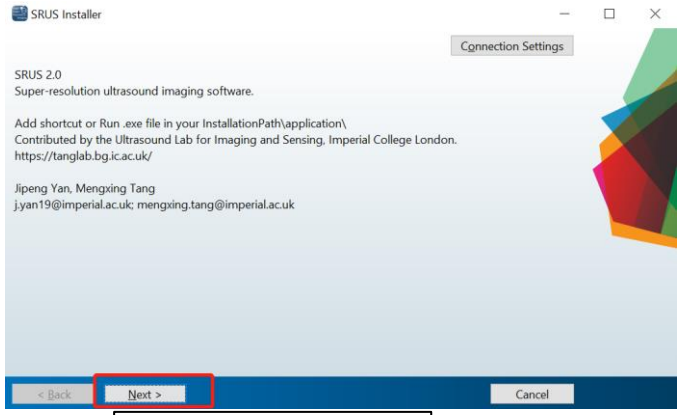
Updates in new versions can be found at the end of this document.

Installation

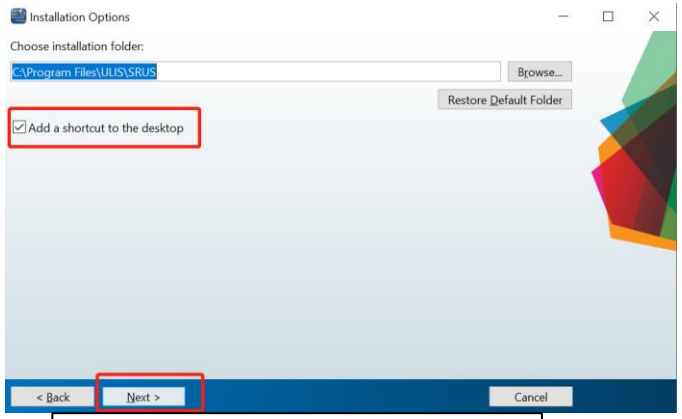
The software was tested using the following system hardware/software:

- Windows 10
- CPU: AMD Ryzen 9 5900 Processor
- GPU: Nvidia Geforce RTX3080
- RAM: 128 Gb

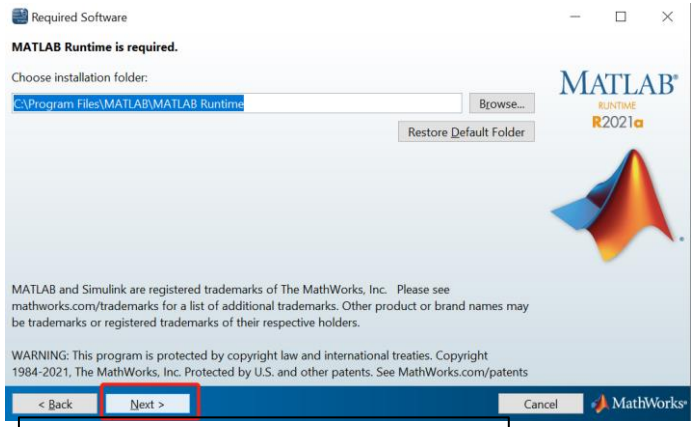
Wait the preparation



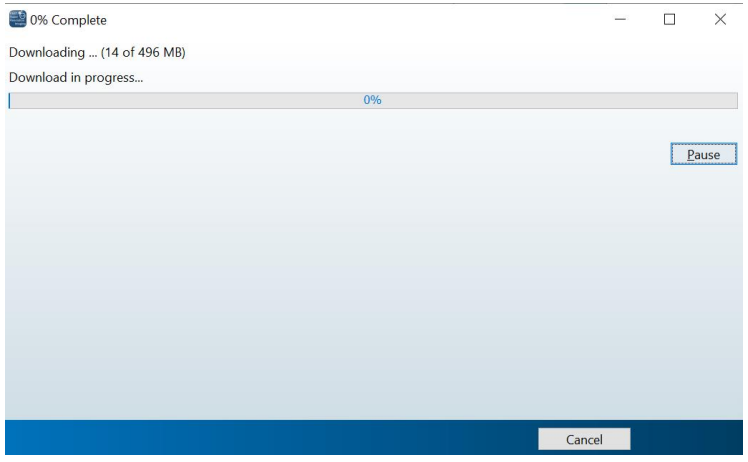
Click “Next”



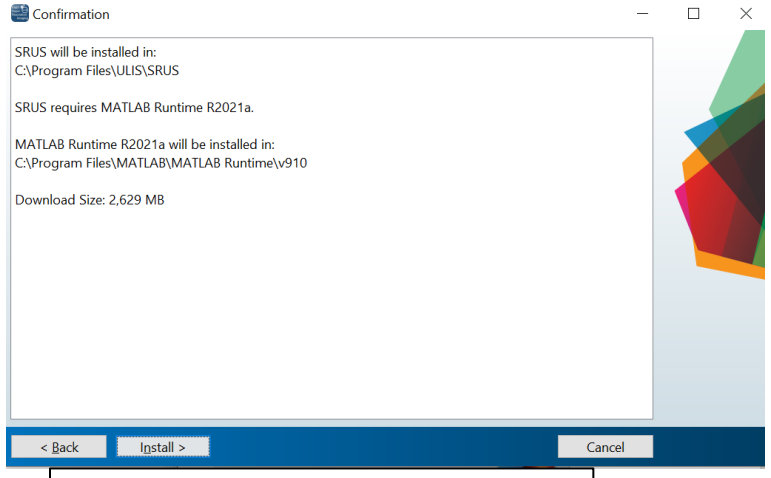
Add shortcut and Click “Next”



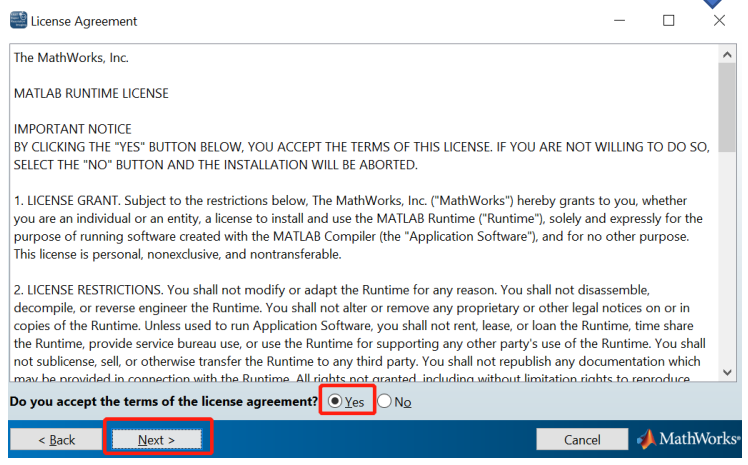
Click “Next”



Wait



Click Install



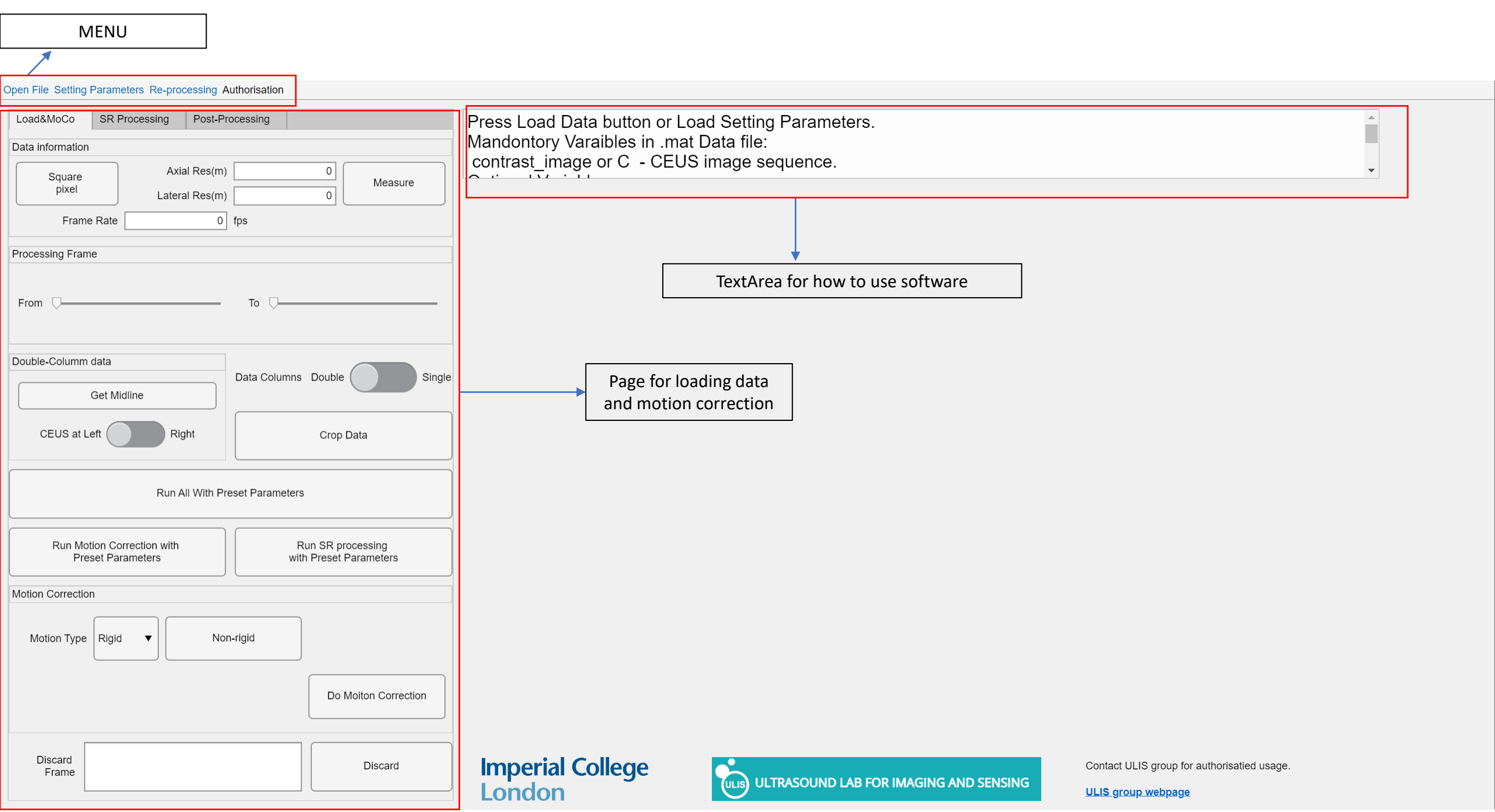
Accept the terms and click “Next”

PS: 1) Runtime installation happens when it is the first time for the PC to install the software.

2) Run .exe as administrator. Otherwise, error might happen if the user wants to install the software in the system disk.

Interface

When Starting, software tries to load previously saved parameters from the file in ‘InstallationPath\application\’. If there is no such a file, the app will use default parameters.


MENU
Open File Setting Parameters Re-processing Authorisation
Load&MoCo
SR Processing
Post-Processing
Data information
Square pixel
Axial Res(m)
0
Lateral Res(m)
0
Measure
Frame Rate
0
fps
Processing Frame
From
To
Double-Columm data
Get Midline
CEUS at Left
Right
Data Columns
Double
Single
Crop Data
Run All With Preset Parameters
Run Motion Correction with Preset Parameters
Run SR processing with Preset Parameters
Motion Correction
Motion Type
Rigid
Non-rigid
Do Moiton Correction
Discard Frame
Discard
Press Load Data button or Load Setting Parameters.
Mandontory Varaibles in .mat Data file:
contrast_image or C - CEUS image sequence.
TextArea for how to use software
Page for loading data and motion correction
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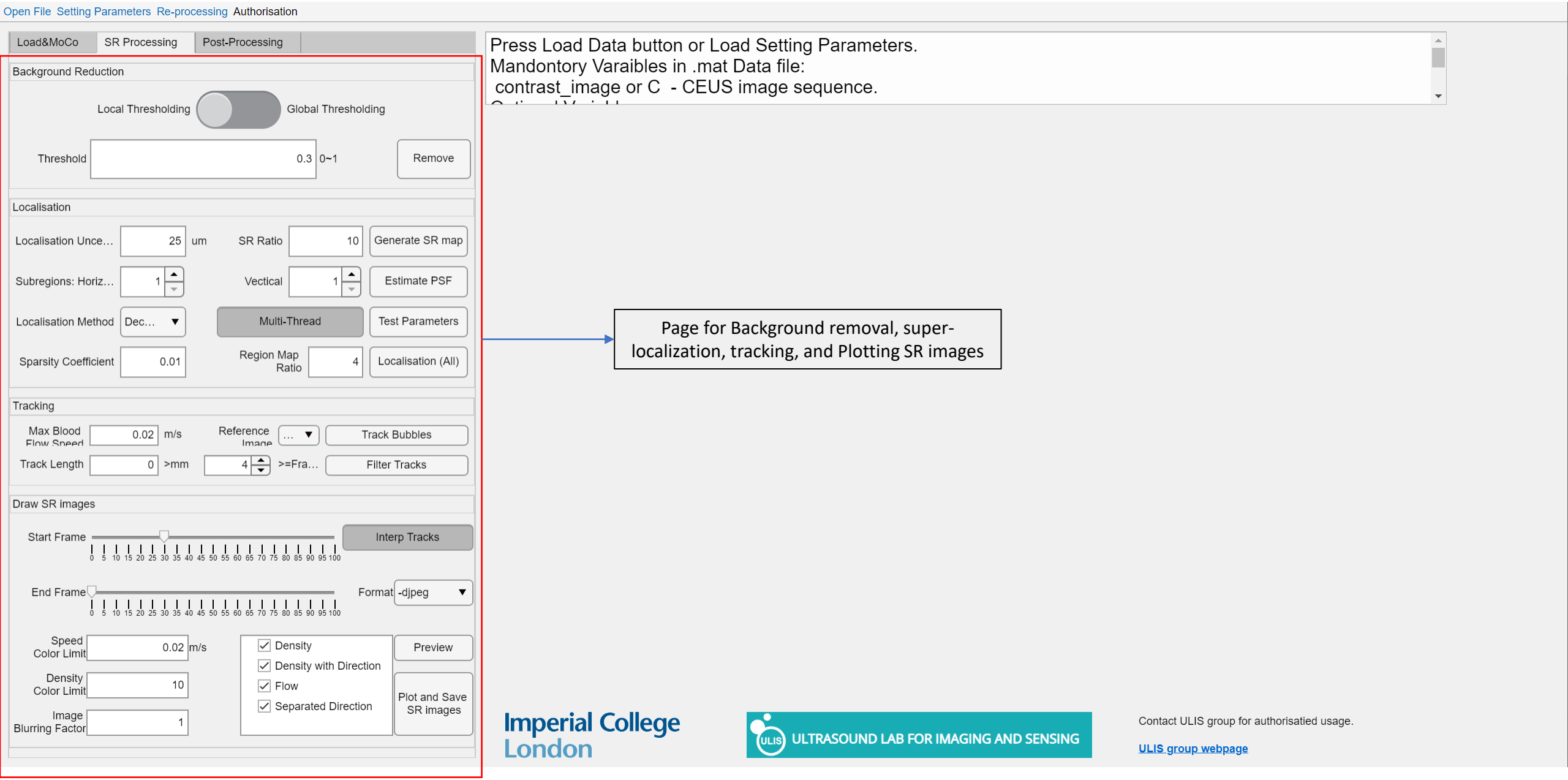
ULIS group webpage


Open File Setting Parameters Re-processing Authorisation
Load&MoCo
SR Processing
Post-Processing
Background Reduction
Local Thresholding
Global Thresholding
Threshold
0.3
0~1
Remove
Localisation
Localisation Unce…
25
um
SR Ratio
10
Generate SR map
Subregions: Horiz…
1
Vectical
1
Estimate PSF
Localisation Method
Dec…
Multi-Thread
Test Parameters
Sparsity Coefficient
0.01
Region Map Ratio
4
Localisation (All)
Tracking
Max Blood Flow Speed
0.02
m/s
Reference Image
Track Bubbles
Track Length
0
>mm
4
>=Fra…
Filter Tracks
Draw SR images
Start Frame
Interp Tracks
End Frame
Format
-djpeg
Speed Color Limit
0.02
m/s
Density Color Limit
10
Image Blurring Factor
1
Density
Density with Direction
Flow
Separated Direction
Preview
Plot and Save SR images
Press Load Data button or Load Setting Parameters.
Mandontory Varaibles in .mat Data file:
contrast_image or C - CEUS image sequence.
Page for Background removal, super-localization, tracking, and Plotting SR images
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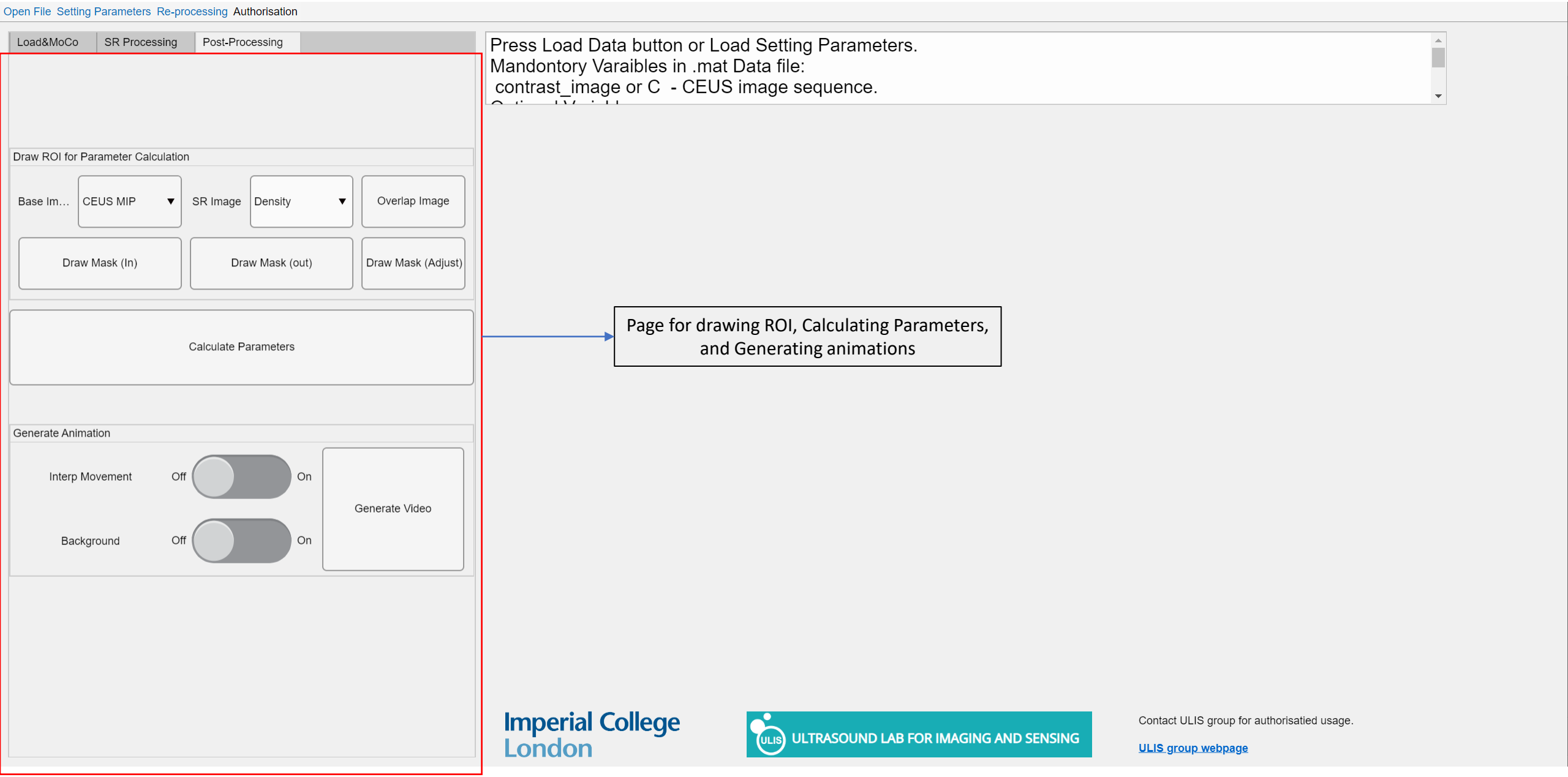
Open File
Setting Parameters
Re-processing
Authorisation
Load&MoCo
SR Processing
Post-Processing
Press Load Data button or Load Setting Parameters.
Mandontory Varaibles in .mat Data file:
contrast_image or C - CEUS image sequence.
Draw ROI for Parameter Calculation
Base Im…
CEUS MIP
SR Image
Density
Overlap Image
Draw Mask (In)
Draw Mask (out)
Draw Mask (Adjust)
Calculate Parameters
Generate Animation
Interp Movement
Off
On
Background
Off
On
Generate Video
Page for drawing ROI, Calculating Parameters, and Generating animations
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Authorisation

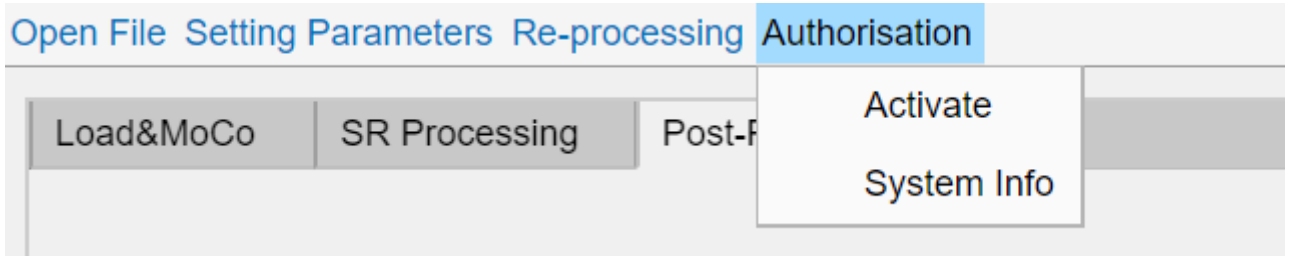
Software is free for research. Getting authorisation can help us know who is using the software.

Limitation without authorisation

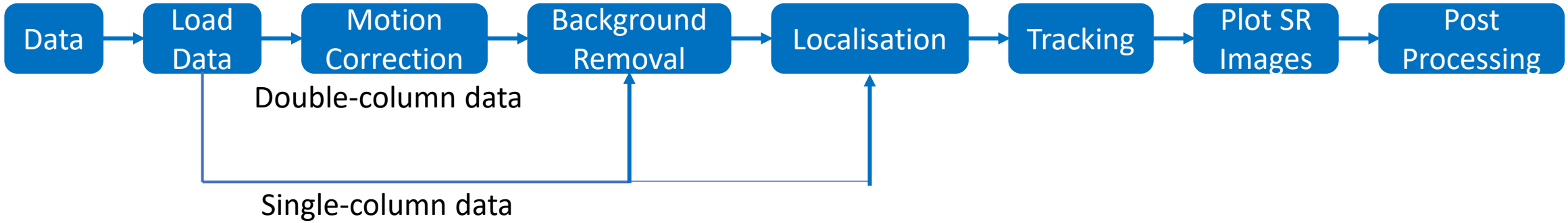
The user can still use the software without authorization, but below two modules are not available and plotted SR images will be with our Lab Logo.

Steps to get authorization

1. Click authorisation and then system info to generate an identical file for your PC.
2. Send the generated file to us
3. You will get a “Key” from us.
4. Click activate and select the “Key” file.



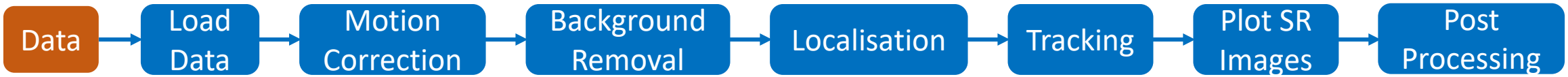
Please do not delete the key file after activation. When you move the key to another folder, you need to activate the software again by selecting the key in the new folder. The key is valid for one year and you can renew it by contacting us with your system info.



Operation Flow

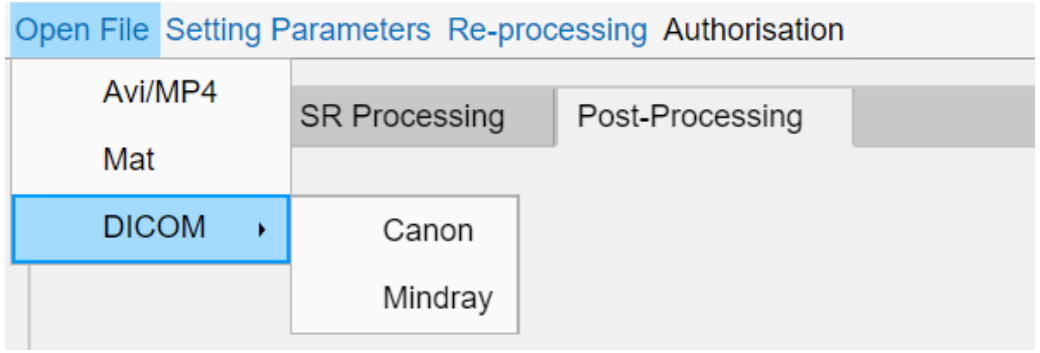
The operation on the software always follows from left to right and top to bottom. If changing parameters in one step, the user need to redo the processing after this step.

Single-column data should be motion corrected before being load by the software.



The user can click Open File and the find supported data type.

1. DICOM from other companies might be able to be loaded by one of the listed selections. If not, you can contact us.

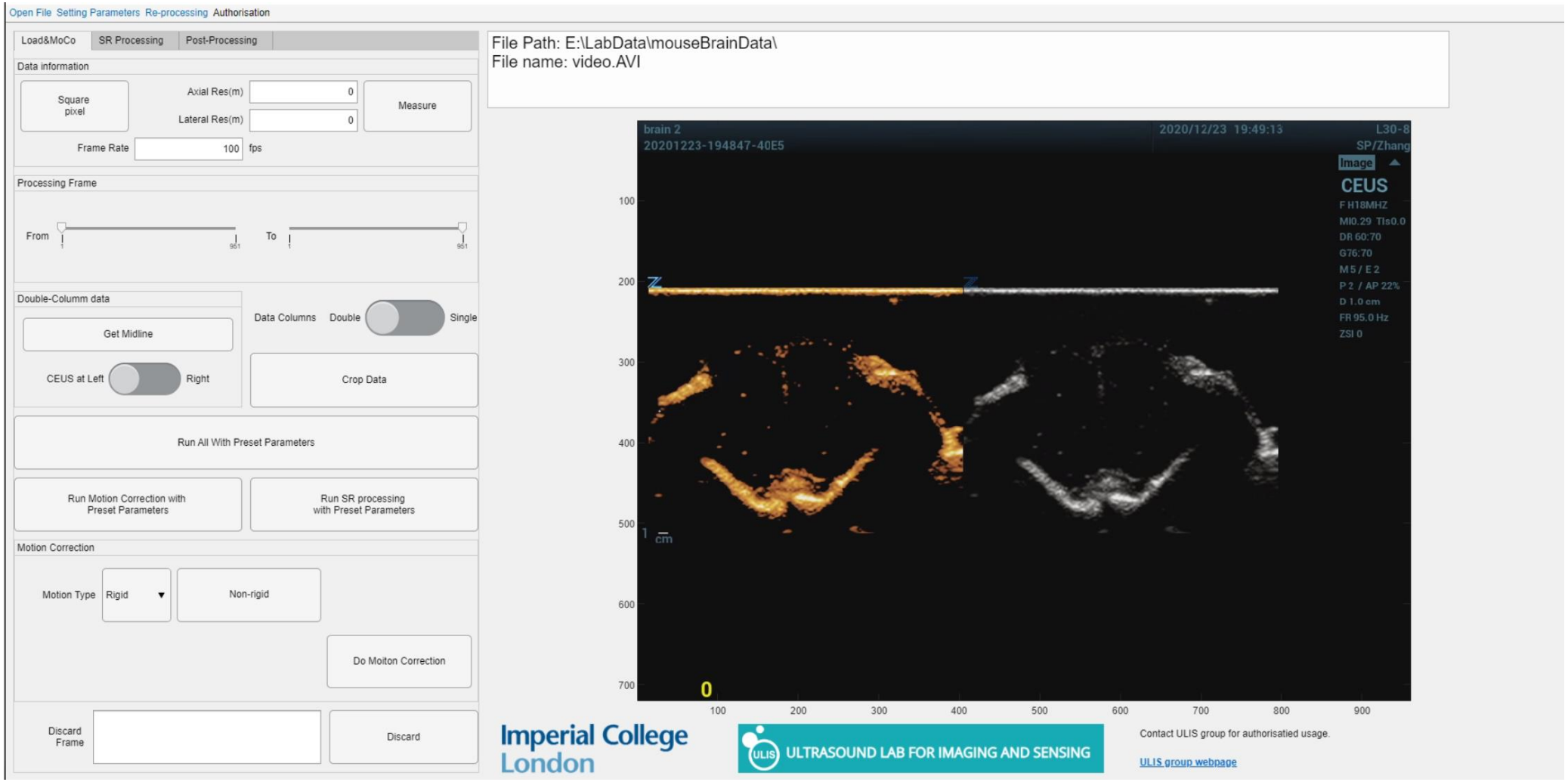


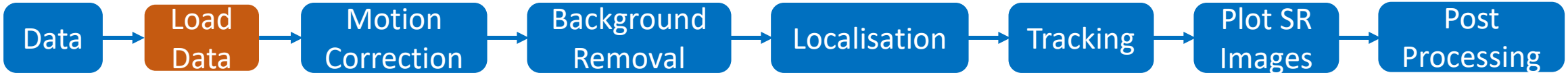
2. Mat file can be data has been pre-processed by the user. The user can skip **Motion Correction** and/or **Background Removal** if the data has been processed through these steps. Requirements of the variable name in the Mat file can be found in the Software description file.

3. **All the folder names in the path should not have any ‘space’ and “special characters”. Otherwise, the software cannot create a result folder in the same folder of the data. For example, the folder name should be ‘ClinicalData’ instead of ‘Clinical Data’**

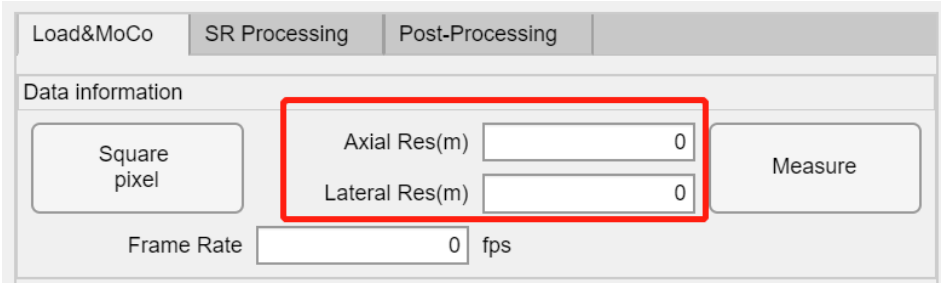
Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

After opening file, data can be load and the user can see one frame of the image





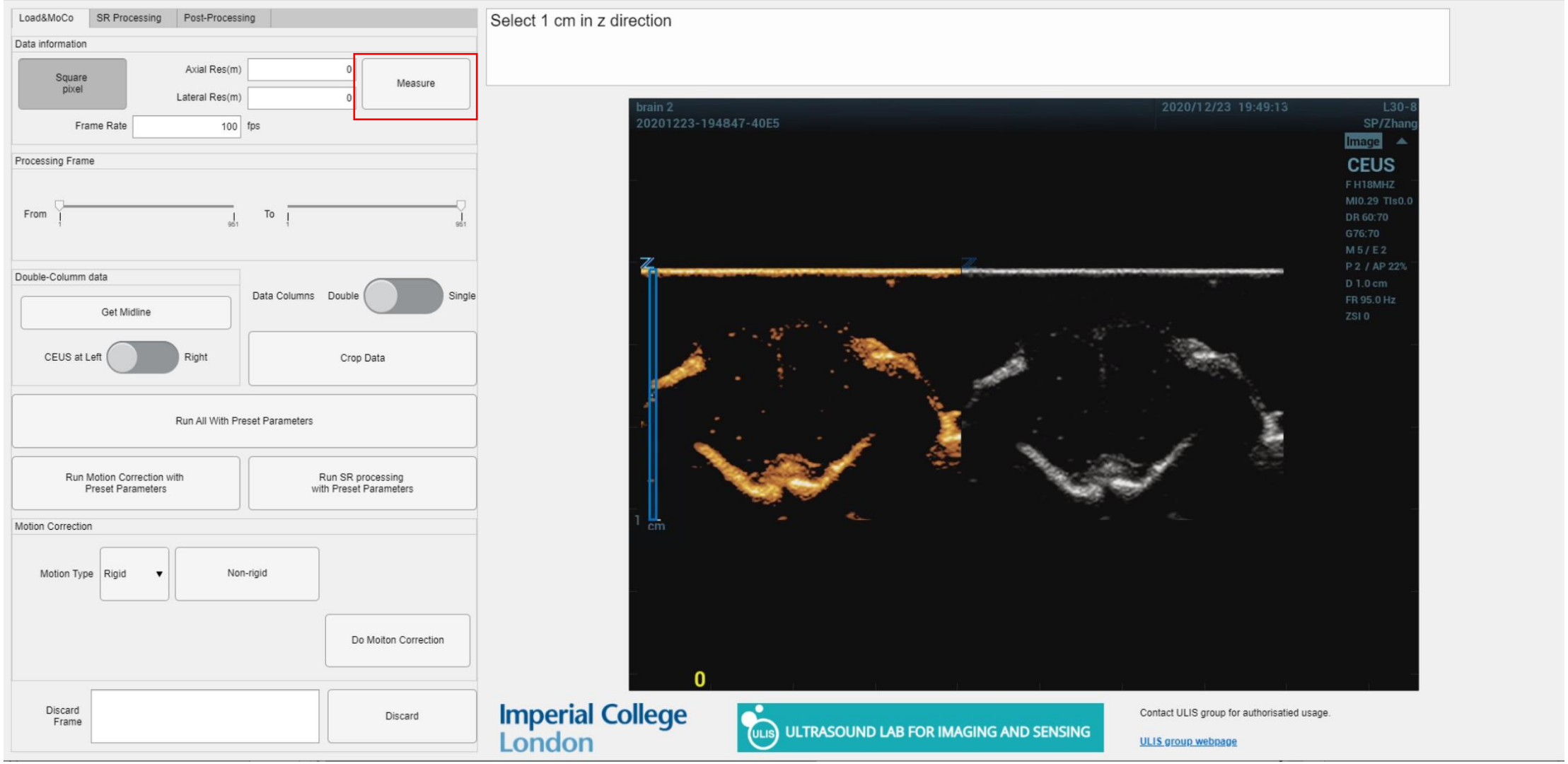
If pixel resolution cannot be read from file, they will be zeros and need the user to measure from the image or to be input by the user.



Sometimes, there is only a scale along the depth direction in the image. In this case, the pixel resolutions along the depth and lateral are generally same. The user can push the **'Square Pixel' button down**, only measure the pixel resolution along the depth and then get two resolutions.

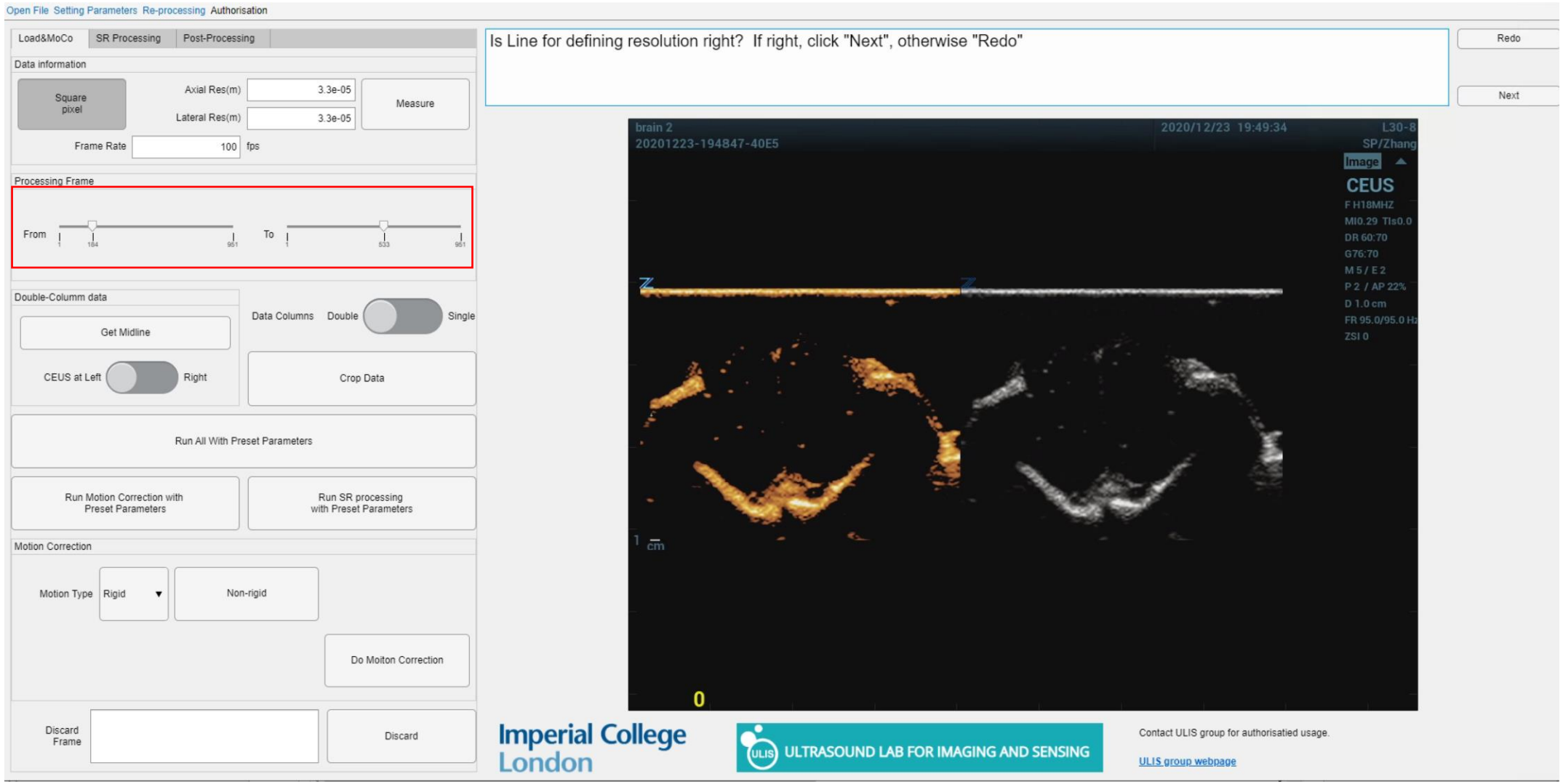
The user should **check if the frame rate is right**. Frame rate read from the DICOM file might be different from the value used in acquisition. Some machines dowsample the frame rate when saving the data. It is the frame rate of saved data that should be used. Frame rate read from MP4 and AVI files is the value of the saved video, which might also differ from that of data.

Click **Measure** button to measure pixel size from the image.
If the user want to measure pixel size again, set the values as zeros and Click **Measure** button



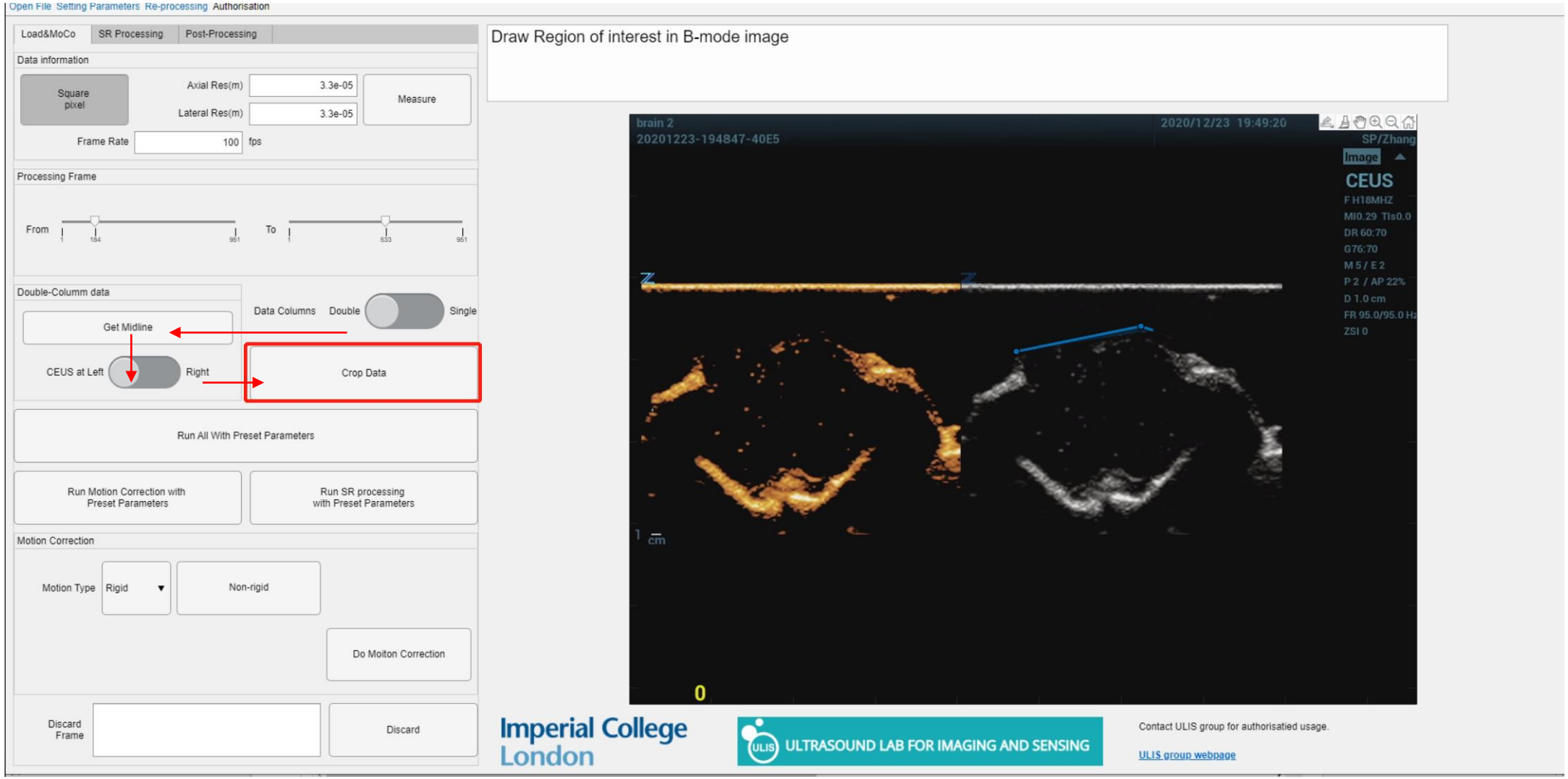
Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

Select frames to be processed by dragging the two sliders



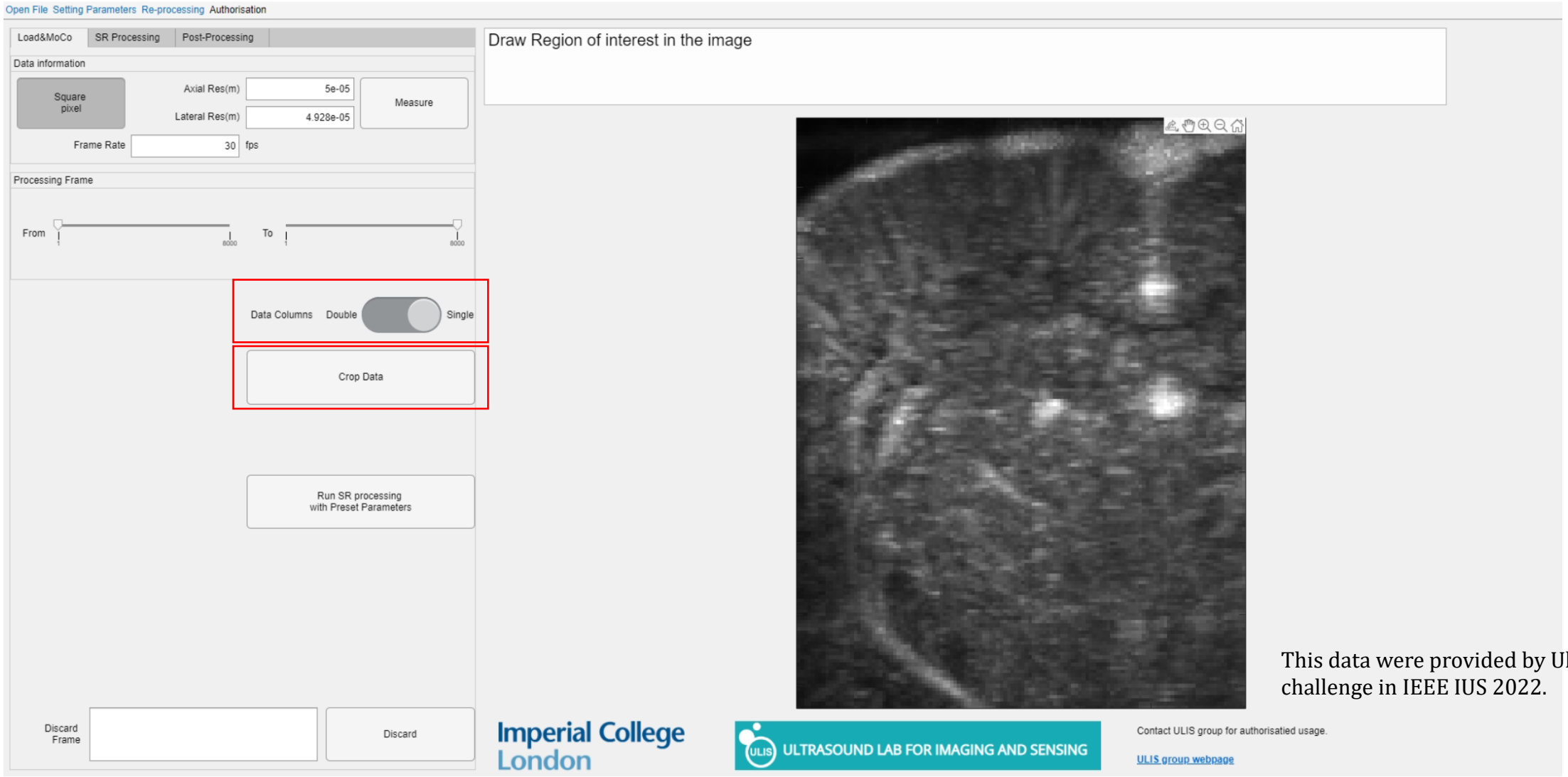
Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

Crop Data: Double-column.



Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

Crop Data: Single-column.

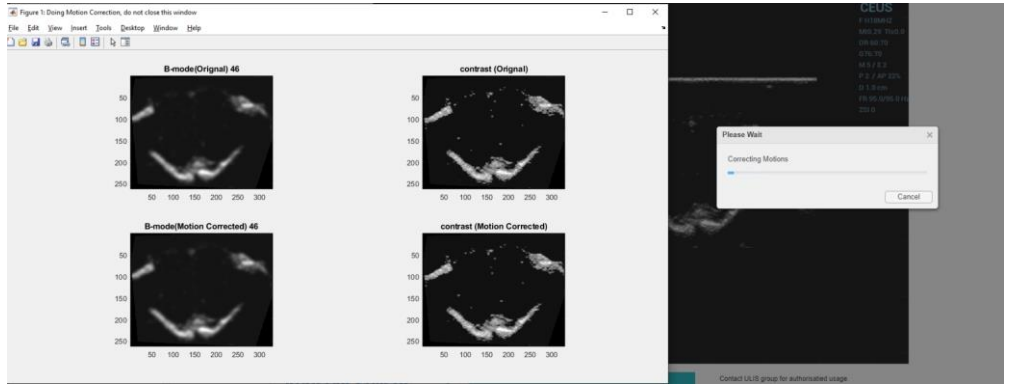


This data were provided by Ultra-SR challenge in IEEE IUS 2022.

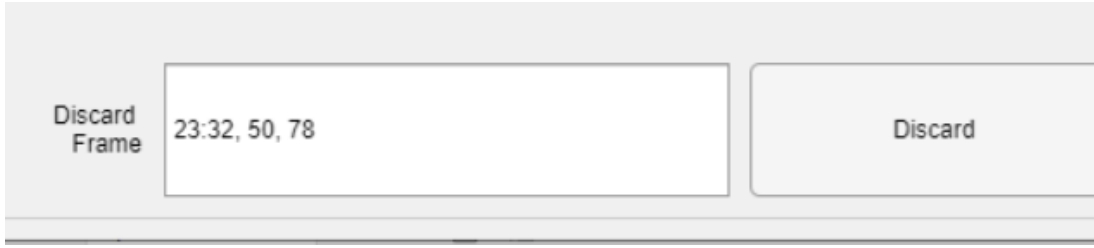
Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

Motion correction components only work when there are B-mode data.
Set motion correction parameters:

Click 'Do motion correction' button and wait.
If motion is still obvious after motion correction, the user can cancel the processing and adjust parameters for motion correction. If still not work, the user has to abandon data or contact us for help.

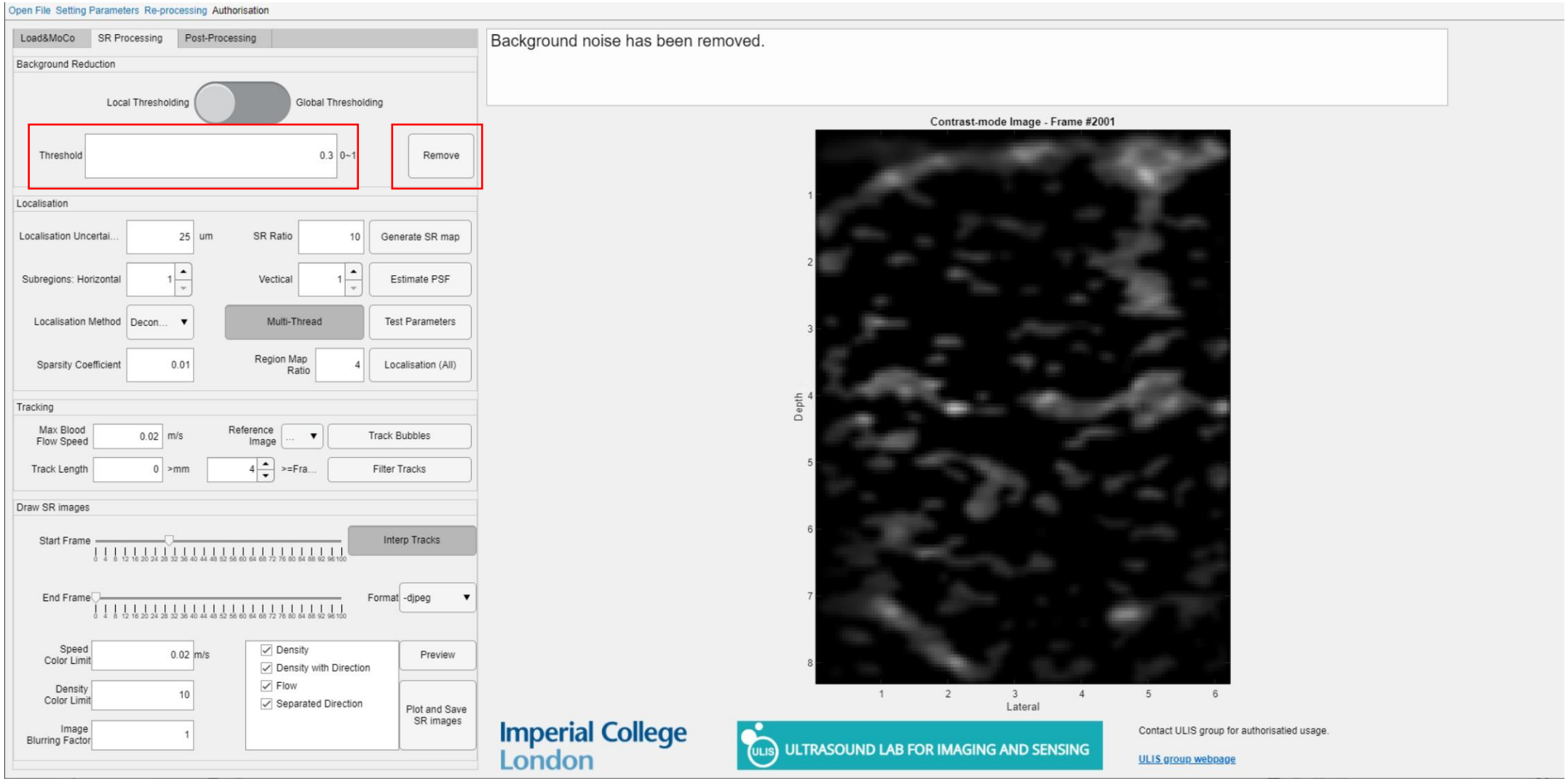


User can discard part of frames that are not rightly corrected by inputting the frame number and click **Discard**. The right example means frames from 23 to 32 and frame 50 and 78 will not be used in the following processing,

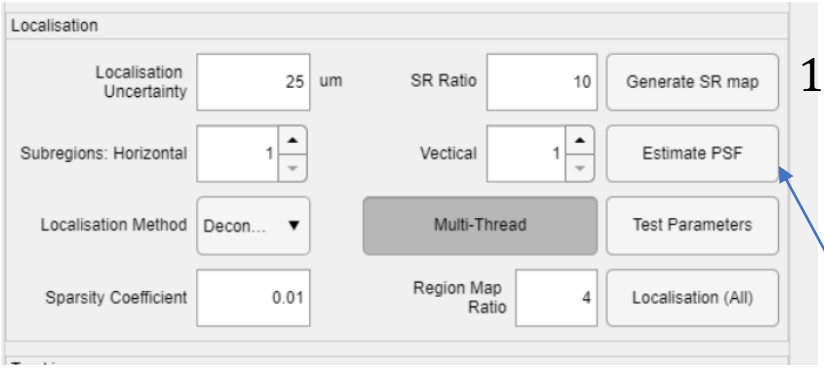


Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

Input the number and click **Remove** button. Higher the number, less noise and less signal.



Data → Load Data → Motion Correction → Background Removal → **Localisation** → Tracking → Plot SR Images → Post Processing



1. Input localization uncertainty and SR ratio and click **Generate SR map** button.

2. Use Default\Last PSF or estimate PSF from the data by clicking **Estimate PSF** button.
Estimated PSF will be saved in the result folder.
If there is a PSF file in the result folder, click **Estimate PSF** button will load the file;
If the user want to estimate new PSF, the user should remove the PSF File from the folder and then click **Estimate PSF** button.

Data → Load Data → Motion Correction → Background Removal → **Localisation** → Tracking → Plot SR Images → Post Processing

Estimate PSF

Open File Setting Parameters Re-processing Authorisation

Load&MoCo | SR Processing | Post-Processing

Background noise has been removed.

Background Reduction

Local Thresholding — Global Thresholding

Threshold: 0.3 (0~1) — Remove

Localisation

Localisation Uncertainty: 25 um — SR Ratio: 10 — Generate SR map

Subregions: Horizontal: 2 — Vectical: 2 — Estimate PSF

Localisation Method: Decon... — Multi-Thread — Test Parameters

Sparsity Coefficient: 0.01 — Region Map Ratio: 4 — Localisation (All)

Tracking

Max Blood Flow Speed: 0.02 m/s — Reference Image — Track Bubbles

Track Length: 0 >mm — 4 >=Fra... — Filter Tracks

Draw SR images

Start Frame — Interp Tracks

End Frame — Format: -djpeg

Speed Color Limit: 0.02 m/s

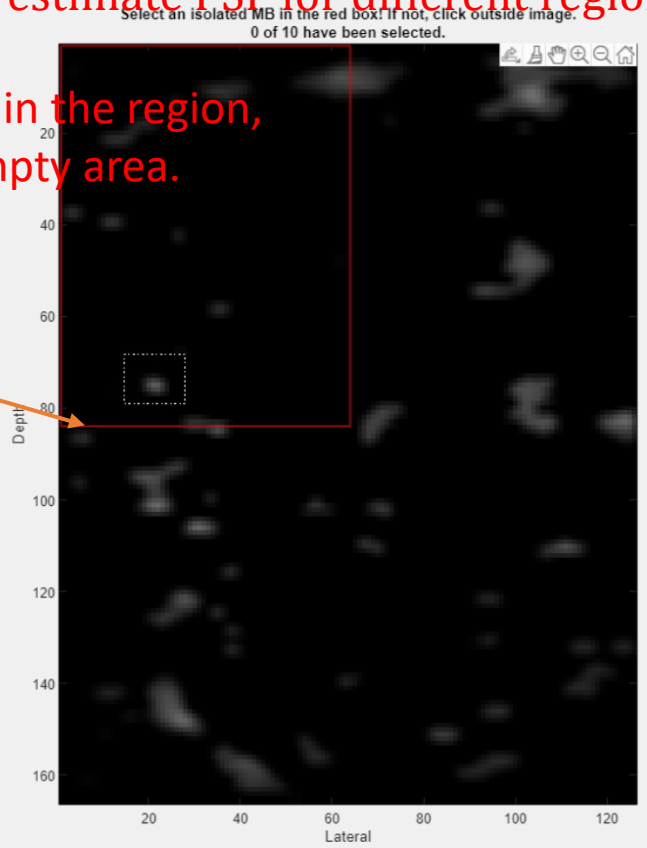
Density Color Limit: 10

Image Blurring Factor: 1

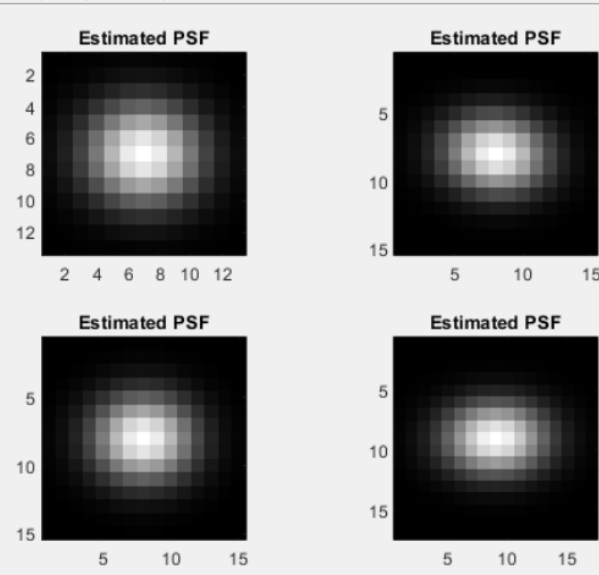
Density / Density with Direction / Flow / Separated Direction — Preview — Plot and Save SR images

Set number of subregions, if PSF varies a lot in different regions . Set them to estimate PSF for different regions.

If there is no bubbles in the region, just pick ten black/empty area.



PSF for different regions



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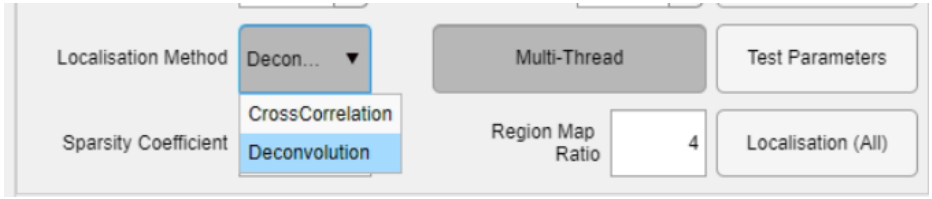
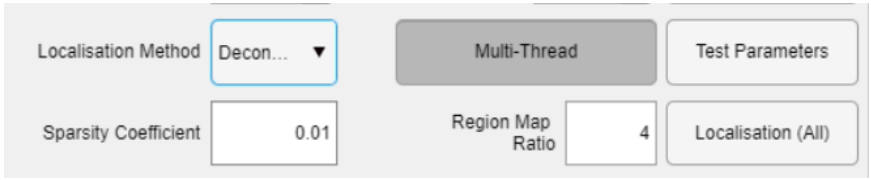
Data → Load Data → Motion Correction → Background Removal → **Localisation** → Tracking → Plot SR Images → Post Processing

Select localization method: cross-correlation usually gives a faster computation but worse performance at high bubble concentrations

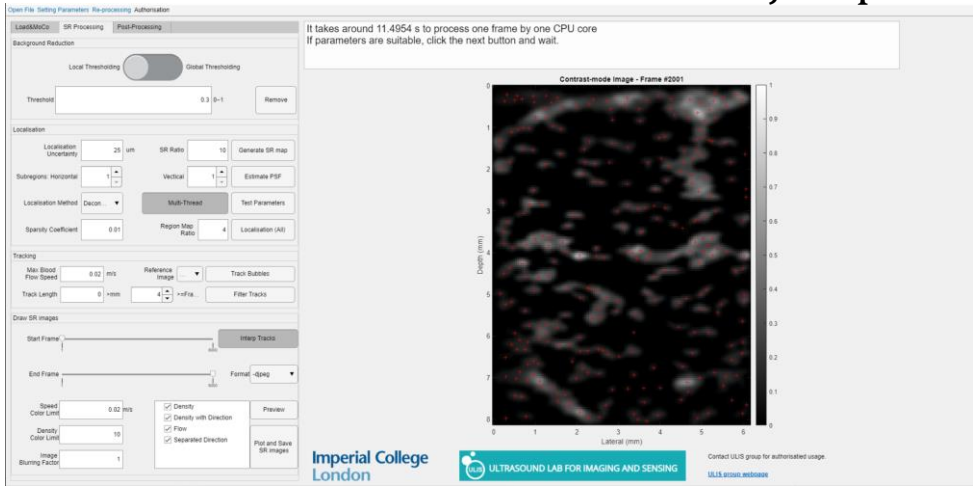


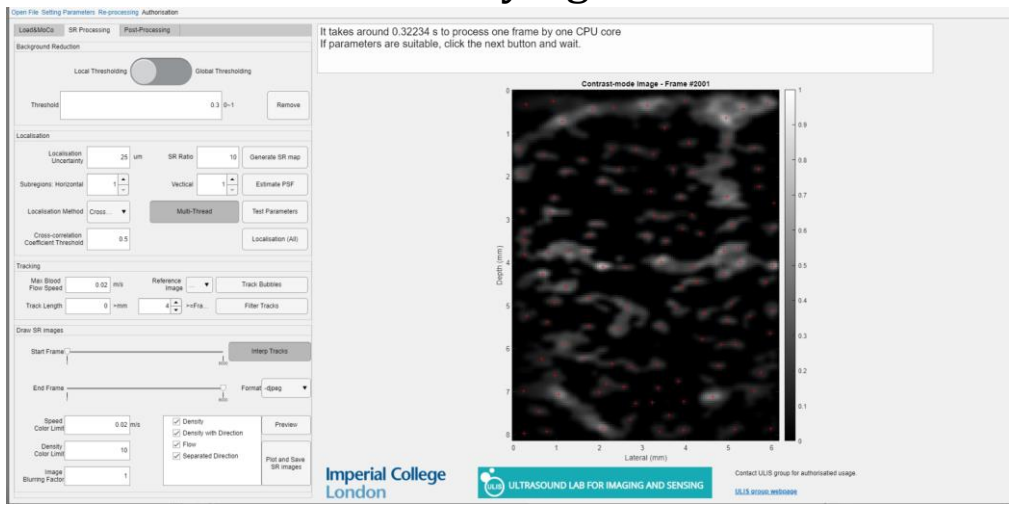
Deconvolution parameters



Cross-correlation paramters

Click **Test Parameters** button and adjust parameters if the localisation is not satisfying

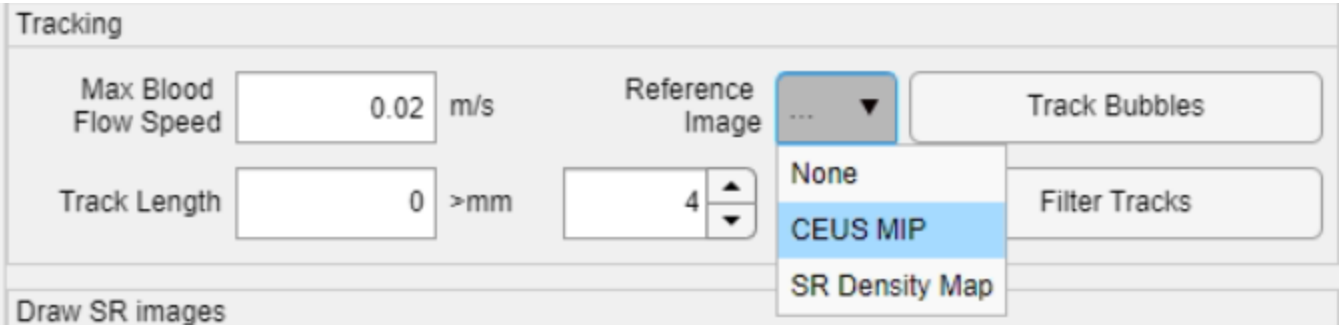




Click **Localisation (All)** button to process all the frames

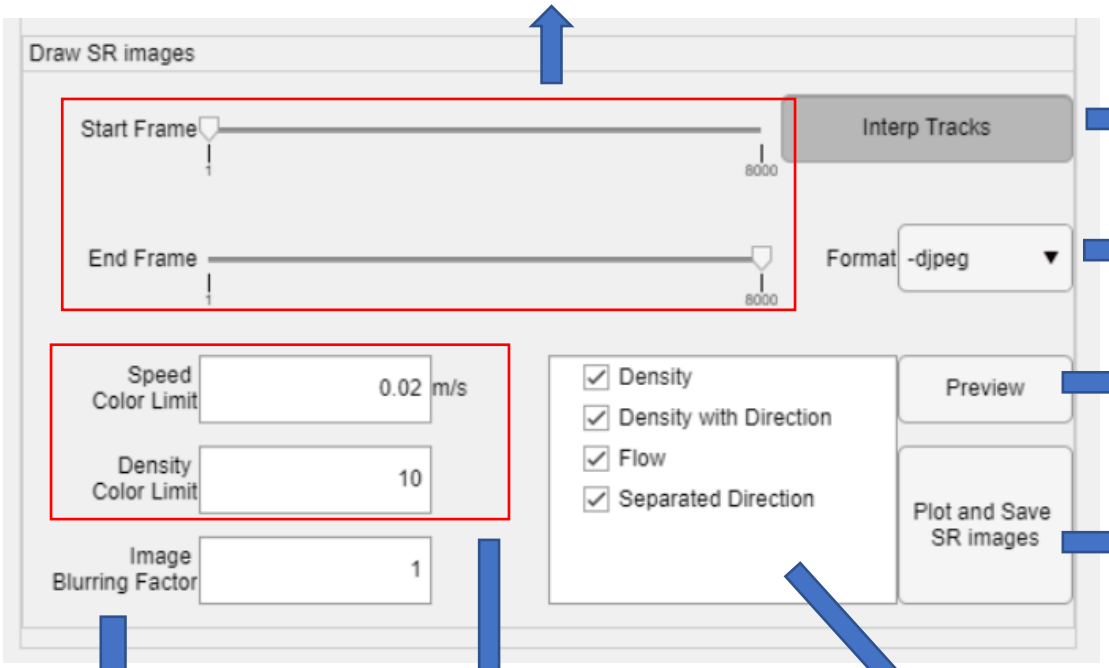
Data → Load Data → Motion Correction → Background Removal → Localisation → **Tracking** → Plot SR Images → Post Processing

Set max blood flow speed; chose the reference image and click **Track Bubbles** button.
After finishing tracking, set filters and click **Filter Tracks** button



Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

Use sliders for Start and End frames to select the temporal range the user want to reconstructed for SR images and quantified in post-processing.



Suggest to press this button down to enhance reconstructed vessel saturation.

Format of saved SR images

Click to preview SR density map to adjust dynamic range and blurring

Click to generate all maps.

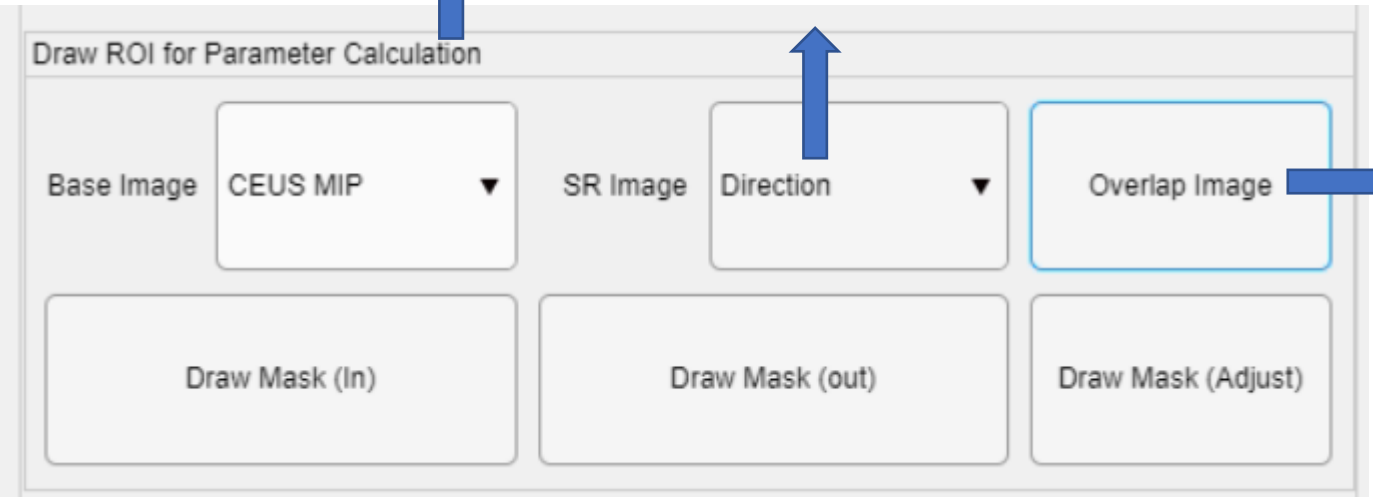
Dynamic range of SR images

Control of blurring (>0)

Select what maps to be generated. It is suggested to select at least the first three one to have all the functions and metrics in the post-processing

Select the image at bottom: CEUS MIP or B-mode. B-mode is not available for single column data.

Select the image at top: SR density map or density map with direction.



Overlap two selected images.

Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

Open File Setting Parameters Re-processing Authorisation

Load&MoCo | SR Processing | Post-Processing

Finish ROI

Draw ROI for Parameter Calculation

Base Image: CEUS MIP ▼ | SR Image: Direction ▼ | Overlap Image

Draw Mask (In) | Draw Mask (out) | Draw Mask (Adjust)

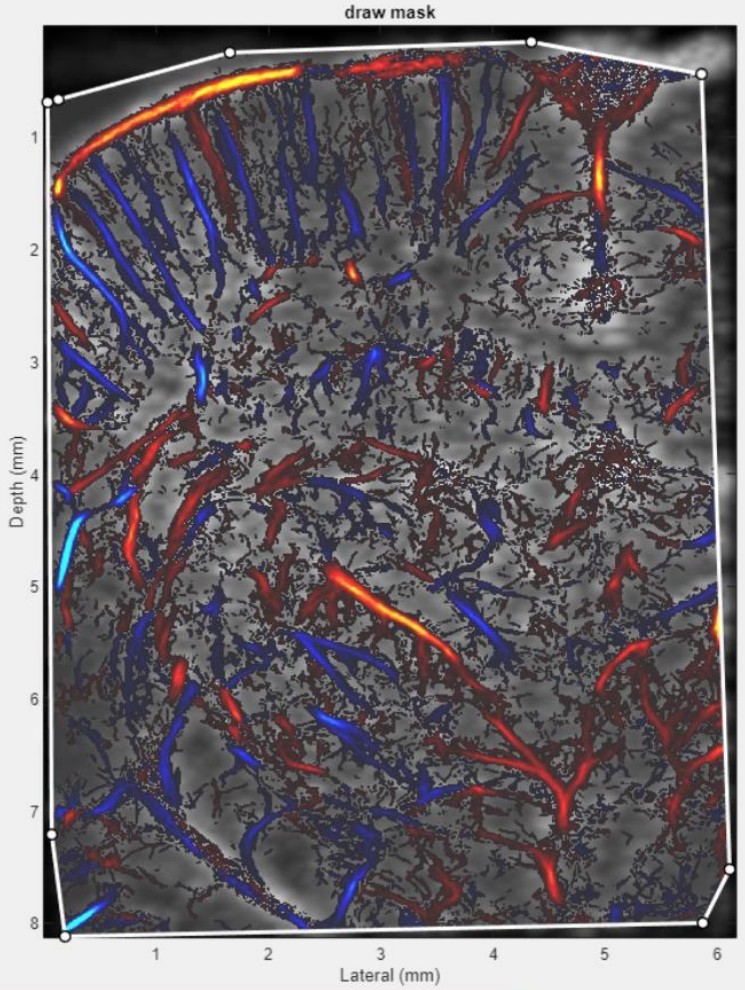
Calculate Parameters

Generate Animation

Interp Movement: Off On

Background: Off On

Generate Video



Remove wrong localisations at the edge of image.

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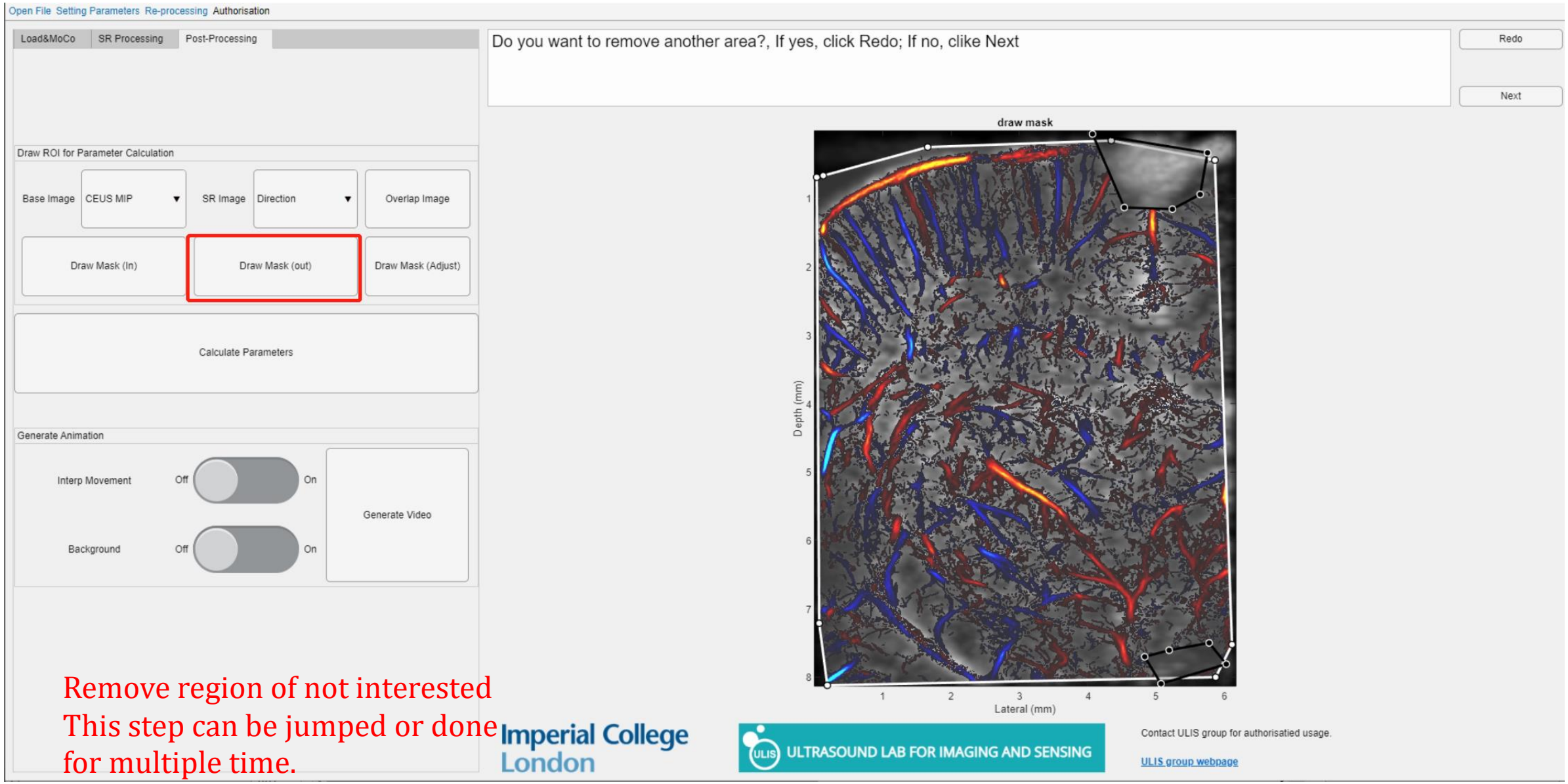
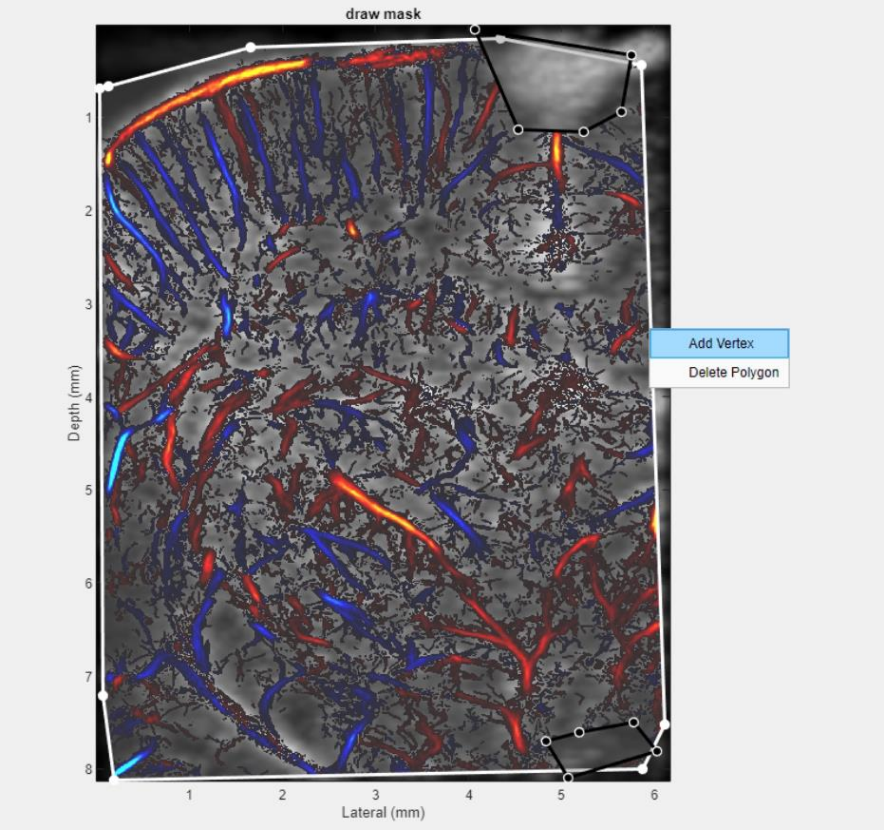
Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing



Remove region of not interested
This step can be jumped or done for multiple time.

The user can adjust ROI by dragging vertex or adding vertex.
After finishing, click **Draw Mask (adjust)** button to update the mask.



From GUI 2.1

Button: Draw Mask (adjust)

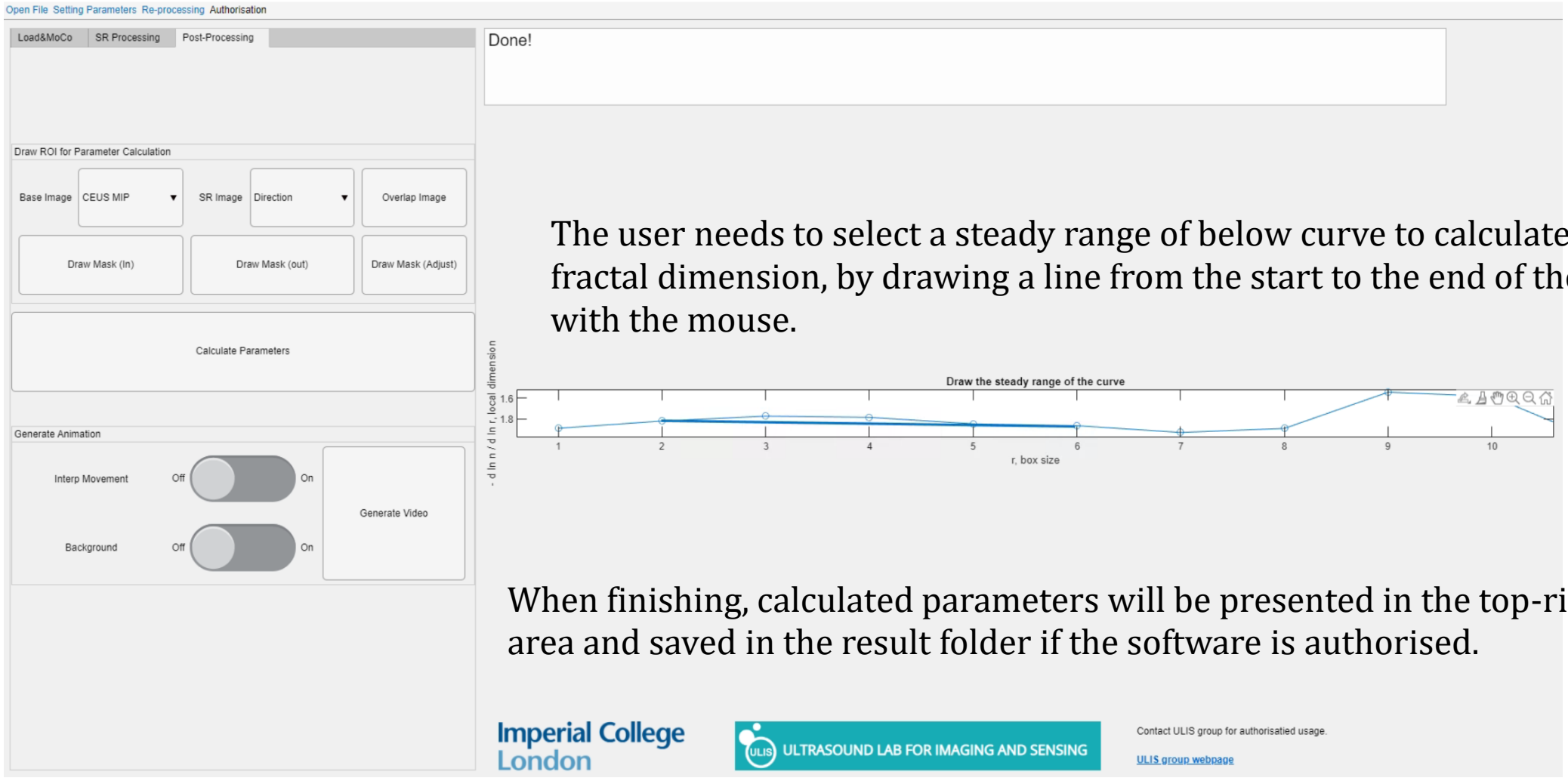
Replaced by

Button: Confirm Mask

If the user want to redo all the ROIs, click **Overlap** button and draw ROIs.

Data → Load Data → Motion Correction → Background Removal → Localisation → Tracking → Plot SR Images → Post Processing

Click **Calculate Parameter** button, images within the masks will be generated and most of metrics will be automatically calculated.



The user needs to select a steady range of below curve to calculate the fractal dimension, by drawing a line from the start to the end of the range with the mouse.

When finishing, calculated parameters will be presented in the top-right area and saved in the result folder if the software is authorised.

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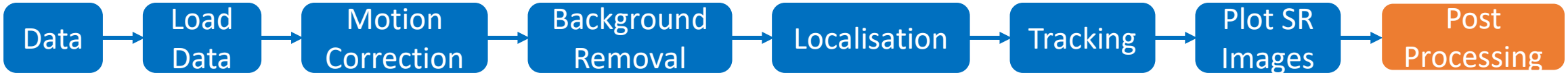
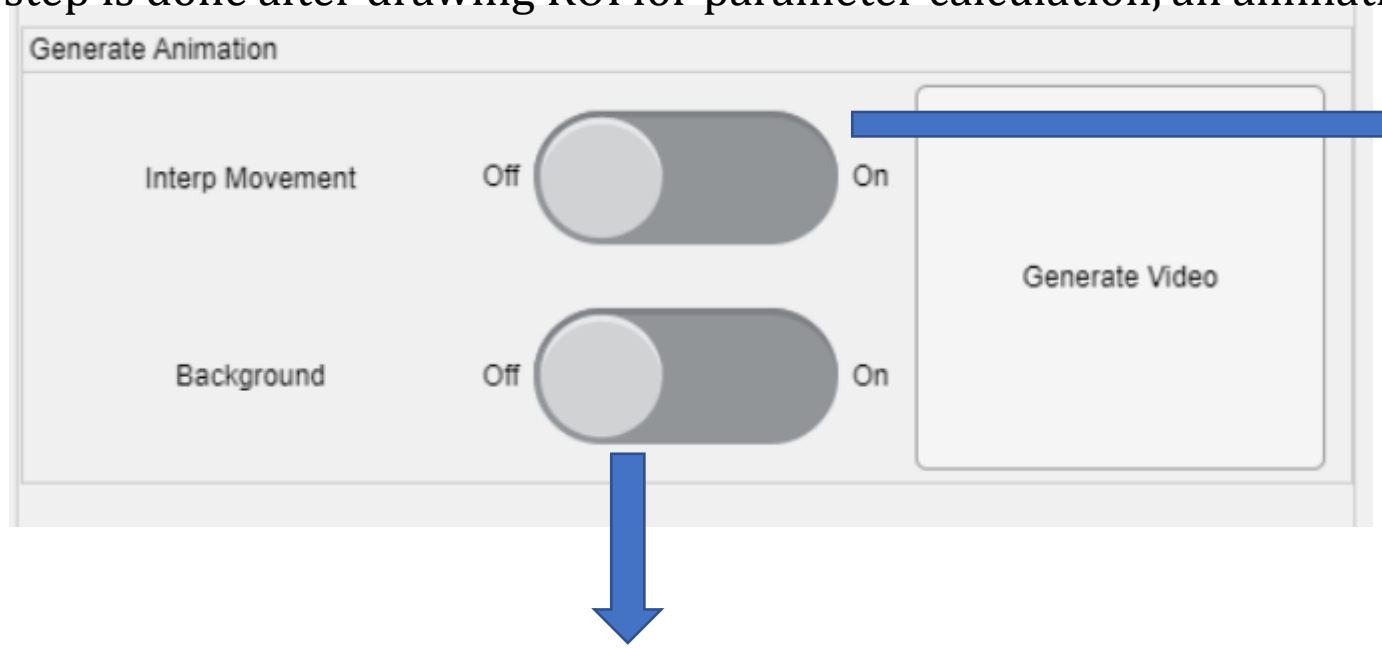
Contact ULIS group for authorisatied usage.

ULIS group webpage



Click **Generate Video** button to generate animations. Video can be found in the result folder. Density map with direction has to be generated for this step.

If this step is done before drawing ROI for parameter calculation, an animation will be generated for the whole image.
If this step is done after drawing ROI for parameter calculation, an animation will be generated with in the Mask.



If on (Suggested), put part of localised bubbles in one frame and move bubbles along interpolated tracked trajectories.

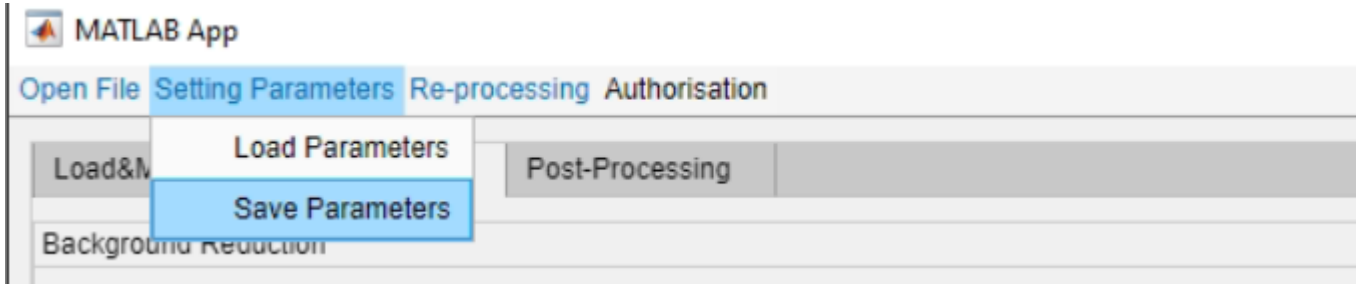
Otherwise, put part of localised bubbles in one frame and other parts of bubbles appear in sequence.

If on, density map with direction will be set as background.
Otherwise, no background.

Quick Run

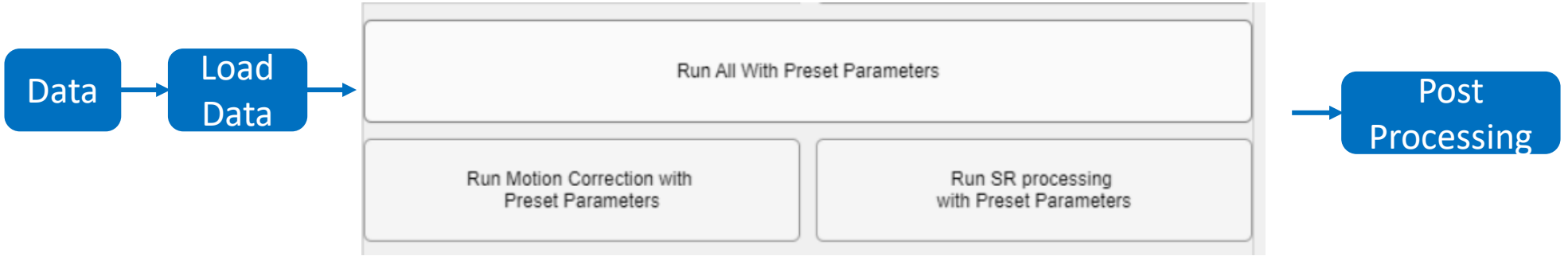
User can save the setting parameter and process the data with same experiment protocol without going through each step manually.

User can save setting parameters for processing by click **Save Parameters**.
User can save the file anywhere.
If the file is saved in Folder 'InstallationPath\application\', the saved parameters will be default parameters for opening the software next time.
User can use **Load Parameters** to load parameters in any folder.



After loading and cropping the data, user can click

1. **Run all** to do all the processing automatically.
2. **Run Motion** correction to only do motion correction automatically;
3. **Run SR Processing** to only do motion correction automatically.



Re-Processing

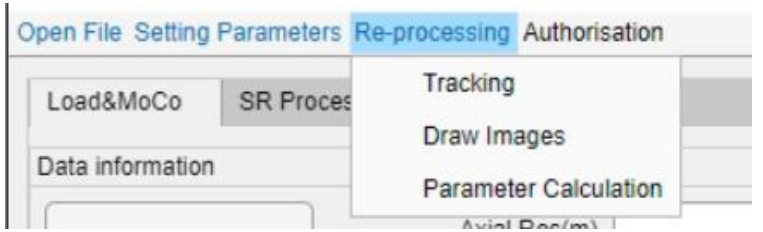
Pre-process data with new parameters.

Re-process Localisation:

User can load motion-corrected data by Open File-Mat, and then do

Re-process Tracking:

User can click Re-processing - Tracking, load Localisation result File, and then do



Re-draw Images:

User can click Re-processing – Draw Images, load Tracking Result File, and then do

Re-Calculate parameters:

User can click Re-processing – Parameter calculation, load SR Maps File, then do

Updates in SRUS 2.1

GUI 2.0->2.1

Localisation 2.0->3.0

Plotting 2.0 ->2.1

Parameter Calculation 2.0 ->2.1

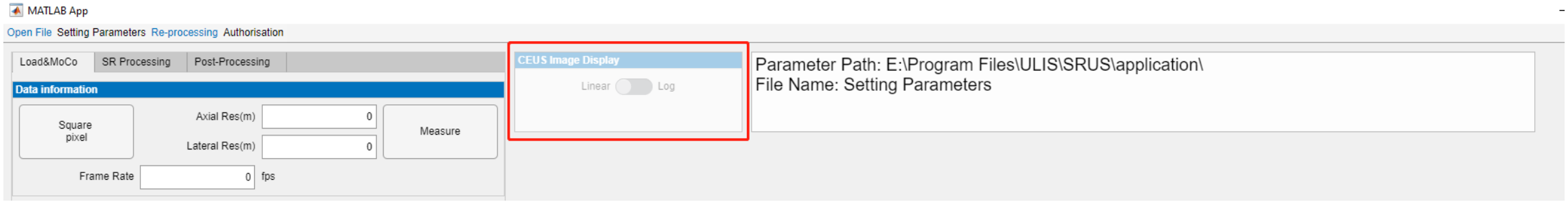
Localisation 3.0:

Normalized cross-correlation can be done with spatial-varying PSFs and computation was optimised for faster speed and less memory.

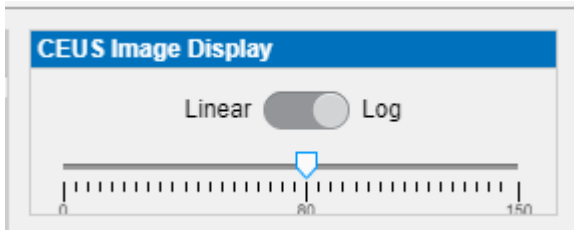
An additional filter is added in Deconvolution to remove noise.

GUI 2.1:

Add a new panel for choose display mode and change dynamic range (dB scale) if log (log compression) is chosen.



It is only enabled when Mat data is loaded. The display setting will take effect when CEUS images are plotted next time. With below setting, CEUS image will be displayed in log compression with dynamic range from -80 to 0 dB



Folder for files used to set the software is moved to the installation path of the software.

Plotting 2.1:

A flow magnitude map calculated by averaging speed of each passing bubble was added.

Parameter Calculation 2.1:

Selection for calculated parameters and if replotting images in ROI were added**.**

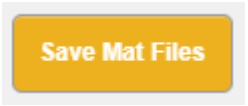
Updates in SRUS 2.2

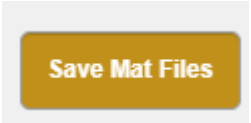
GUI 2.1->2.2

Localisation 3.0->3.1

Plotting 2.1 ->2.2

GUI 2.2:

Unpressed: 

Pressed: 

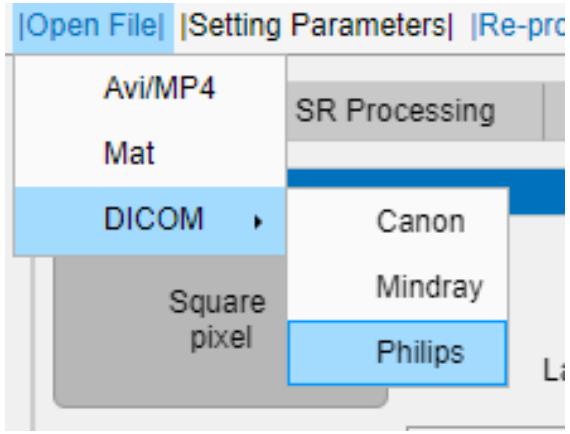
1. Add a state button at the middle button.

1)The button is default ‘Pressed’. In this case, processed results are saved in Mat files after ‘Motion correction’, ‘Localisation’, ‘Tracking’, and ‘Plotting’, each time of which might take much time.

2) The user can make the button unpressed to reduce consuming time when tunning the processing parameters.

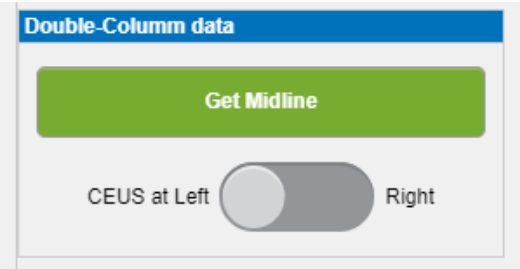
3) **The user is suggested to press the button again to save all Mat files, after fixing processing parameters**. Mat files can be re-processed by the software. ‘Batch Processing’ will be provided to deal with Mat files in the future.

2. Add “Philips” as a new option in the ‘Open File’ menu.

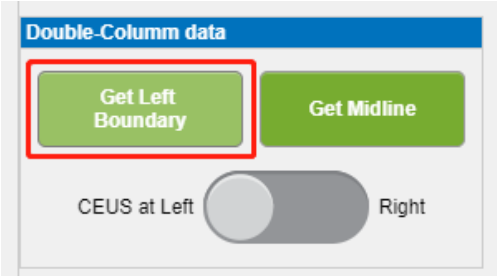


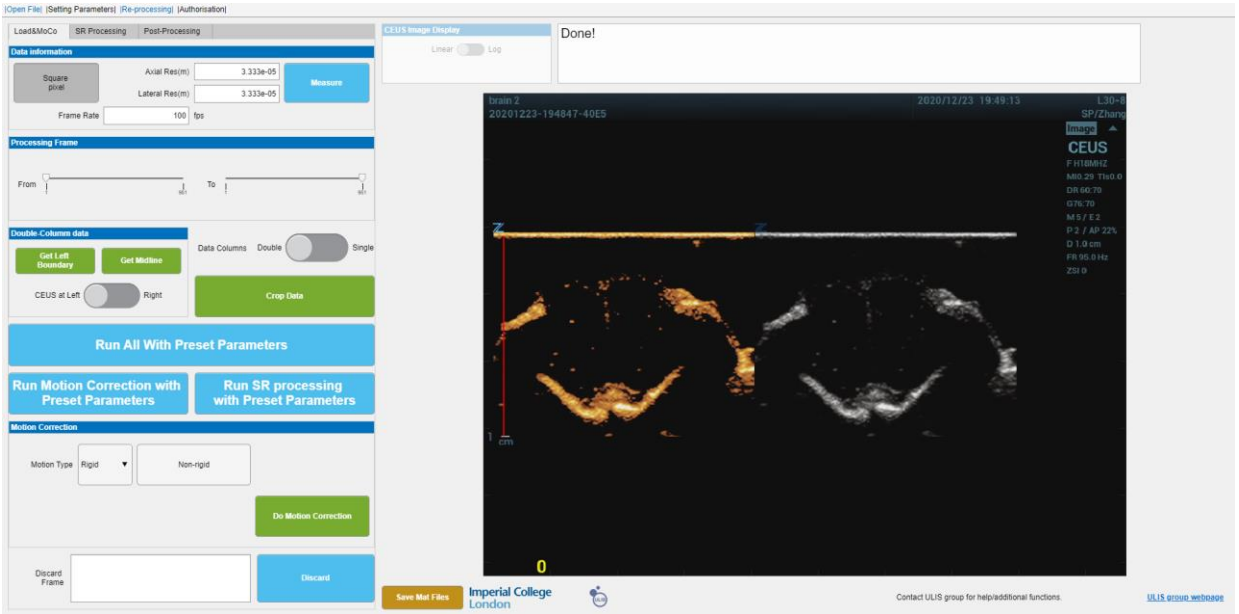
3. Add “Get left boundary”, to deal with some cases where the left edge of the ultrasound image is not the edge of the whole image.

GUI 2.1:

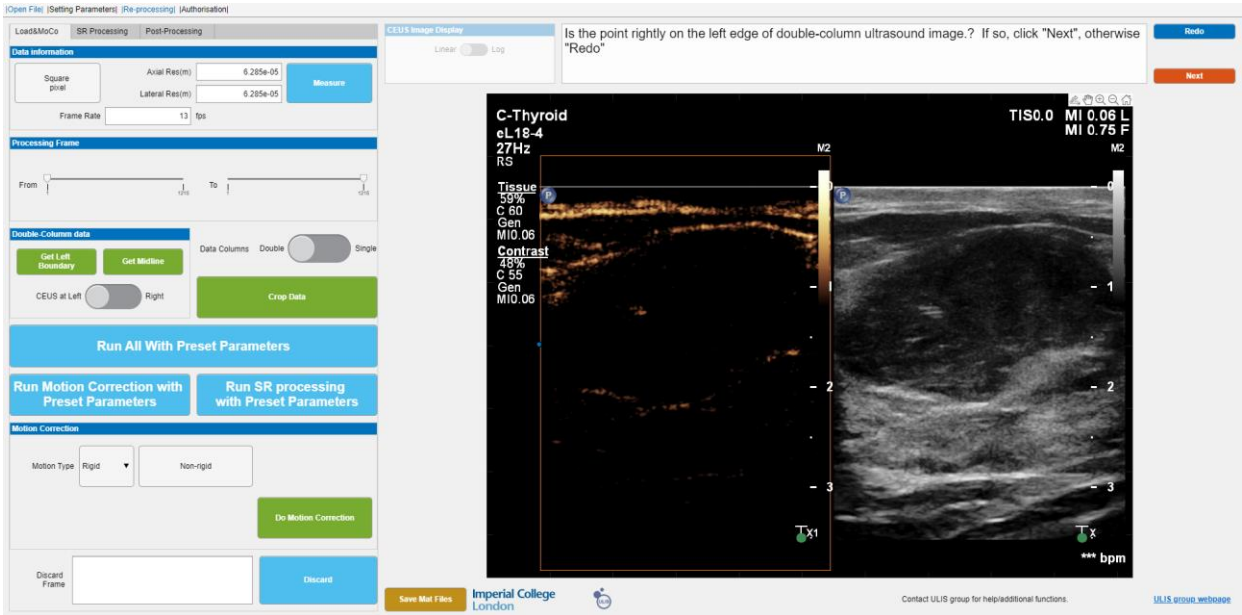


GUI 2.2:





Left edge of ultrasound image is the edge of the whole image.
The user does not need to click the “Get left boundary” button.



Left edge of ultrasound image is not the edge of the whole image.
The user needs to click the “Get left boundary” button.

Localisation 3.0->3.1

"Localisation (all)" works stable where there are blank (no signal) CEUS frames in the sequence.

Plotting 2.1 ->2.2

The user can choose if saving Maximum Intensity Projection (MIP) image and Averaged (Stacked) Image of CEUS Sequence.