Localization and Tracking Toolbox for Ultrasound Superresolution

User Guide

V1.1 2020/12/17

Authors:

Baptiste Heiles, Arthur Chavignon, Vincent Hingot, Pauline Lopez, Eliott Teston, Olivier Couture

Laboratoire d'Imagerie Biomedicale, Team PPM. 15 rue de l'Ecole de Medecine, 75006, Paris

Corresponding author:

Baptiste Heiles, baptiste.heiles@gmail.com

Academic references to be cited

Details of the code published in 2020 article by Heiles, Chavignon, Hingot, Lopez, Teston, and Couture. Open Platform for Ultrasound Localization Microscopy: performance assessment of localization algorithms

1. General information

Aim

LOTUS is software for ultrasound localization microscopy. Individual and isolated microbubbles are localized with sub-pixel precision. Then a tracking algorithm pairs microbubbles' positions into long trajectories. It enables microvascular imaging in various organs.

Minimum requirements

LOTUS software integrates MATLAB Runtime R2020b (9.9) (MathWorks). We recommend using Microsoft Windows 10 (version 1803 or higher), with 4 GB RAM minimum, and 5 GB of free space.

Installation instructions

1. Download LOTUS from Github repository
2. Unpack the archive in a preferred directory.
3. Launch the installer LOTUS_v1_1_installer.exe
4. Follow the instructions
5. Restart your computer
6. LOTUS should be now available for use in the start-up menu

Input data type

LOTUS software accepts a list of .mat file with images organized in a [space, space, time] matrix. Images can be complex or real, without log compression. For long acquisition, data should be split into multiple individual files of a maximum of 2000 images to prevent time-consuming filtering (max 200 MB per file). The name of the variable containing the images is assumed to be IQ by default. In the case where LOTUS can not clearly identify the name of the variable, it will ask the user to define a name in a pop-up dialog box.

Image visualization

Images will be saved in the specified folder. We recommend using ImageJ software to visualize tiff images and adjust brightness/contrast/color balance. (https://imagej.nih.gov/ij/)

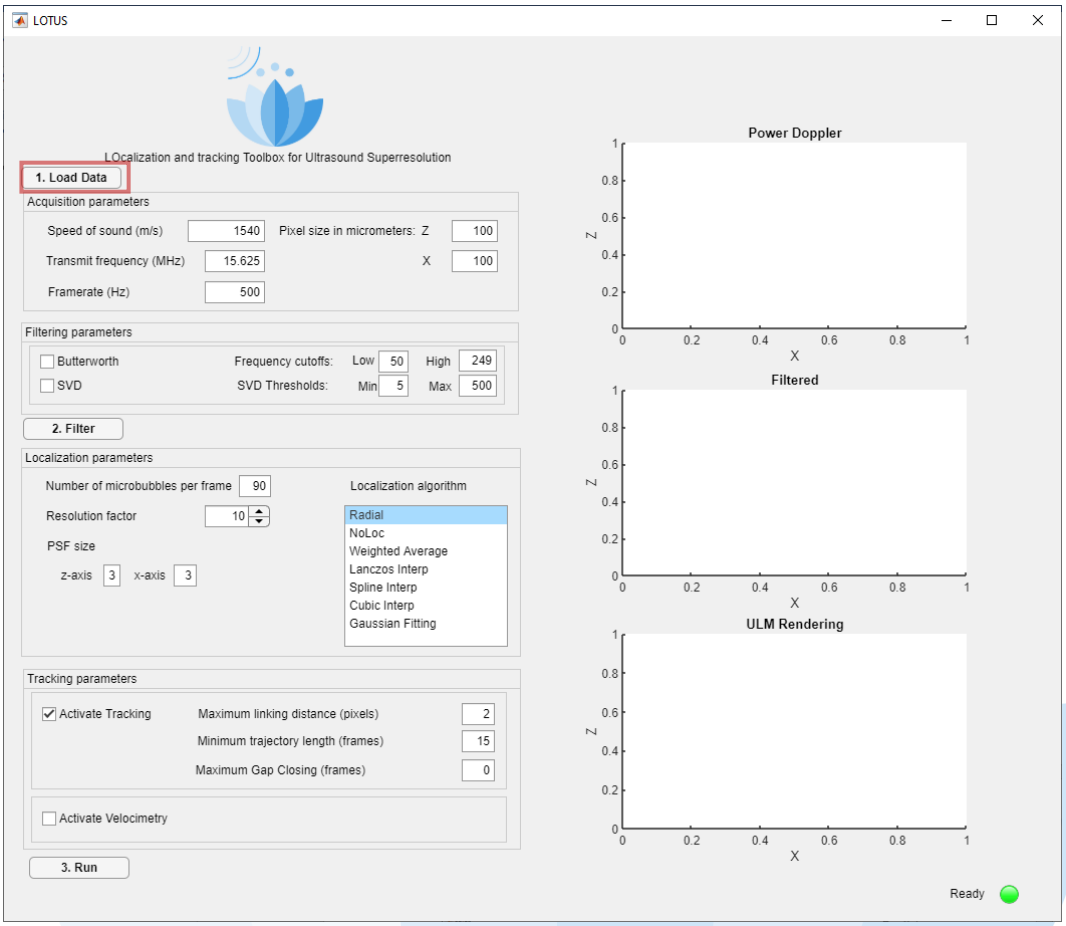
Disclaimer

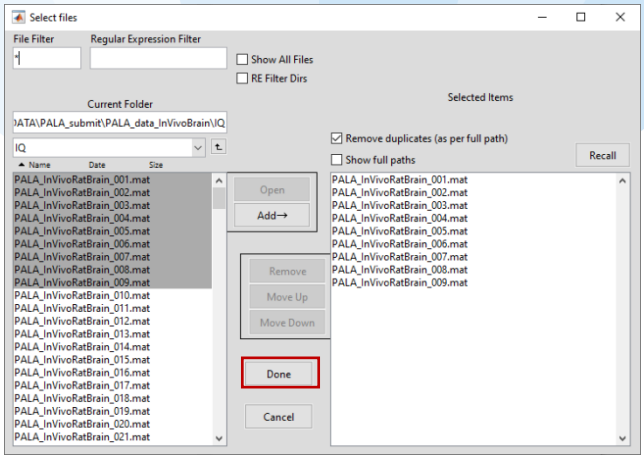
THIS SOFTWARE IS PROVIDED BY THE AUTHORS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE AUTHORS AND CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY,

OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

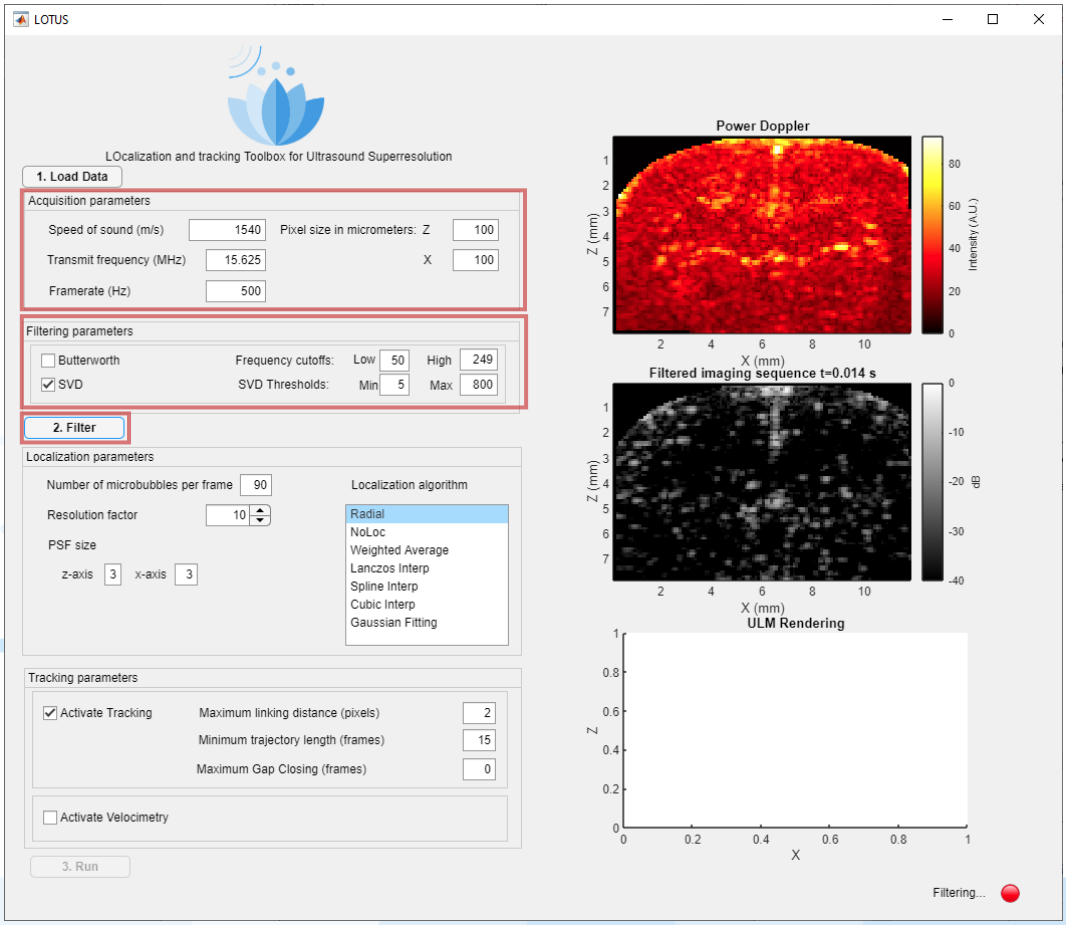
2. Open LOTUS and load data

Click on "Load Data" to import stacks of images. For .mat files, images must be stored in a variable *IQ(n_x, n_z, n_t)*. Pixel size must be provided in micrometers.





3. Select acquisition and filtering parameters



Acquisition parameters

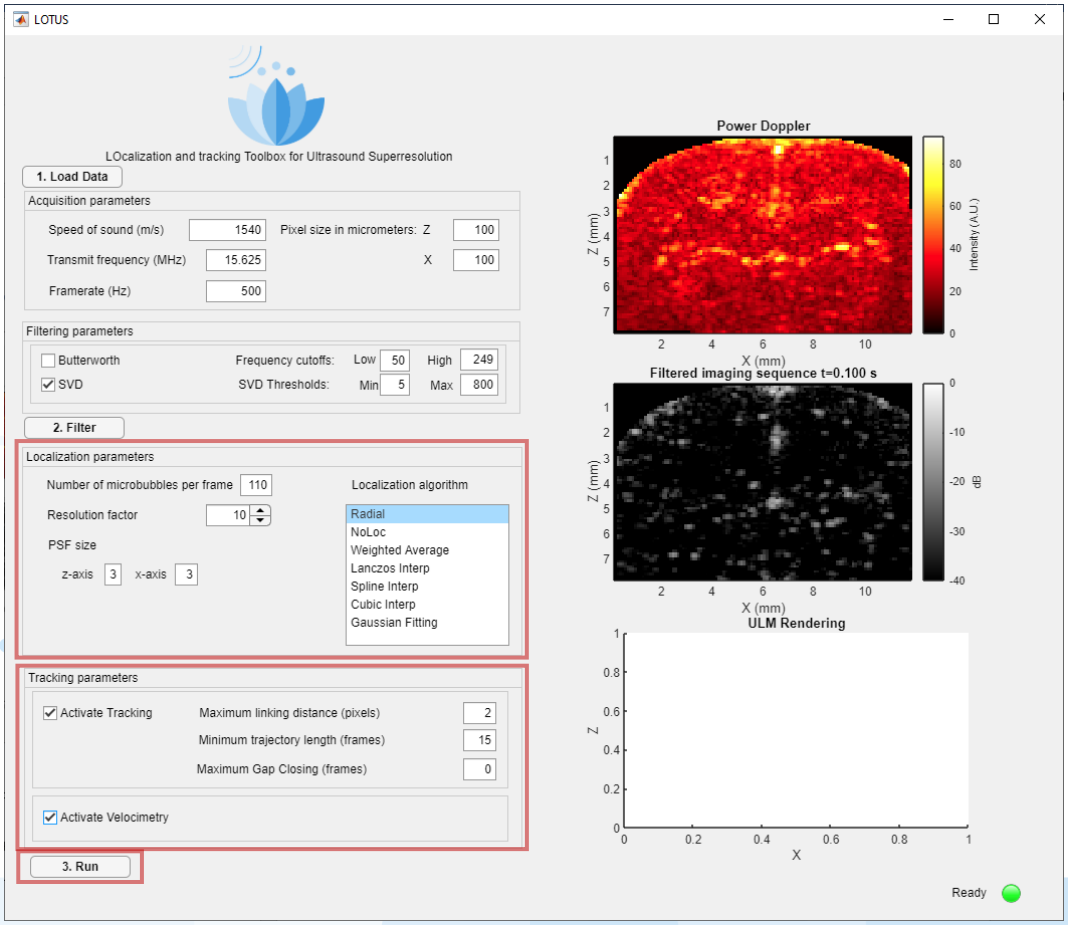
- Speed of sound: media speed of sound in meters per second
- Transmit frequency: in MHz, for wavelength estimation
- Framerate: compounded frame rate of the images fed to LOTUS in Hz
- Pixel size in micrometers: height [z] and width [x] of pixels in micrometers

Filtering parameters

- Singular Value Decomposition: adjust the minimum and maximum kept eigenvalues
- Butterworth: adjust the range of the bandpass filter in Hz

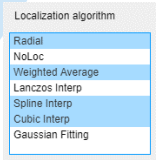
Note: You can click on “2. Filter” to visualize the result of the filtering in the middle figure. It is highly recommended to try a few parameters and then run the entire algorithm to avoid unnecessary calculations.

4. Select localization and tracking parameters



Localization parameters:

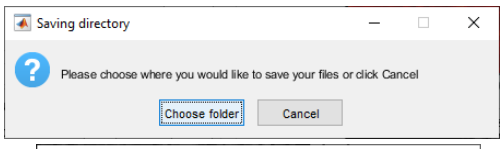
- Number of microbubbles per frame: estimated number of microbubbles in a unique frame
- Resolution factor: the resolution factor determines by how much the original pixel size in micrometers will be multiplied by (ex: an original 100x100 micrometers pixel size with a resolution factor of 10 will result in a final image with a pixel size of 10x10 micrometers)
- PSF size: the estimated size of the microbubbles in pixel
- Localization algorithm: select one or multiple localization kernels



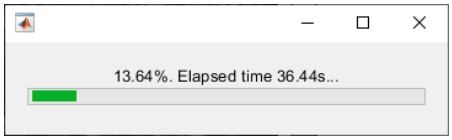
Tracking parameters

- Maximum linking distance: the maximal distance between two microbubbles that can be paired in pixels
- Minimum trajectory length: minimum length of a trajectory to be kept in frames
- Maximum Gap Closing: allowed gap between frames to link microbubbles together

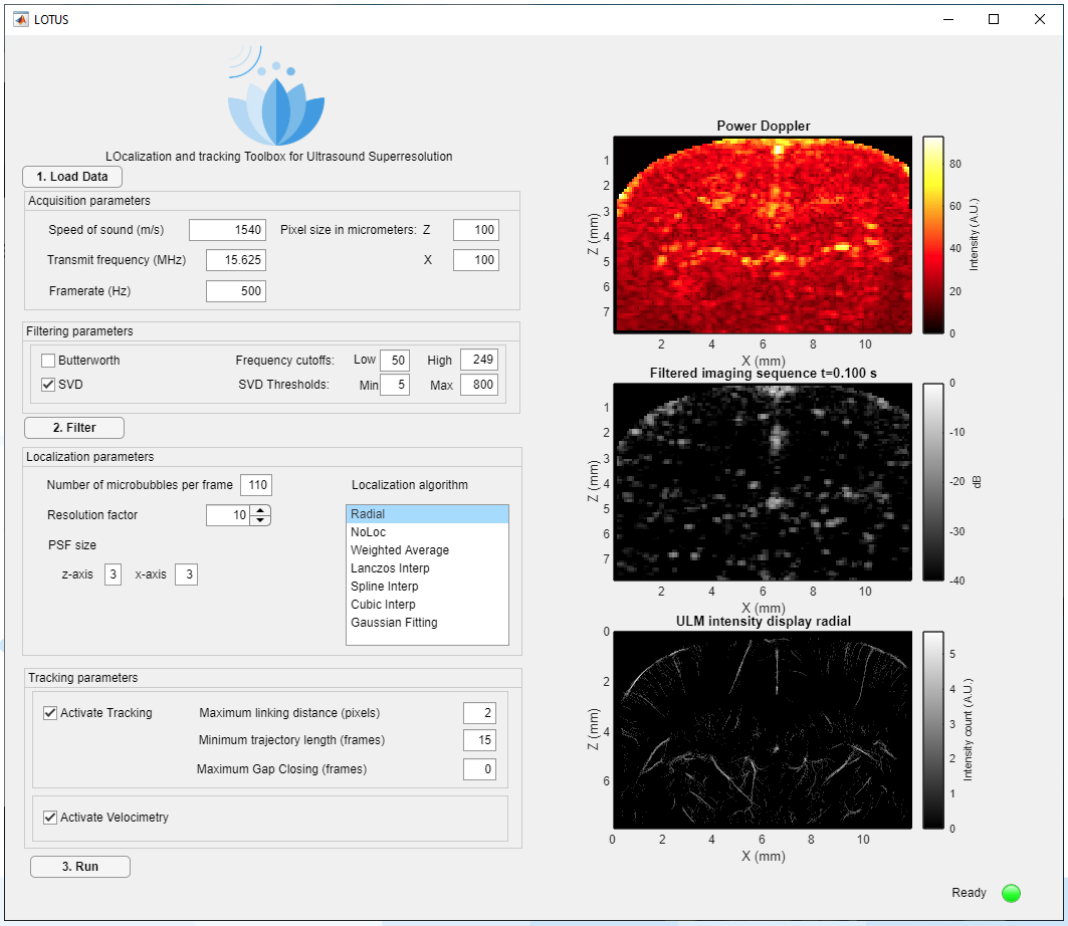
Press "Run" to launch LOTUS. You will be asked to select a saving directory.



LOTUS will then start ULM processing.



5. Display results

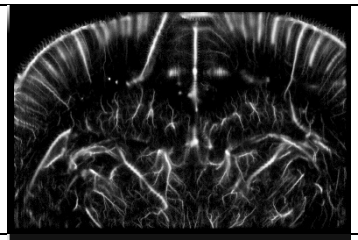
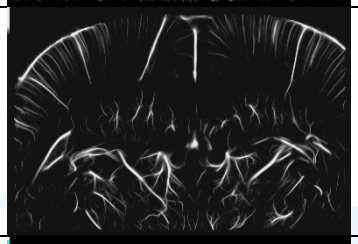
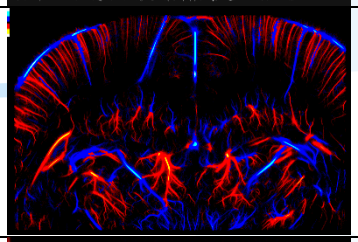
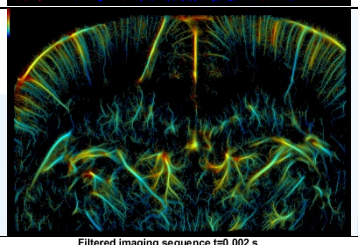
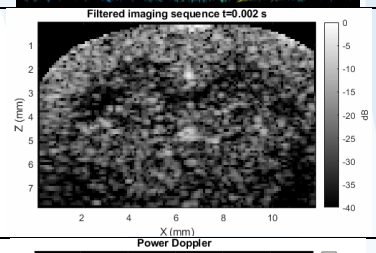
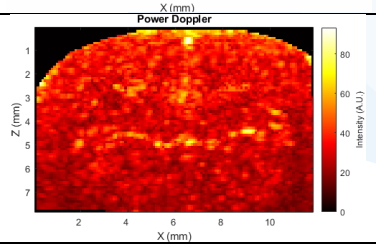


When the processing ends, the intensity rendering is displayed in the GUI.

Additional renderings are directly saved in the saving directory given that one was chosen.

6. Saved files

LOTUS software provides different rendering based on intensity, velocity, and direction of microbubbles' trajectories, saved in the saving directory.

	***LOTUS_MatrixLoc_xxxx_locAlgo.tif*** Intensity rendering with localization of microbubbles
	***LOTUS_MatrixTrack_xxx_locAlgo.tif*** Intensity rendering with tracking of microbubbles and interpolation of trajectories
	***LOTUS_MatrixZdir_xxxx_locAlgo.tif*** Intensity rendering with upward trajectories in red, and downward trajectories in blue
	***LOTUS_MatrixVeLNORM_xxxx_locAlgo.tif*** Velocity rendering with average velocity norm
	***LOTUS_filtered_xxxx.gif*** Movie of the filtered images
	***LOTUS_PDoppler_xxxx.tif*** Power Doppler extracted from the filtered images

Raw data (localization, tracks, and rendering matrices) are saved in MatLab files.