# *iCorrVision-3D*

# Software

V 1.04.22

## User Guide

2022

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iCorrVision-3D

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**About us**

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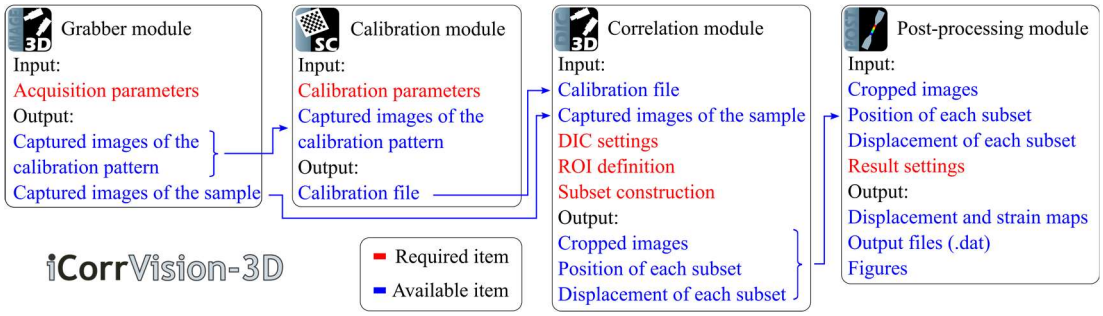
**Project workflow**




**Installation**

To use the software, a virtual environment (venv) should be created using python 3.8 and the libraries inside the *requirements.txt* file. Then, the software can be used directly from the command window or from the Integrated Development Environment (IDE). Find below the list of requirements:

- python 3.8
- filetype 1.0.7
- matplotlib 3.4.2
- scipy 1.6.3
- shapely 1.7.1
- numpy 1.21.0
- opencv-python 4.5.2.54
- pillow 8.2.0
- pip-chill 1.0.1
- pypylon 1.7.2

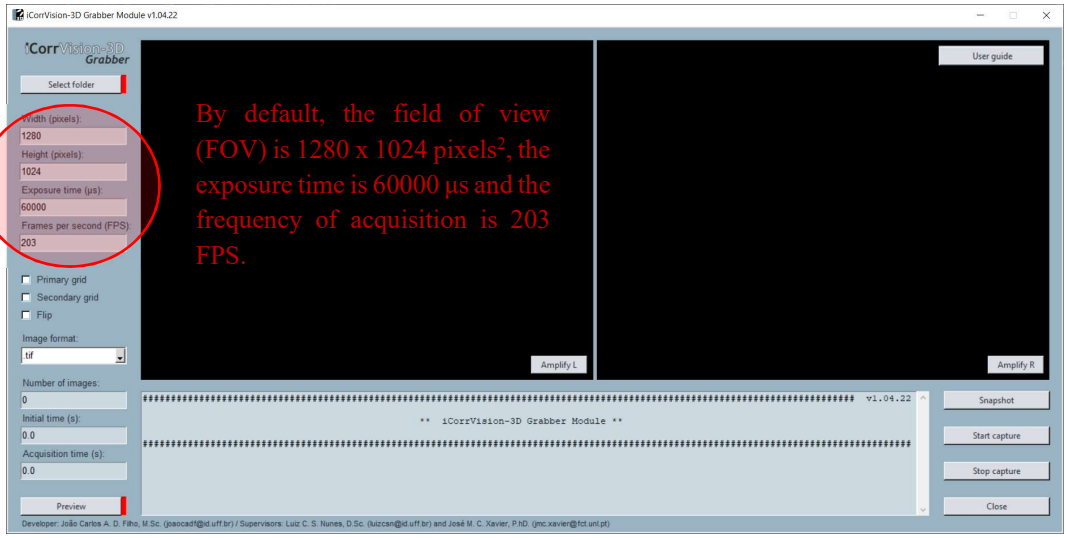
To overcome installation issues, *.exe* files were created for the Windows users. Find the compacted file (.zip) and uncompact it to any directory on your computer. Then, right-click the *.exe* file and crate a shortcut.

## 1. *iCorrVision-3D Grabber* Module

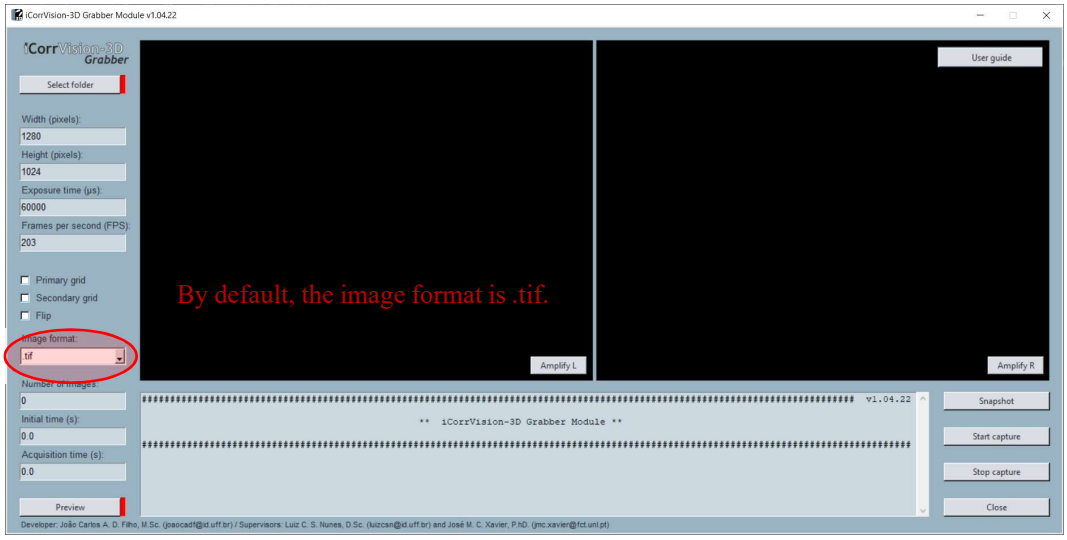
The ***iCorrVision-3D Grabber*** **Module** is responsible for the acquisition of stereo images using two cameras. Here, the **LEFT** (L) camera is denominated **MASTER** camera and the **RIGHT** (L) camera is the **SLAVE** camera. It should be highlighted that the **pypylon** library was used to perform the communication between the hardware (cameras manufactured by *Basler*) and software. NOTE: For other manufacturers, please adjust the code properly.


i. Press the **Select folder** button to select the directory were the stereo pairs will be recorded. In the selected folder, the software automatically crates the **Left** and **Right** folders.

ii. Adjust the acquisition parameters, such as **Width** in pixels, **Height** in pixels, **Exposure time** in µs and **Frames per second** (FPS). NOTE: The parameters are dependent on the camera model used to acquire the images.



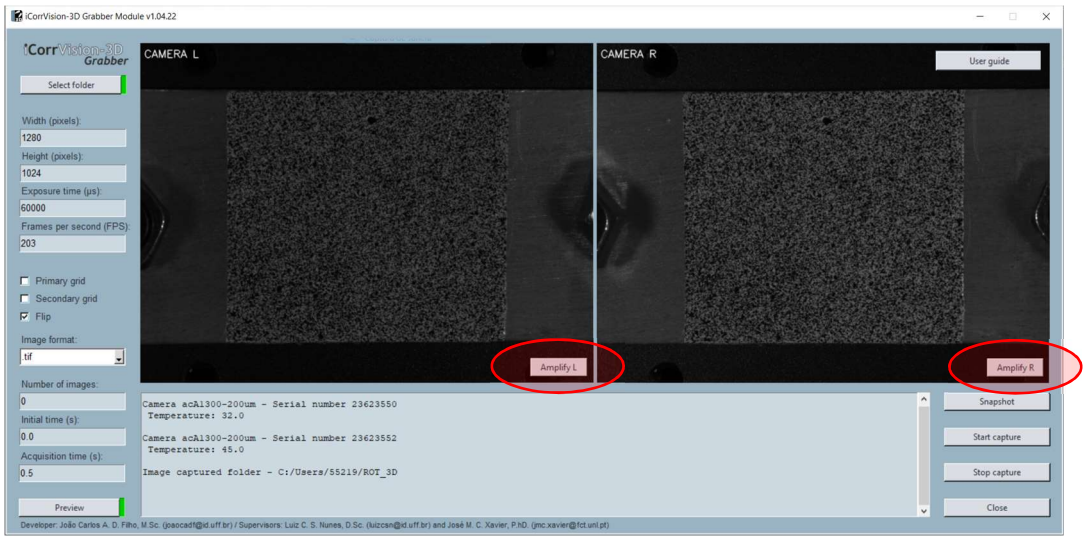

iii. Select the image format between **.bmp**, **.tif**, **.jpg** and **.png**.



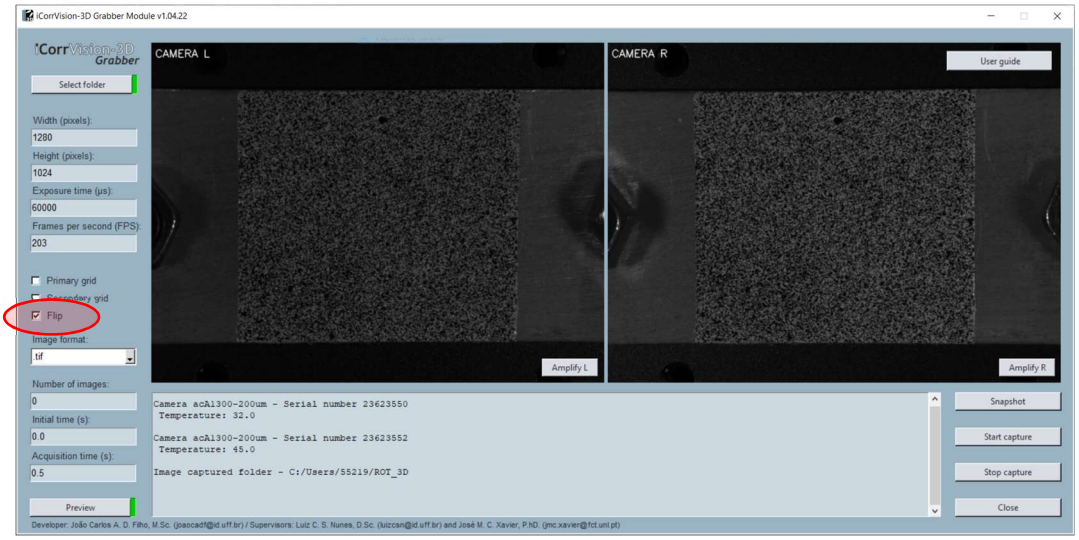

iv. Adjust the grabber parameters, such as **Number of images**, **Initial time** in seconds and **Acquisition time** in seconds.

v. Press the **Preview** button to load the cameras and display the images.

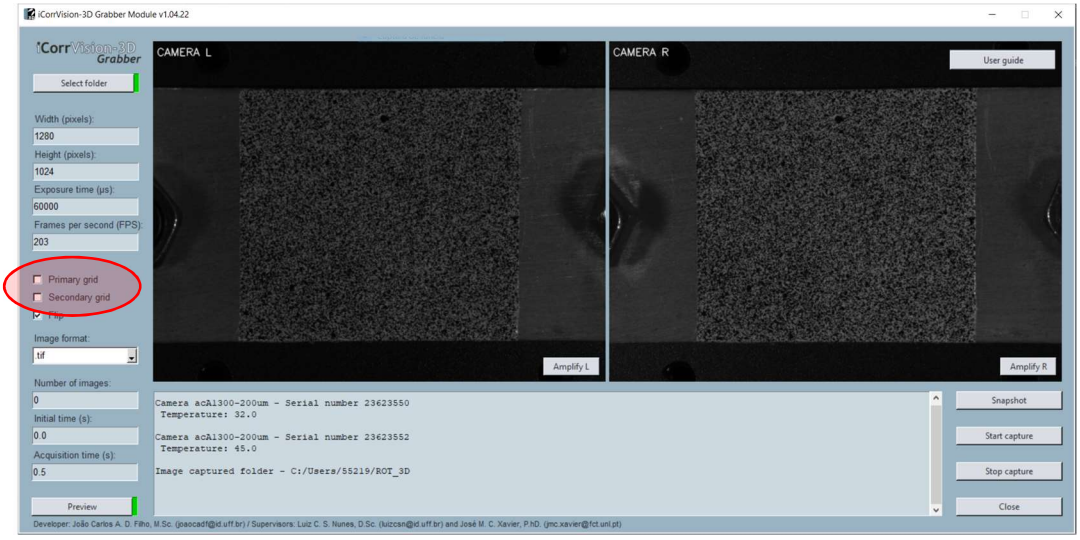

vi. The user can amplify the **LEFT** and **RIGHT** images pressing the **Amplify L** and **Amplify R** buttons, respectively.



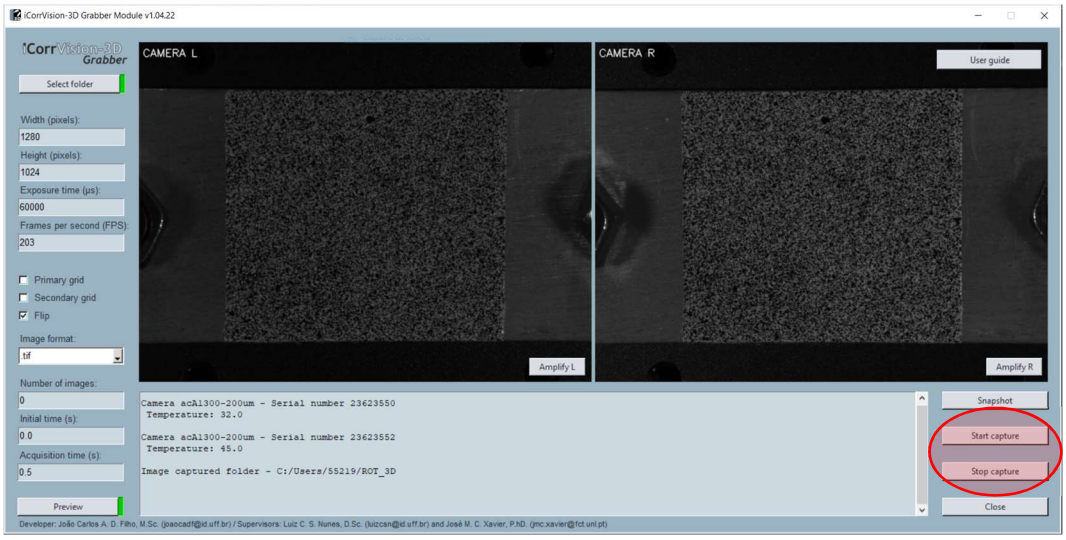

vii. The user can switch between the **LEFT** and **RIGHT** cameras selecting the **Flip** checkbox.



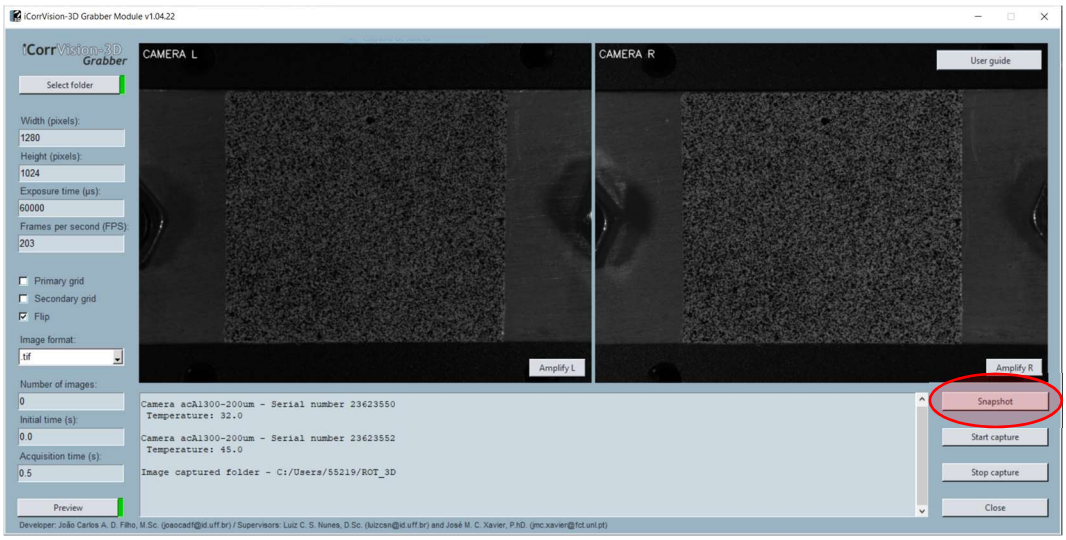
viii. The user can add gridlines to assist the positioning of the camera-lens optical system selecting the **Primary grid** or **Secondary grid** checkboxes.



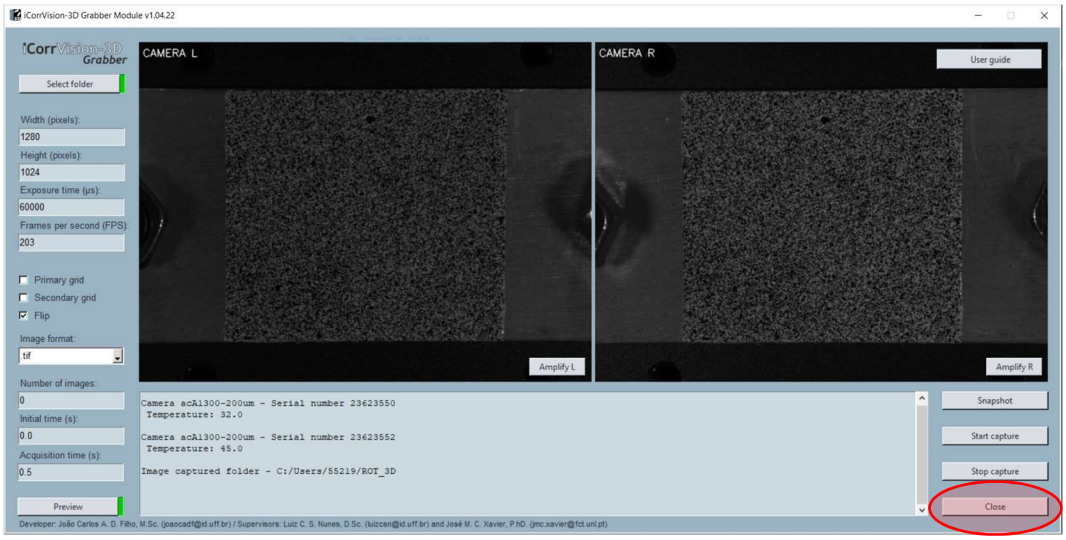

ix. Press **Start capture** button to initialize the stereo acquisition. Then, press **Stop capture** to abort the stereo acquisition. NOTE: Change the directory after the image capture!




x. If the user wat to capture single snapshots, the button **Snapshot** can be used. NOTE: Change the directory after the image capture!



xi. Press **Close** button to close the ***iCorrVision-3D Grabber*** **Module**.

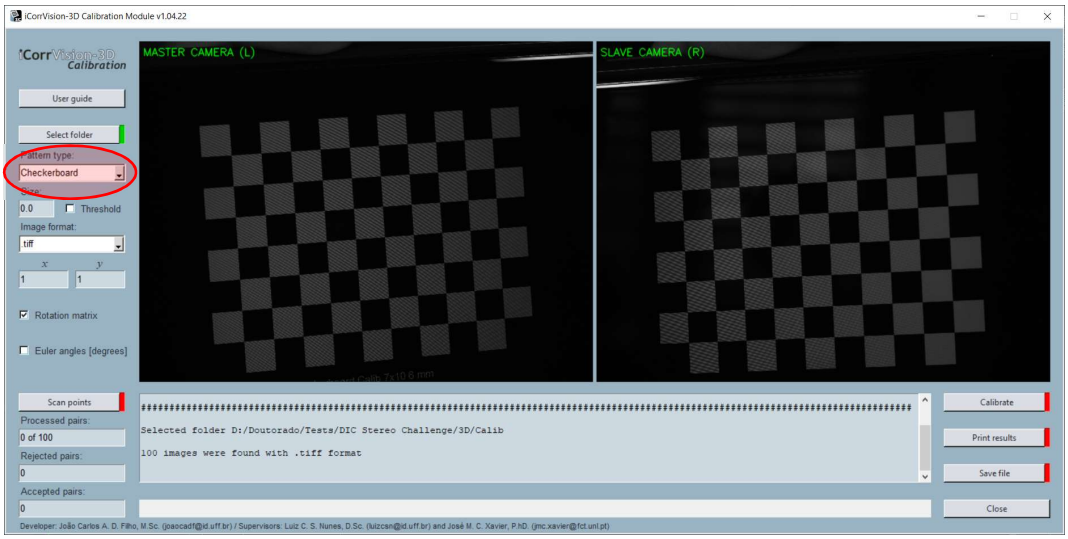



## 2. *iCorrVision-3D Calibration* Module

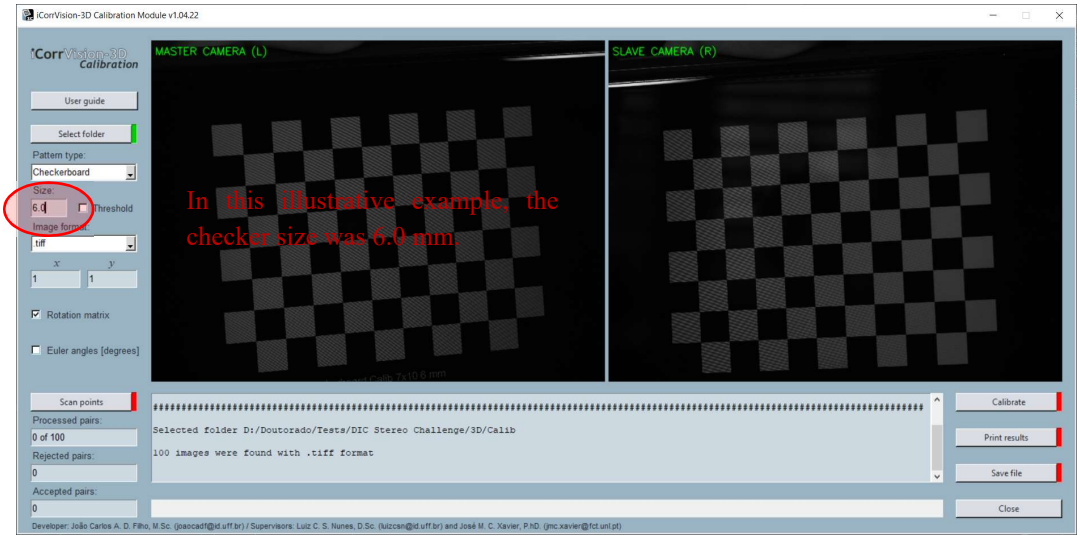
From the ***iCorrVision-3D Calibration*** **Module**, the calibration file can be obtained. Here, the intrinsic and extrinsic parameters of the camera-lens optical system can be encountered. It should be highlighted that the **opencv** library was used to perform the calibration using the Zhang method.

i. Press the **Select folder** button to select the directory were the stereo calibration images were recorded. The selected directory must contain **Left** and **Right** folders.

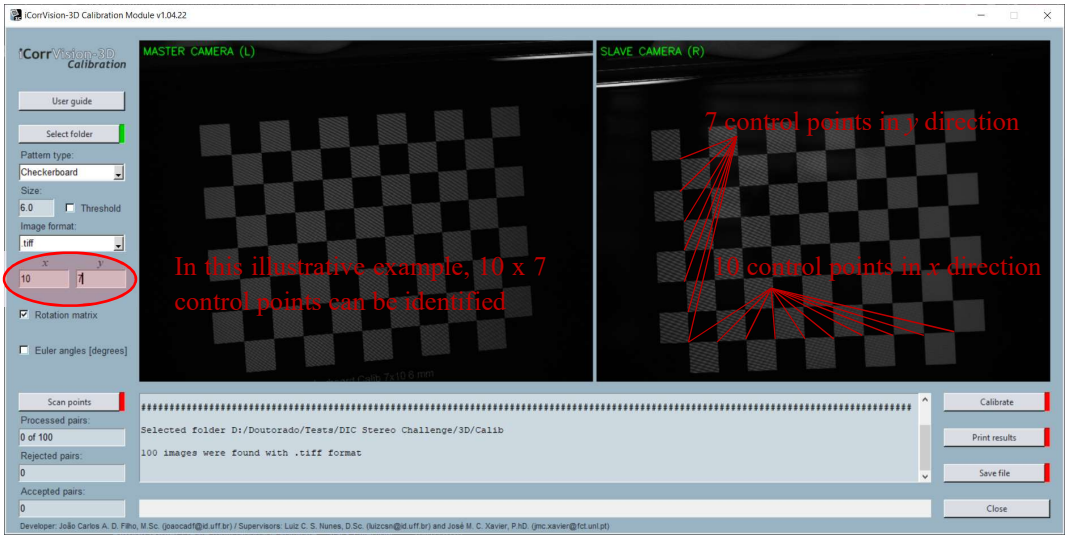

ii. Select the calibration pattern used to perform the calibration of the camera-lens system. NOTE: In this version only the checkerboard type is available!



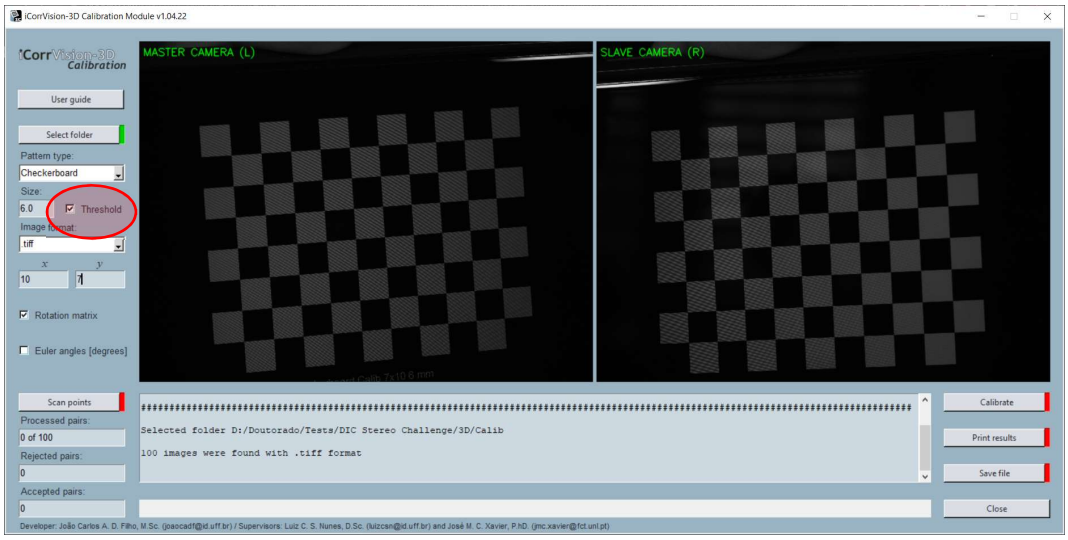

iii. Inform the size of the checker (distance between 2 vertices).



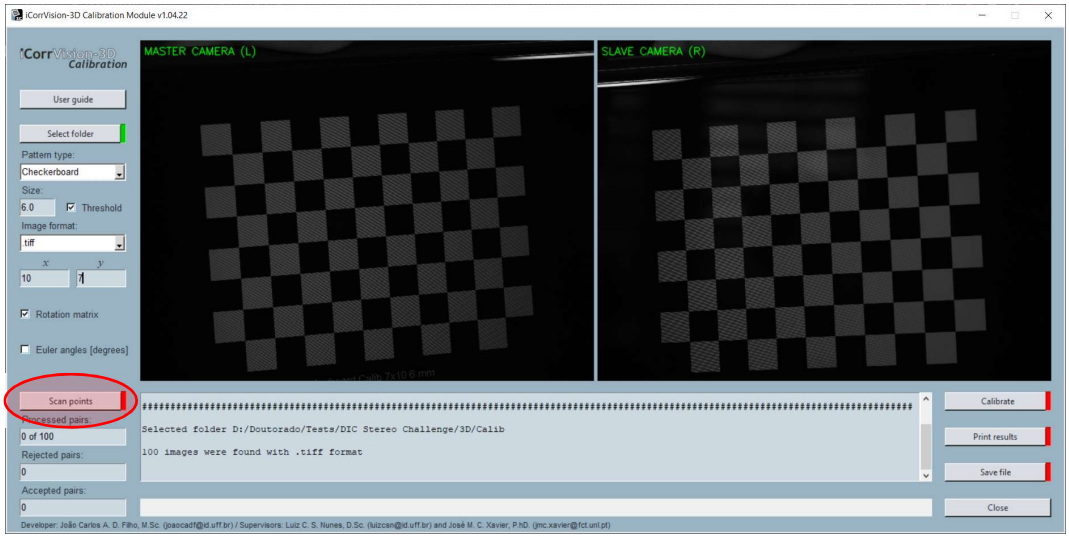
iv. Inform the number of control points in *x* and *y* directions.

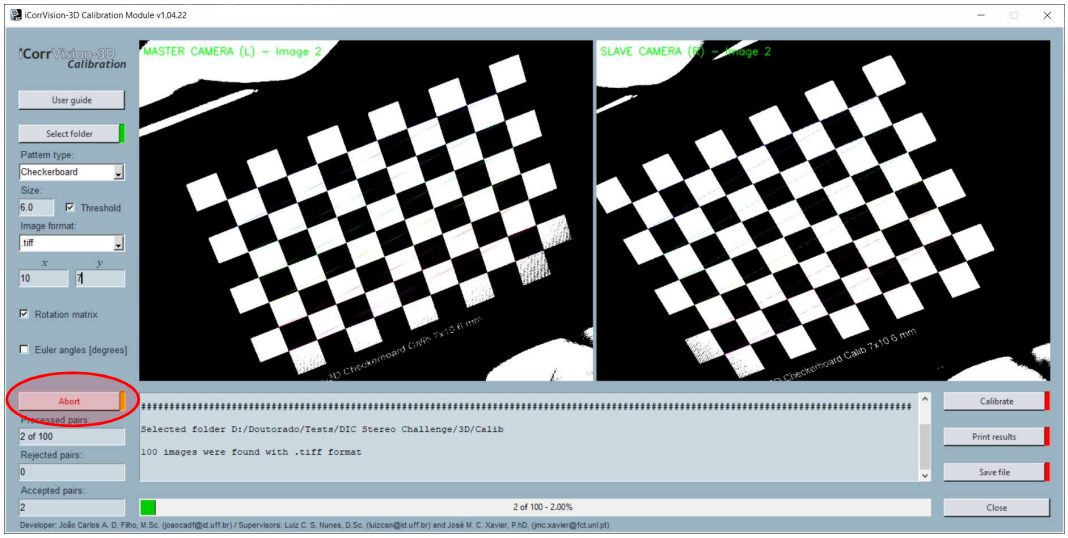


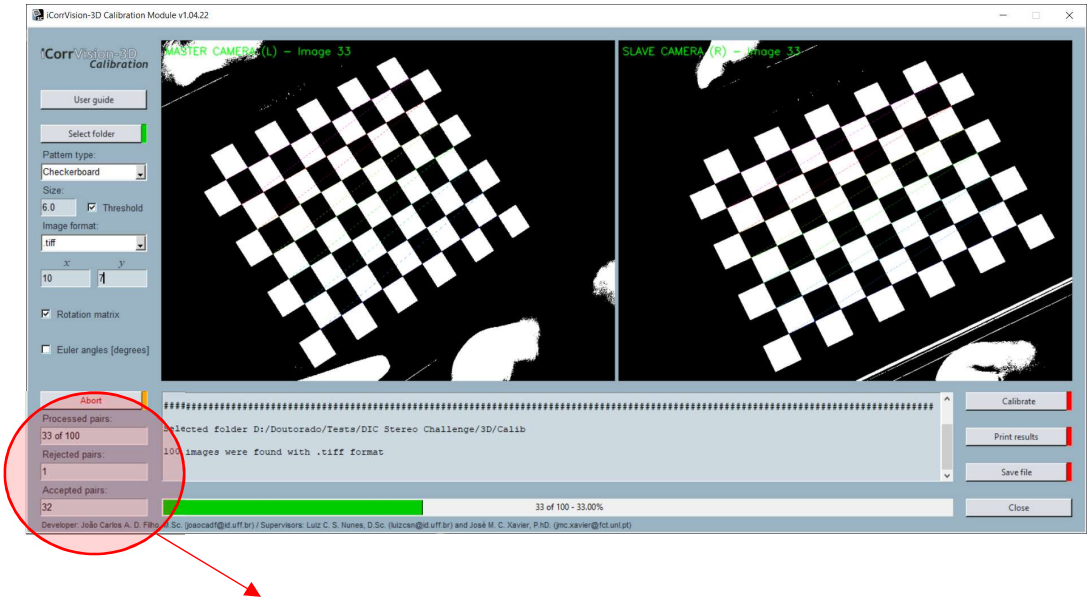

v. If necessary, the **Threshold** checkbox can be used to implement an adaptative image threshold on the captured images.




vi. Press the **Scan points** button to start the detection of points in the captured images. The user can abort the detection pressing the **Abort** button. NOTE: The software can reject or accept the processed pairs.

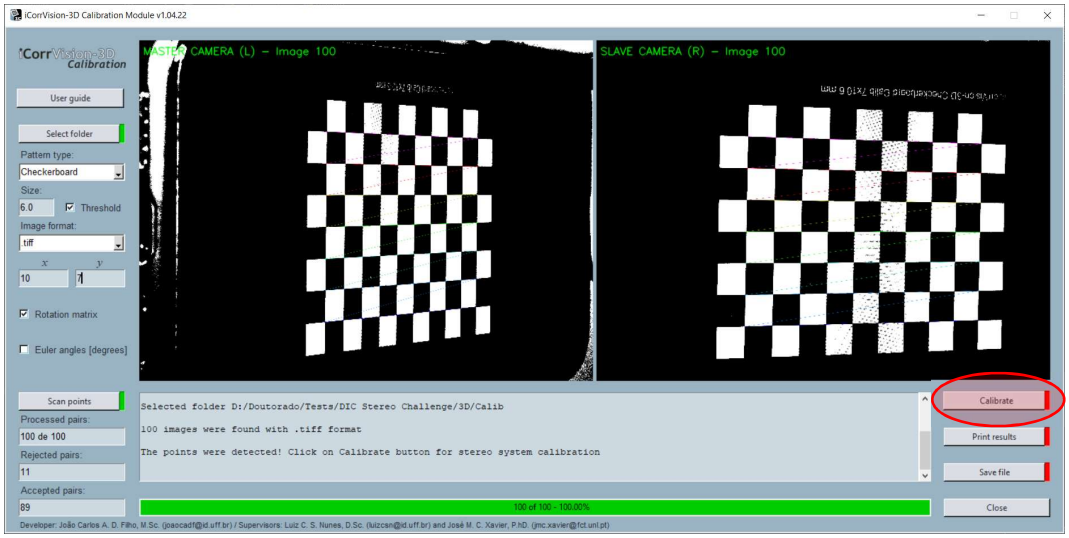




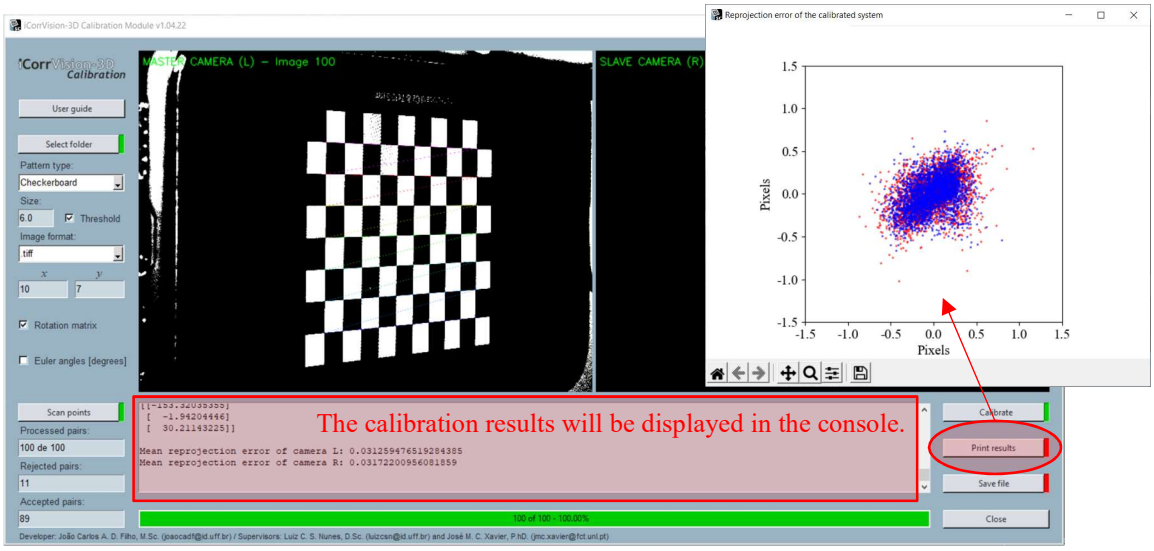




Processed, rejected and accepted pairs

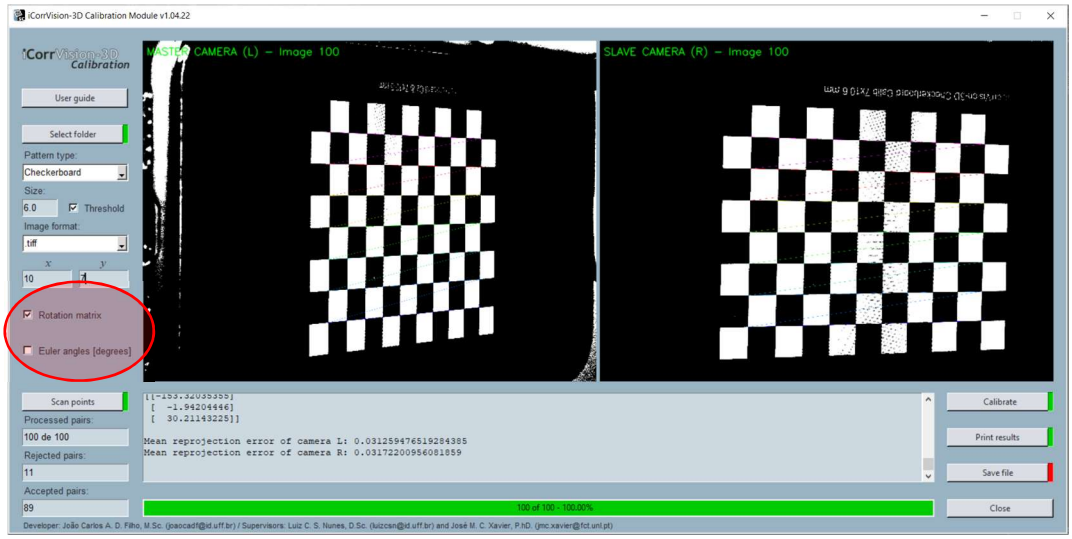
vii. After the detection of the control points, press the **Calibrate** button to start the calibration of the optical stereo system.



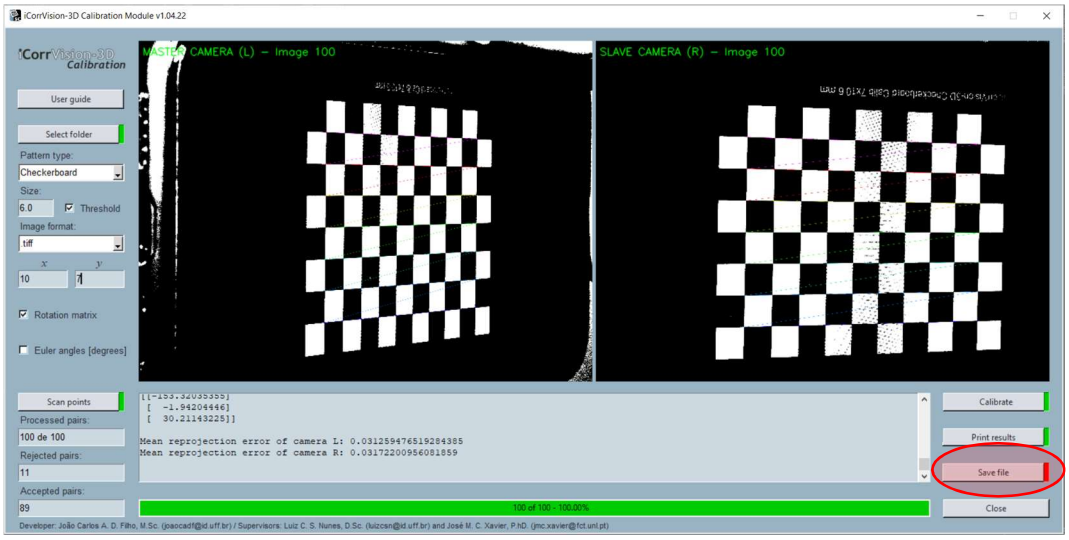
viii. After calibration, the user can press the **Print results** button to visualize the reprojection error. A new window will pop up with the reprojection error results.



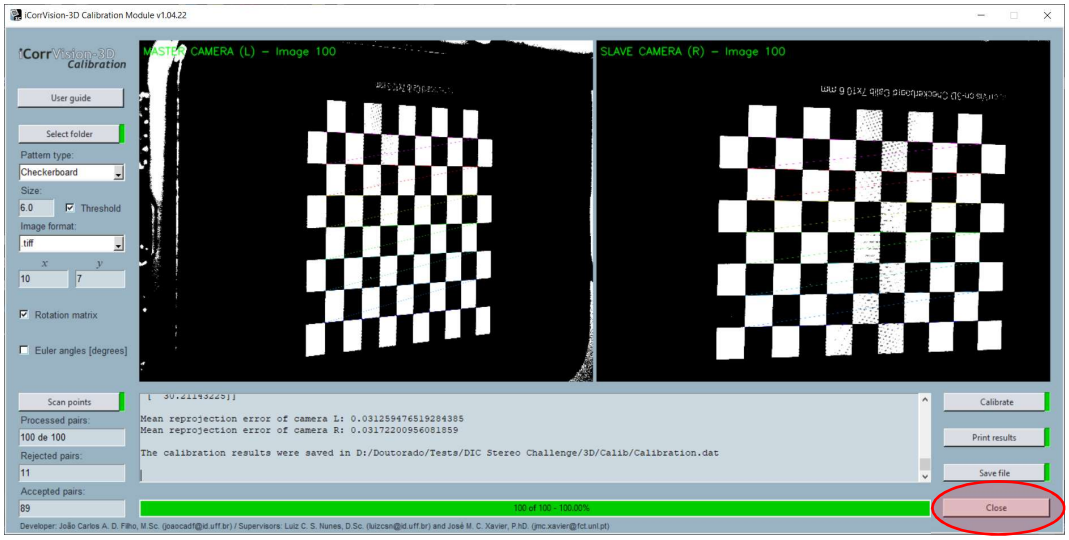

ix. In the calibration file, the user can choose between the **rotation matrix** or **Euler angles**. This functionality is important to maintain the communication between other Digital Image Correlation softwares.



x. Press the **Save file** button to save the calibration file.

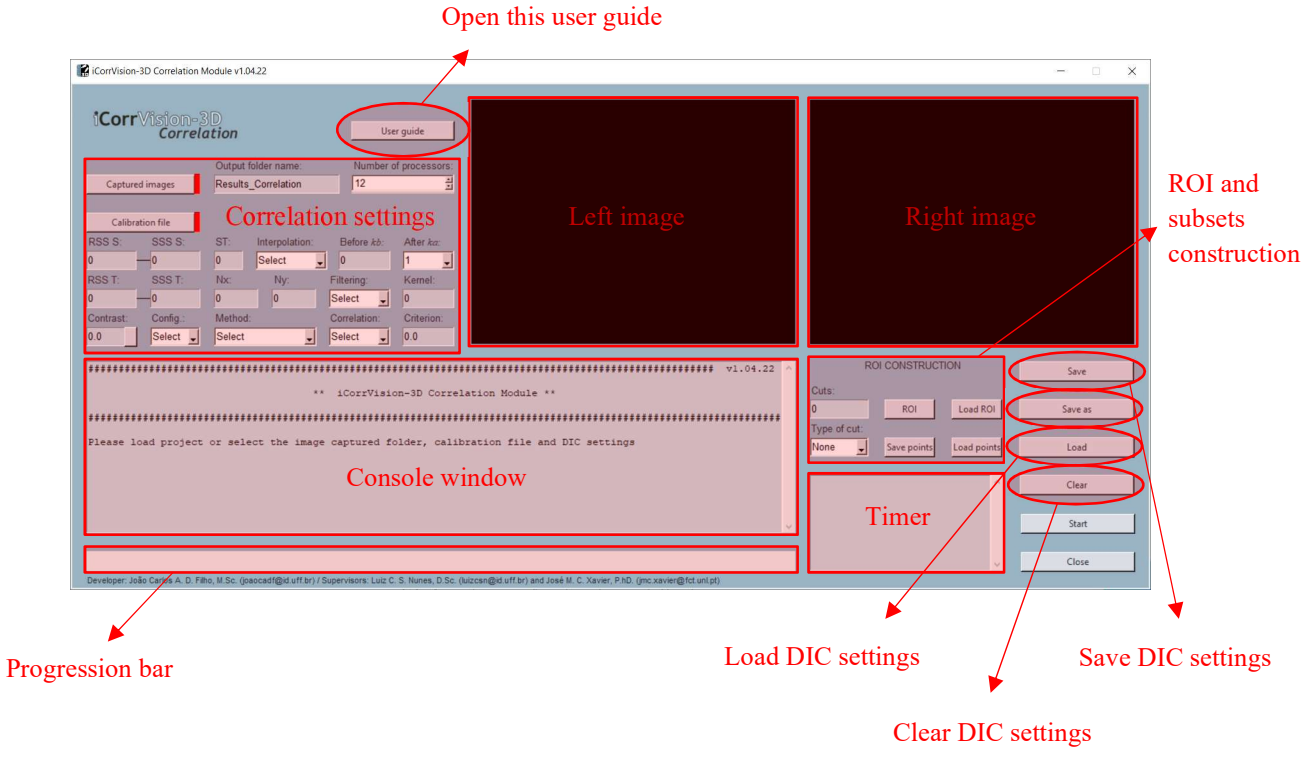


xi. Press **Close** button to close the ***iCorrVision-3D Calibration*** **Module**.

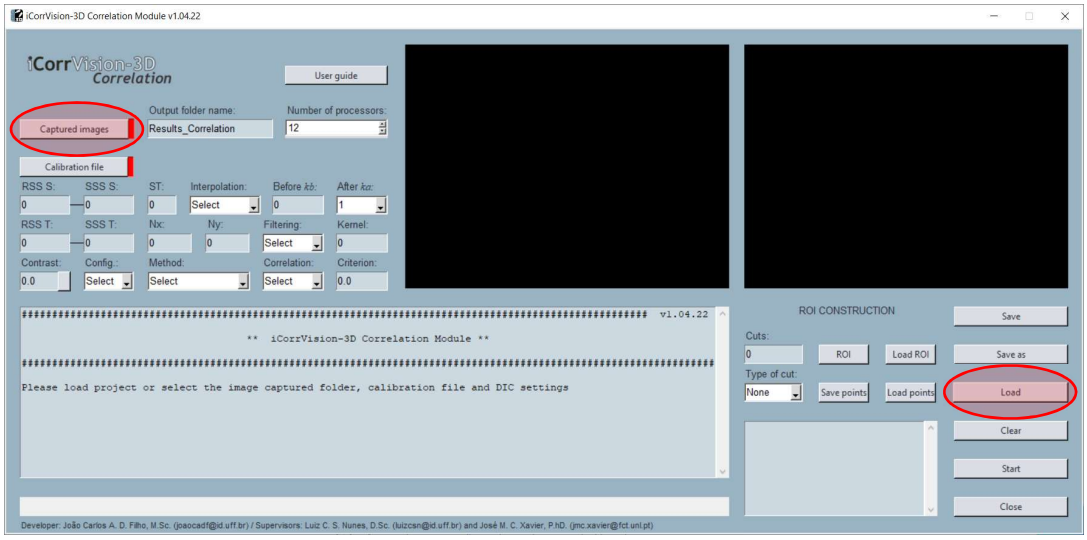



## 3. *iCorrVision-3D Correlation* Module

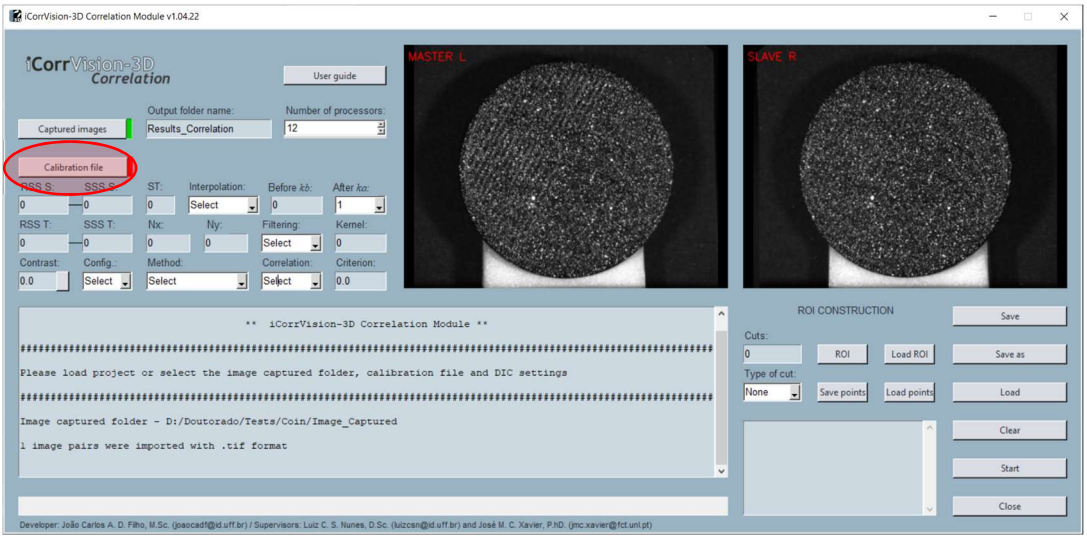
The stereo correlation can be carried out using the ***iCorrVision-3D Correlation*** **Module**. In the following sections, the workflow of the ***iCorrVision-3D Correlation*** **Module** will be addressed.



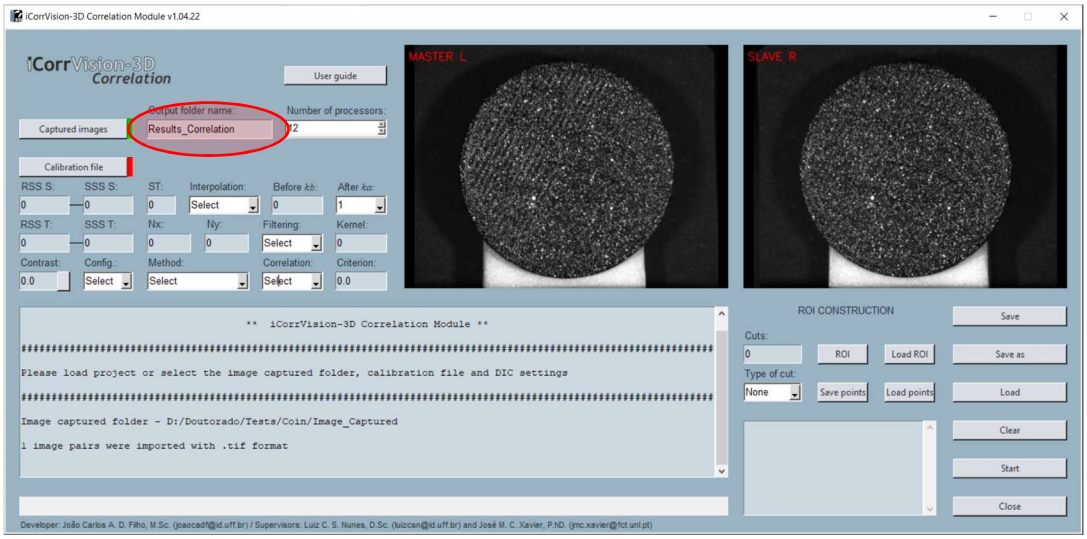
i. Press the **Load** button to select the **.dat** file generated by a previous DIC study and go to step **(v)**. Check if the green indicators appeared next to the **Captured images** and **Calibration file** buttons and if all DIC parameters were automatically filled. If the user is attempting to perform a new DIC project, press the **Captured image** button to load all captured images. Make sure that the folders **Left** and **Right** are inside the **Captured_Image** folder. The ***iCorrVision-3D Grabber*** **Module** can be used to acquire the images.




ii. Press the **Calibration file** button to select the calibration file. This file should be previously generated using ***iCorrVision-3D Calibration*** **Module**.



iii. The user can change the name of the output folder. The name **Results_Correlation** is placed by default.
NOTE: It should be clear that pressing the buttons Start or ROI will delete all files inside the output folder or overwrite them.




iv. Select the most appropriate DIC settings. Table 1 shows each DIC parameter and its descriptions.

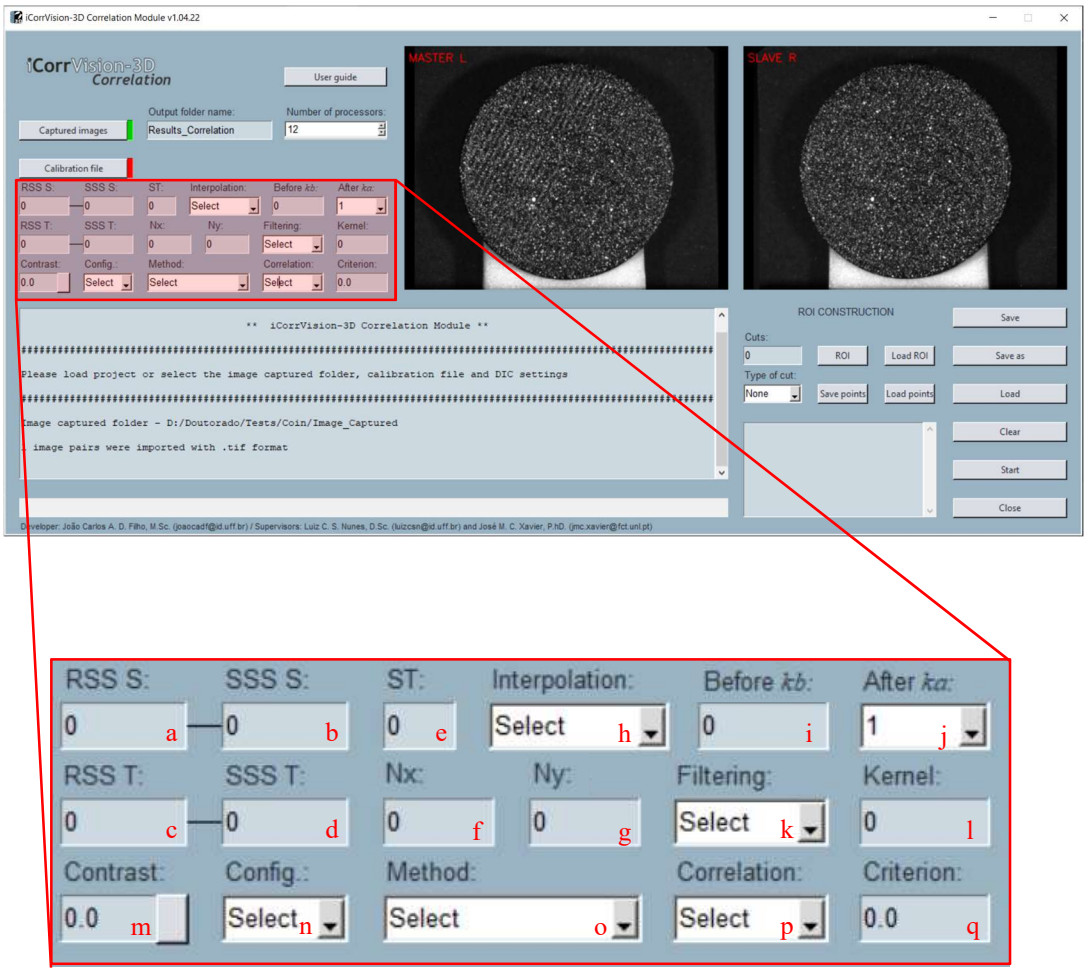
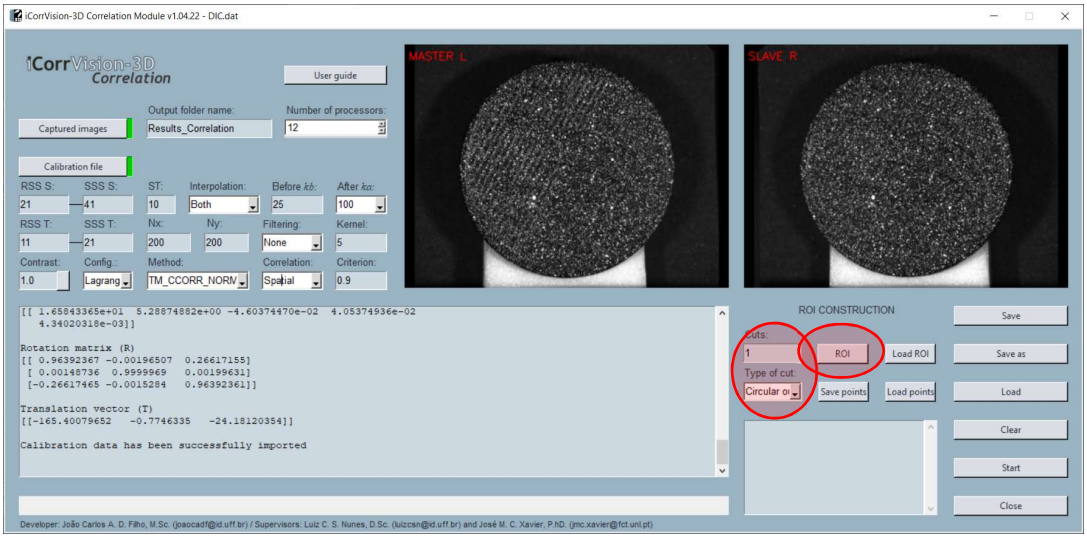


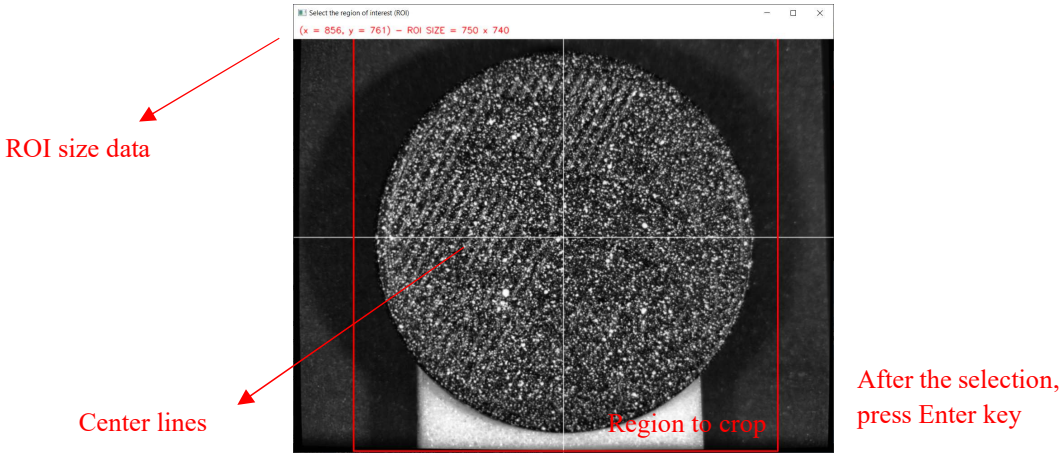
**Table 1.** Description of each DIC parameter available for modifications.

| Parameter | Description |
|---|---|
| RSS S [(a)] | Reference subset size in pixels for stereo correlation. It must be an odd integer. *Ex.: RSS S = 61* |
| SSS S [(b)] | Search subset size in pixels for stereo correlation. It must be an odd integer and greater than **RSS S**. *Ex.: SSS S = 201* |
| RSS T [(c)] | Reference subset size in pixels for temporal correlation. It must be an odd integer. *Ex.: RSS T = 21* |
| SSS T [(d)] | Search subset size in pixels for temporal correlation. It must be an odd integer and greater than **RSS T**. *Ex.: SSS T = 71* |
| ST [(e)] | Subset step in pixels. It must be an integer. This parameter should be used to automatically calculate the **Nx** and **Ny** parameters according to the step size between each DIC calculation point. If ST = 0, the parameters **Nx** and **Ny** must be modified to a value different from 0. *Ex.: ST = 10* |
| Nx [(f)] | Number of steps in x direction. Leave Nx = 0 to automatically calculate the number of elements in x direction according to the value of the subset step (**ST**). It must be an integer. *Ex.: Nx = 20* |
| Ny [(g)] | Number of steps in y direction. Leave Ny = 0 to automatically calculate the number of elements in y direction according to the value of the subset step (**ST**). It must be an integer. *Ex.: Ny = 100* |
| Interpolation [(h)] | Interpolation strategy. It can be selected the interpolation **Before** correlation, **After** correlation or using **Both** strategies. The interpolation is important to reach subpixel values. *Ex.: Interpolation = Both* |
| Before *kb* [(i)] | Interpolation factor. This factor is used to resize the captured images adding subpixel values using bicubic spline interpolator. Care must be taken when selecting the most appropriate interpolation factor since the computational time can be compromised. *Ex.:* $k_b = 25$ |
| After *ka* [(j)] | Interpolation factor. This factor is used to interpolate the correlation matrix adding subpixel values using bicubic spline interpolator. Care must be taken when selecting the most appropriate interpolation factor since the computational time can be compromised. *Ex.:* $k_a = 25$ |
| Filtering [(k)] | Displacement filtering. It can be selected between **None** and **Gaussian** filters. It should be used to smooth displacement full-fields after the correlation. *Ex.: Filtering = Gaussian* |
| Kernel [(l)] | Kernel size in pixels to compute the displacement filtering. It must be an odd integer. *Ex.: Kernel = 5* |
| Contrast [(m)] | Contrast adjustment. It should be used to adjust the image contrast using real values between 0 and 1. Press the button on the right to visualize the contrast adjustment on the captured images. *Ex.: Contrast = 0.2* |
| Config. [(n)] | Configuration. It can be selected between **Eulerian** and **Lagrangian** configurations. *Ex.: Configuration = Lagrangian* |
| Method [(o)] | Correlation function. It can be selected between different correlation functions available in the **opencv** library. *Ex.: Method = TM_CCORR_NORMED* |
| Correlation [(p)] | Correlation technique. It can be selected between **Spatial** and **Incremental** approaches. *Ex.: Correlation = Incremental* |
| Criterion [(q)] | Correlation criterion. The user can select the criterion to be implemented using real values between 0 and 1. Correlation is inexistent for Criterion = 0 and a perfect match is encountered when Criterion = 1. *Ex.: Criterion = 0.9* |

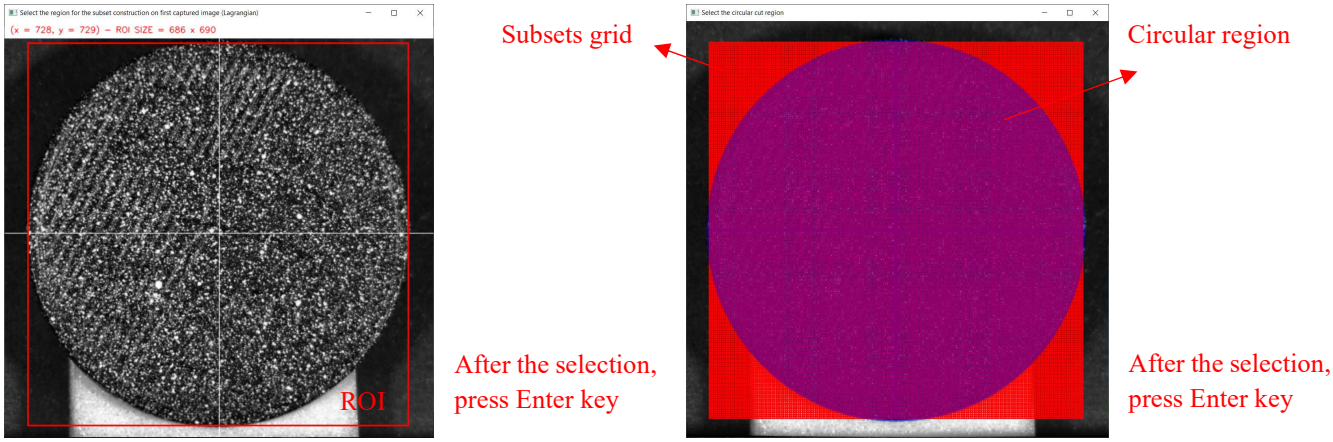
v. Use the interface to construct the Region of Interest (ROI) and the subsets. In the **Cuts** area, inform the number cutting regions and in the **Type of cut**, select the type of region. It can be selected between **Free**, **Rectangular**, **Circular inside** and **Circular outside** regions. Press the **ROI** button to start the ROI and subsets construction. A window will pop up in the screen. First, inform a **.dat** file to save the DIC settings. Then, a second window will pop up in the screen. Now, inform a **.dat** file to save the ROI construction. Use the **Load ROI** button to load a previous ROI construction file.



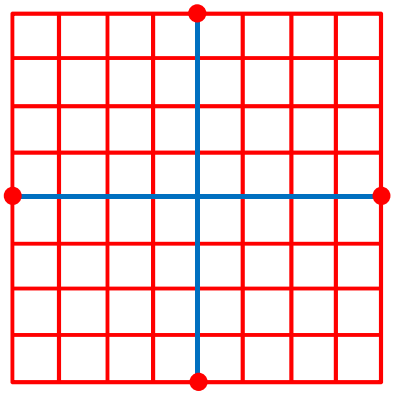

After saving the files, a new window will pop up. Select a region to crop all images. This region must contain the ROI that will be selected. This process will record the cropped images in the automatically created **Imgae_Selection** folder.



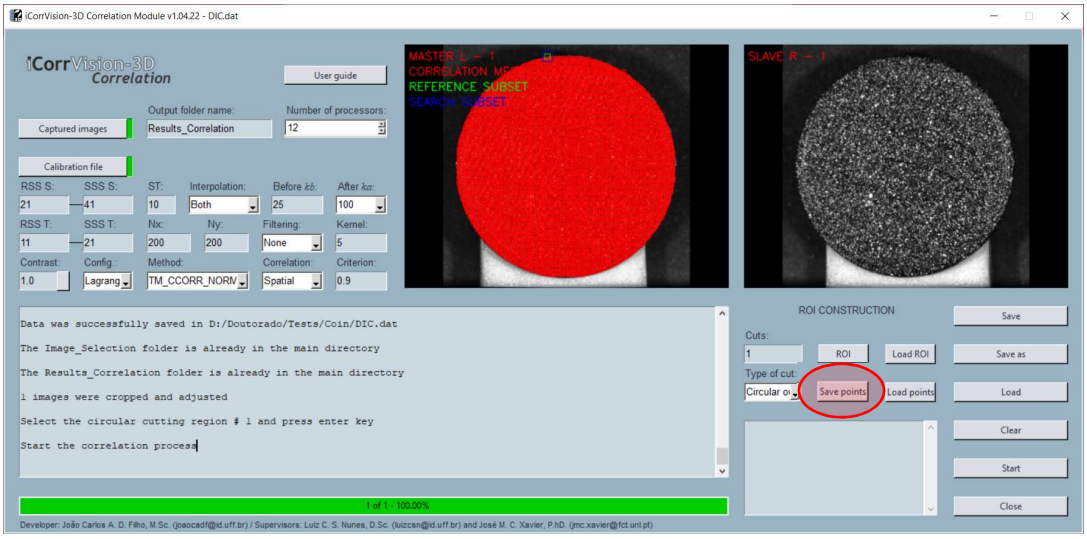

After the cropping process, a new window will pop up in the screen. Select the ROI to construct the subsets where the DIC will be computed. Since in this illustrative example 1 circular outside cutting region was selected, a new window will pop up in the screen where the user can select the circular region to use in the DIC analysis.



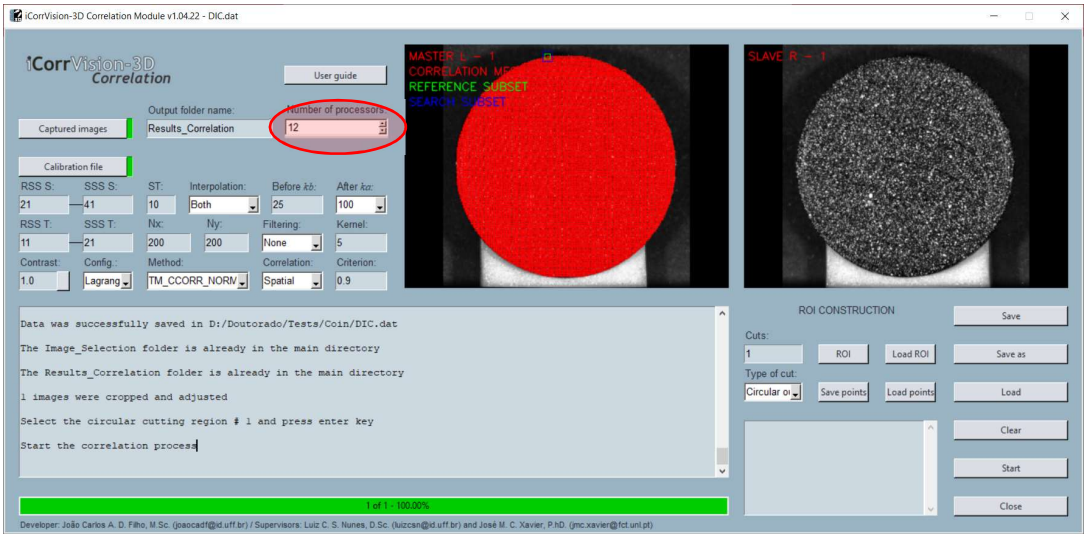
NOTE: Do not remove the depicted points. They are important to compute the rotation matrix and translation vector for referential transformation.



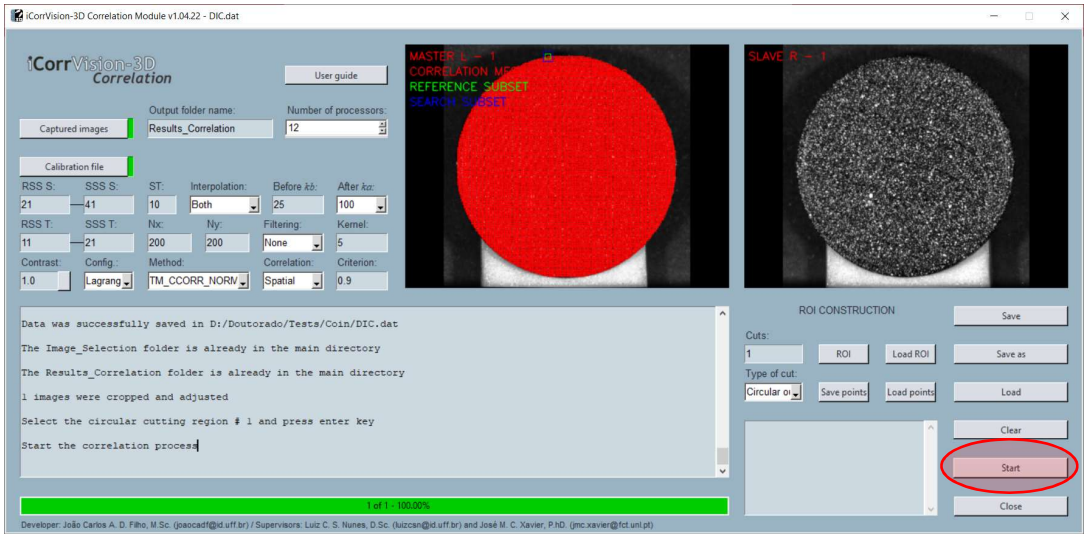
vi. The user can save the generated subset grid pressing the **Save points** button to indicate a directory where the subset grid files will be recorded. Therefore, the position of each subset points can now be used in other projects pressing the **Load points** button and then selecting the directory where the files were created.

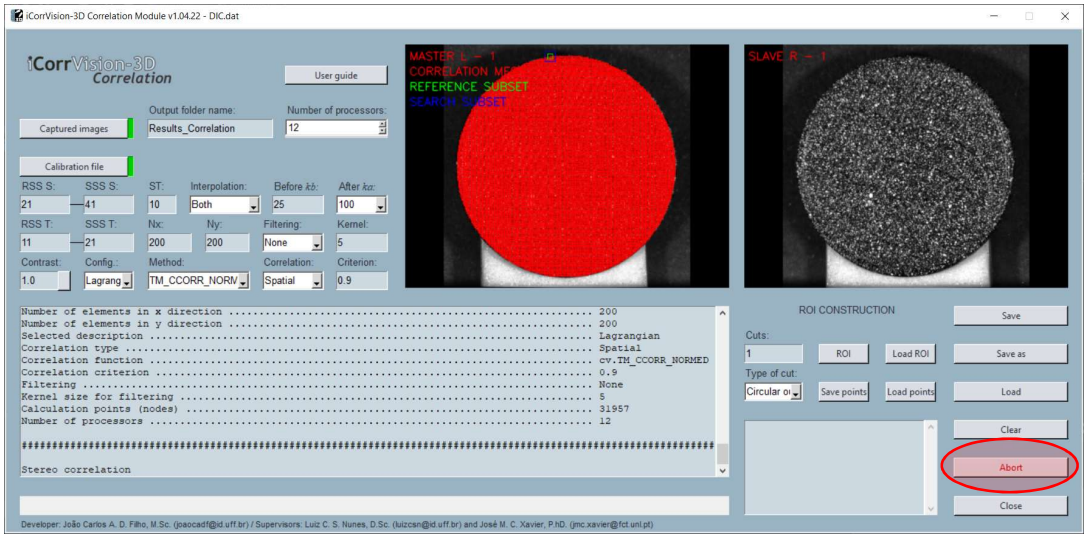



vii. The user can select the number of processors (threads) to be allocated in the DIC analysis. The software fills automatically the maximum number of processors available in the machine. NOTE: Care must be taken when selecting the number of processors, as the process can run out of RAM!

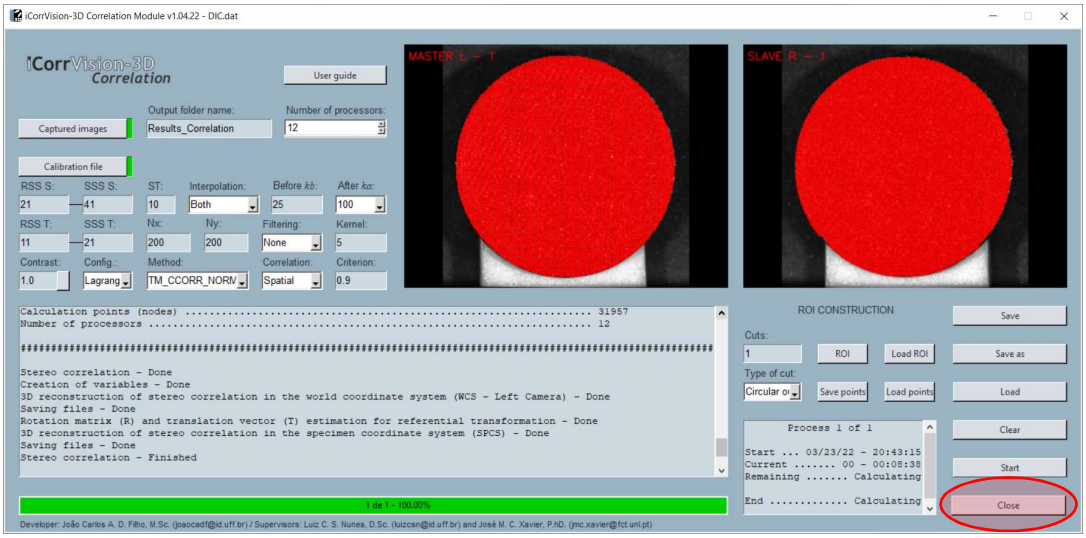


viii. Press the **Start** button to initialize the stereo correlation. The user can abort the correlation pressing the **Abort** button.



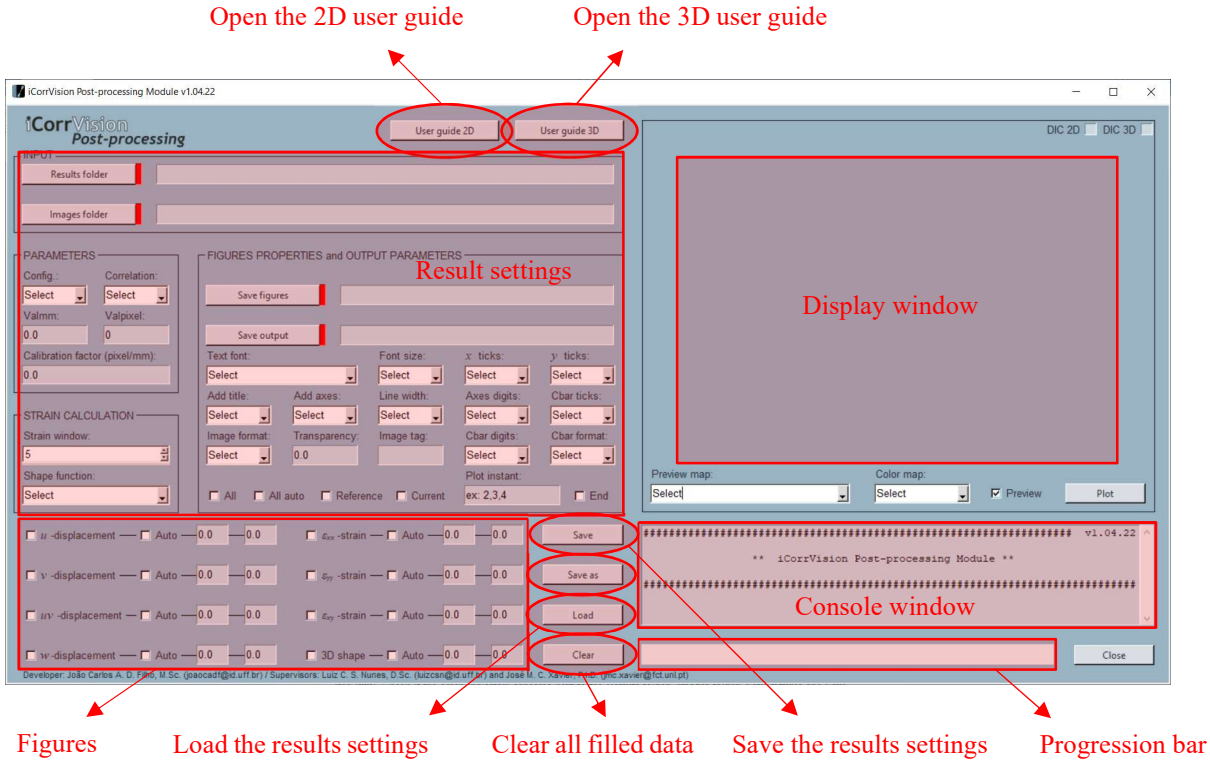




ix. Press **Close** button to close the ***iCorrVision-3D Correlation*** **Module**. Now, the ***iCorrVision Post-processing*** **Module** can be used for visualization.

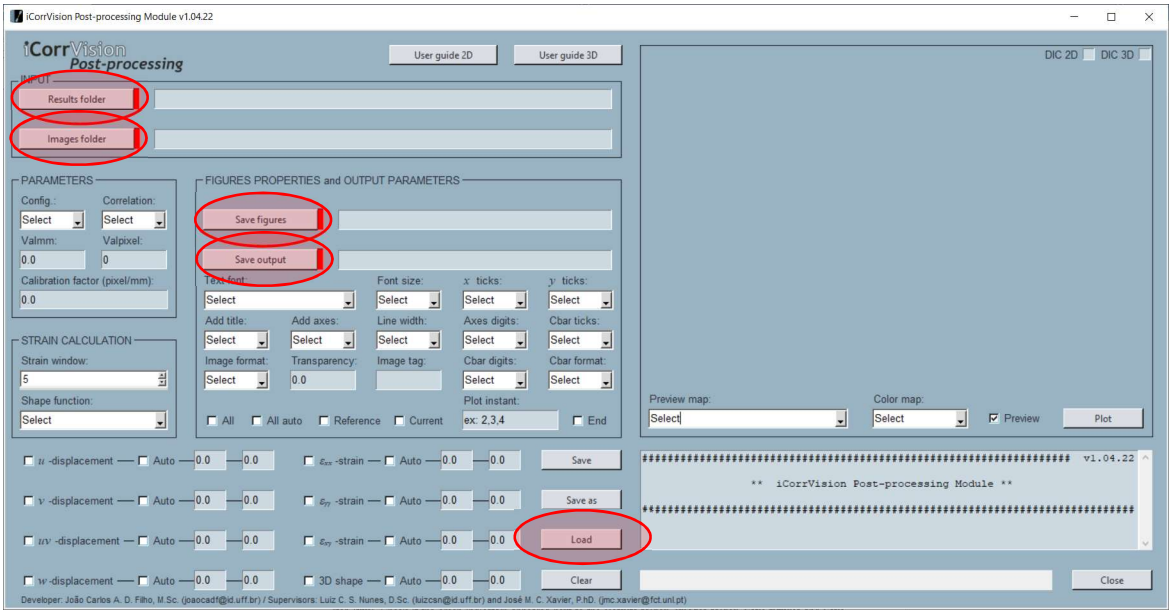


## 4. *iCorrVision Post-processing* Module

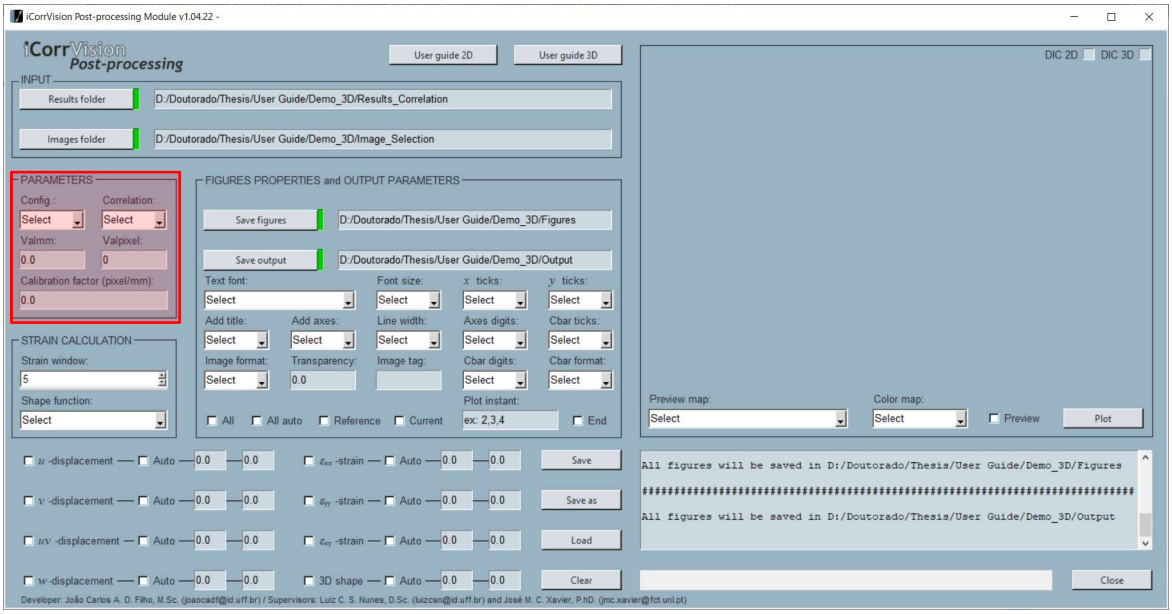
The results can be post-processed and displayed using the ***iCorrVision Post-processing*** **Module**. From this module, the full-field strains can be computed using the displacement maps and the reconstruction of the 3D shape can be obtained.



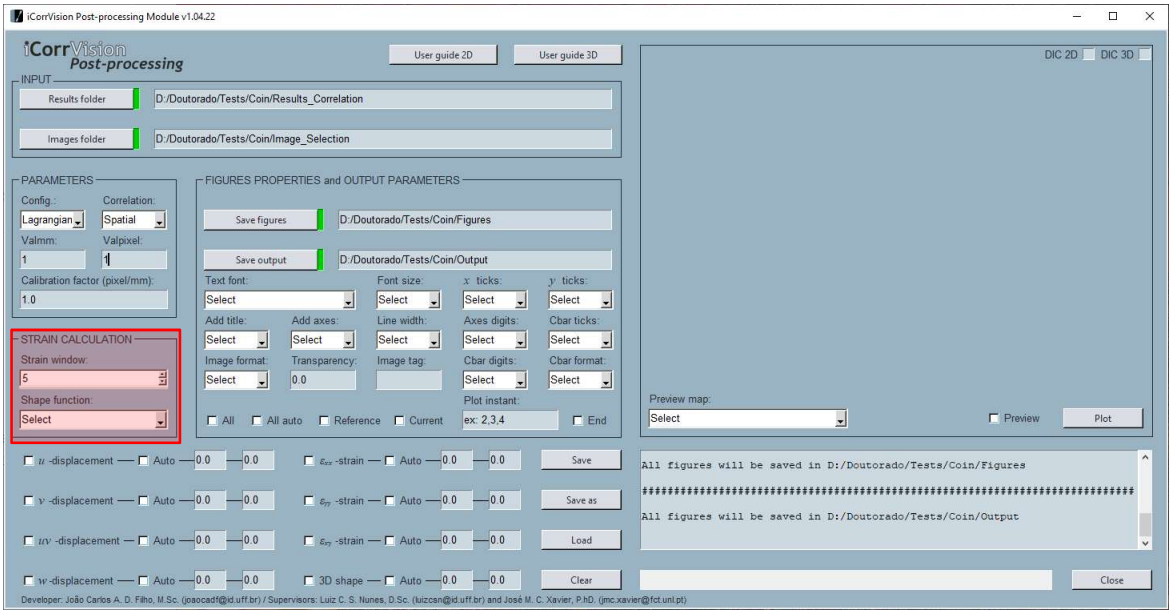

i. Press the **Load** button to select the **.dat** file generated by a previous post-processing study and go to step **(viii)**. Check if the green indicators appeared next to the **Results folder**, **Images folder**, **Save figures** and **Save output** buttons and if all result parameters were automatically filled. If the user is attempting to perform a new post-processing project, press the **Results folder** button to load the correlation results obtained by the ***iCorrVision-3D Correlation*** **Module**, **Images folder** button to load the cropped images, **Save figures** button to indicate the directory where the figures will be recorded and **Output folder** button to designate a directory where the output data will be stored.



ii. Fill the DIC settings used in the ***iCorrVision-3D Correlation*** **Module**. NOTE: For 3D analysis the software fills automatically the Valmm and Valpixel variables. It should be remembered that the calibration file is responsible to perform the correspondence between pixels and mm for 3D analysis.




iii. Fill the strain calculation interface, selecting the **Strain window** (must be an integer odd number) and the **Shape function** (**None**, **Bilinear** or **Biquadratic**). NOTE: If the user selects the None option, the displacement map will not be fitted using a polynomial shape function and the full-field strains will not be computed.



iv. Fill the figures parameters. Table 2 shows each parameter and its description.

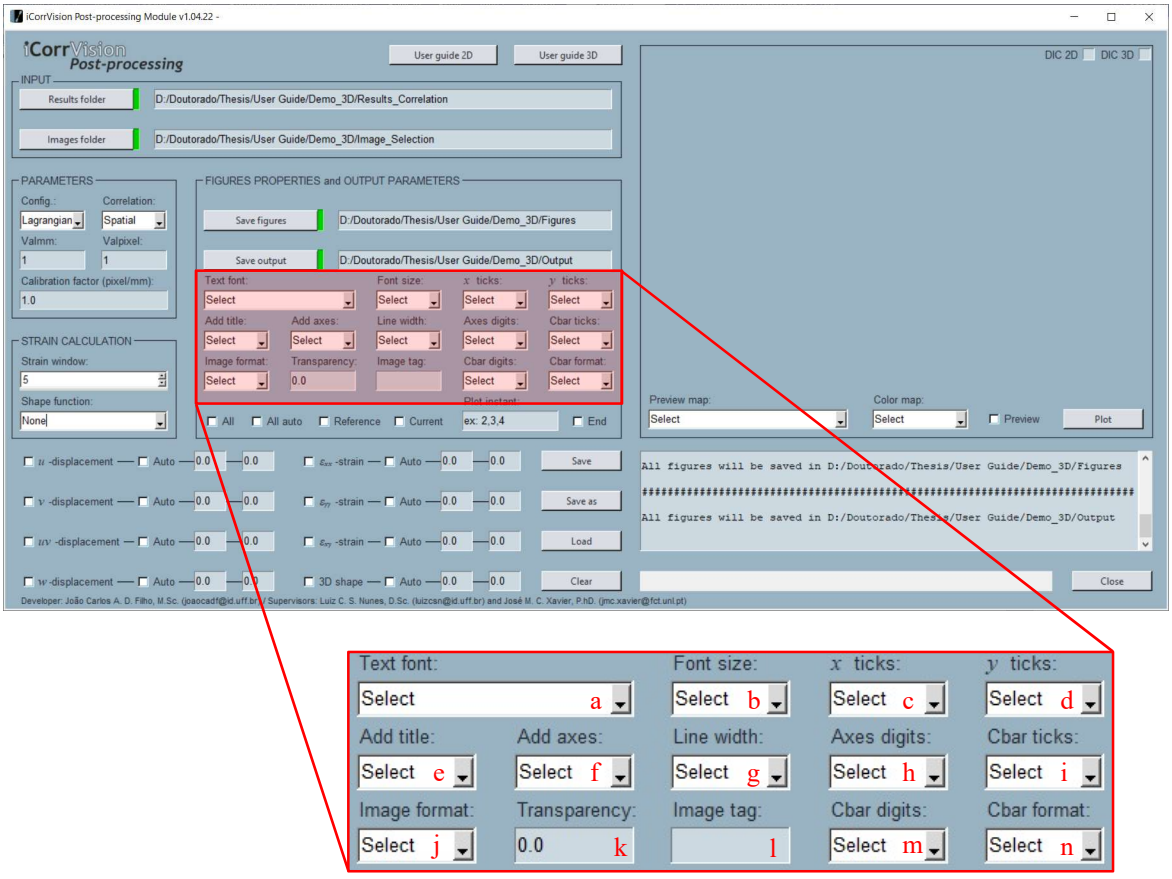
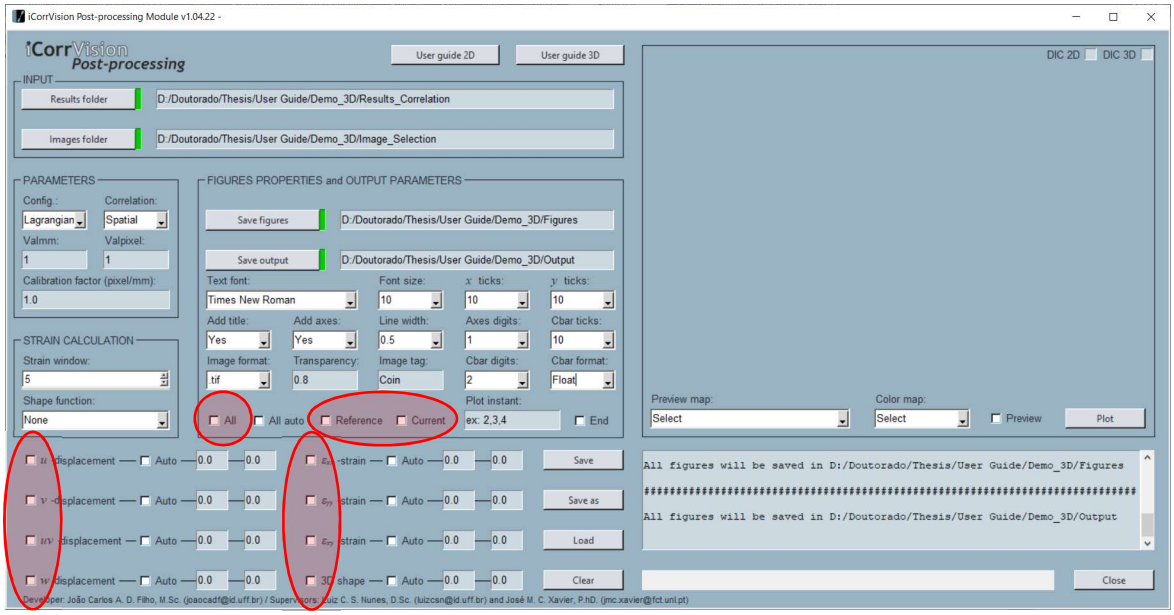


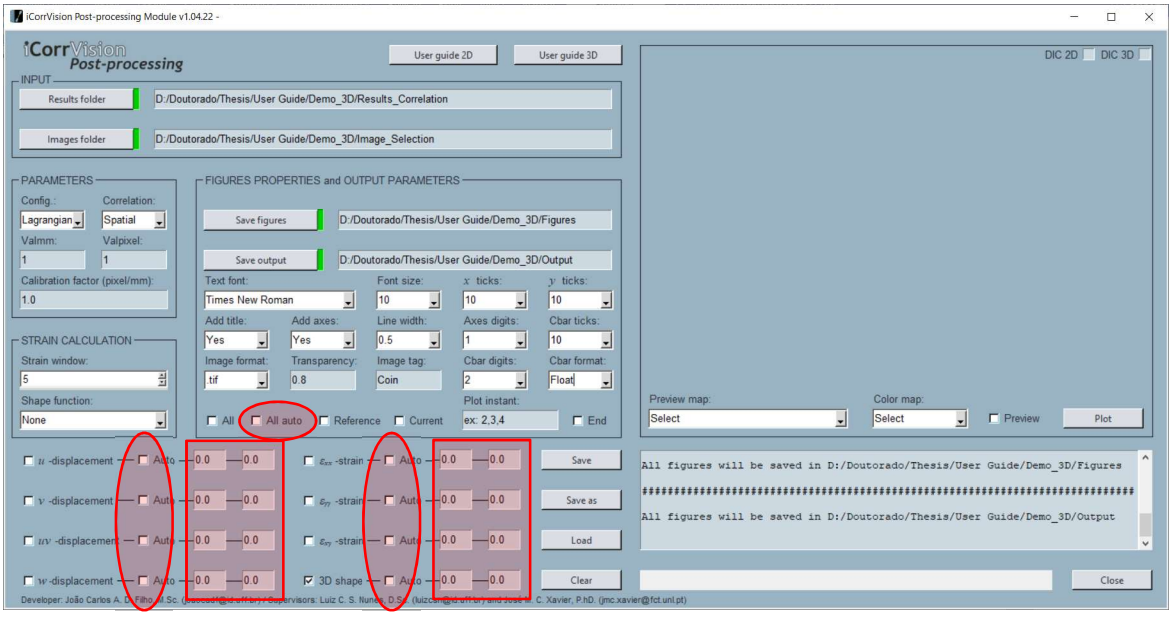

**Table 1.** Description of each results parameter available for modifications.

| Parameter | Description |
|---|---|
| Text font [a] | Choose the text font to be used. *Ex.: Times New Roman* |
| Font size [b] | Select the font size. *Ex.: 10* |
| *x* ticks [c] | Number of ticks in the *x* axis. *Ex.: 10* |
| *y* ticks [d] | Number of ticks in the *y* axis. *Ex.: 10* |
| Add title [e] | Choose between **Yes** and **No** to add title in the figures. *Ex.: Yes* |
| Add axes [f] | Choose between **Yes** and **No** to add the *x* and *y* axes in the figures. *Ex.: Yes* |
| Line width [g] | Width of the grid lines used to plot the reference and current subset position. *Ex.: 0.5* |
| Axes digits [h] | Number of digits (*x* and *y* axes). *Ex.: 2* |
| Cbar ticks [i] | Number of ticks to be used in the color bar. *Ex.: 10* |
| Image format [j] | Select the most appropriate image format. It can be selected between **.bmp**, **.tif**, **.jpg**, **.png** and **.pdf**. *Ex.: .tif* |
| Transparency [k] | Opacity of the full-field displacements and strains. Must be a real number between 0 and 1. *Ex.: 0.8* |
| Image tag [l] | An image tag can be added in the file names. *Ex.: Coin* |
| Cbar digits [m] | Number of digits in the color bar. *Ex.: 2* |
| Cbar format [n] | Color bar number format. It can be selected between **Float** and **Scientific**. *Ex.: Float* |

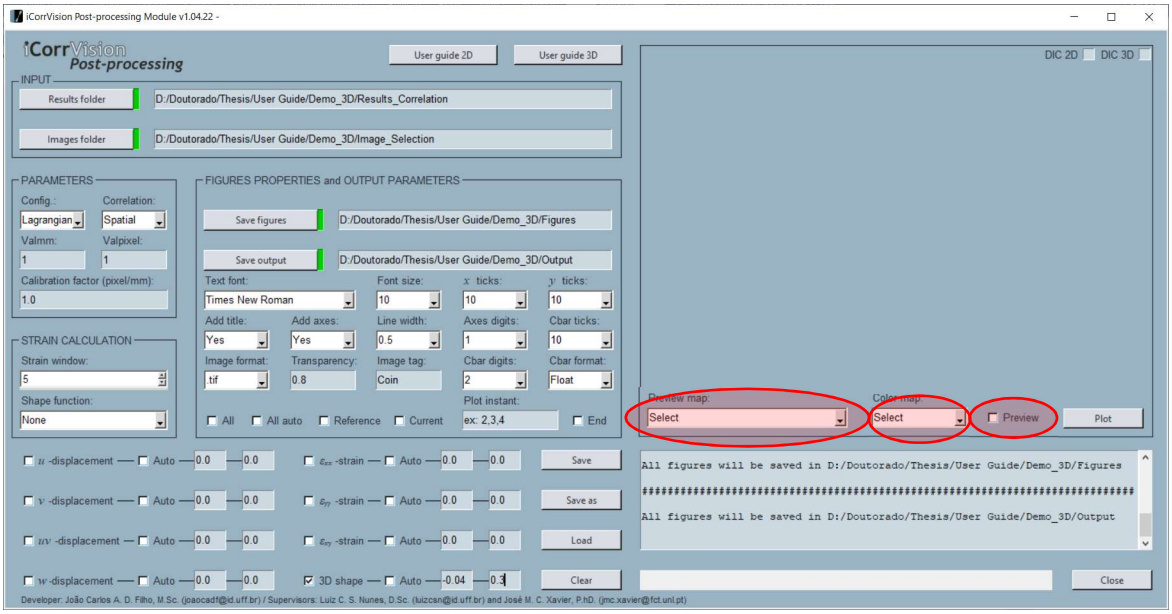
v. Use the checkboxes to select the full-field displacements and strains to be plotted. Activate the **All** checkbox to activate all outputs.



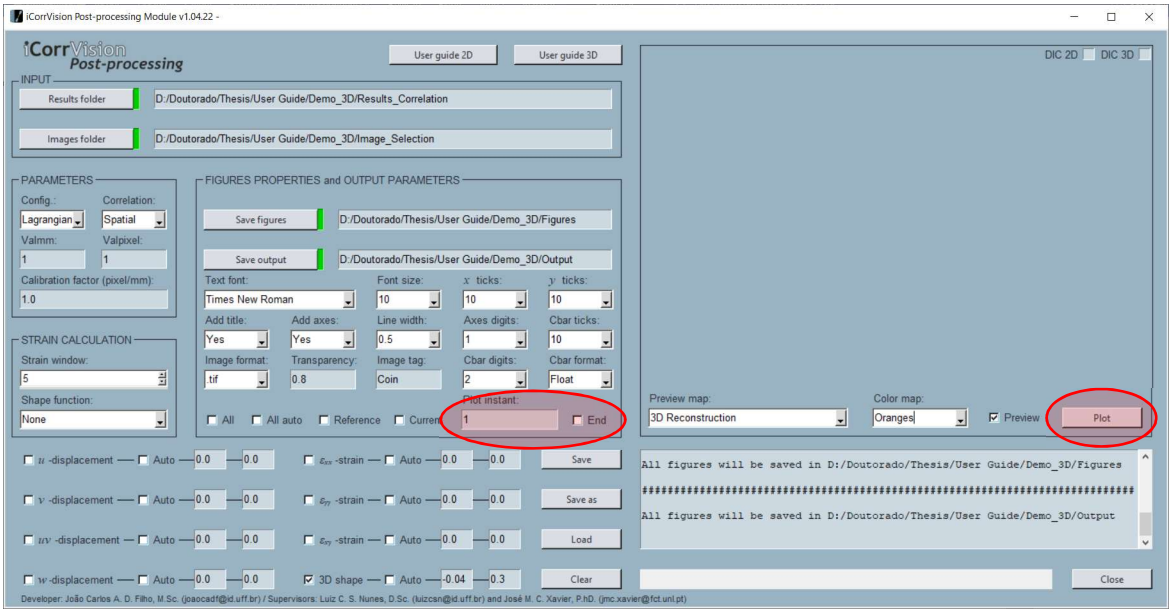

vi. Use the **Auto** checkboxes to use the automatic limits (maximum and minimum) of the color bar. In order to change the color bar limits, use the spaces next to the **Auto** checkboxes to inform the minimum and maximum limits. Activate the **All auto** checkbox to activate the automatic limits for all plots.



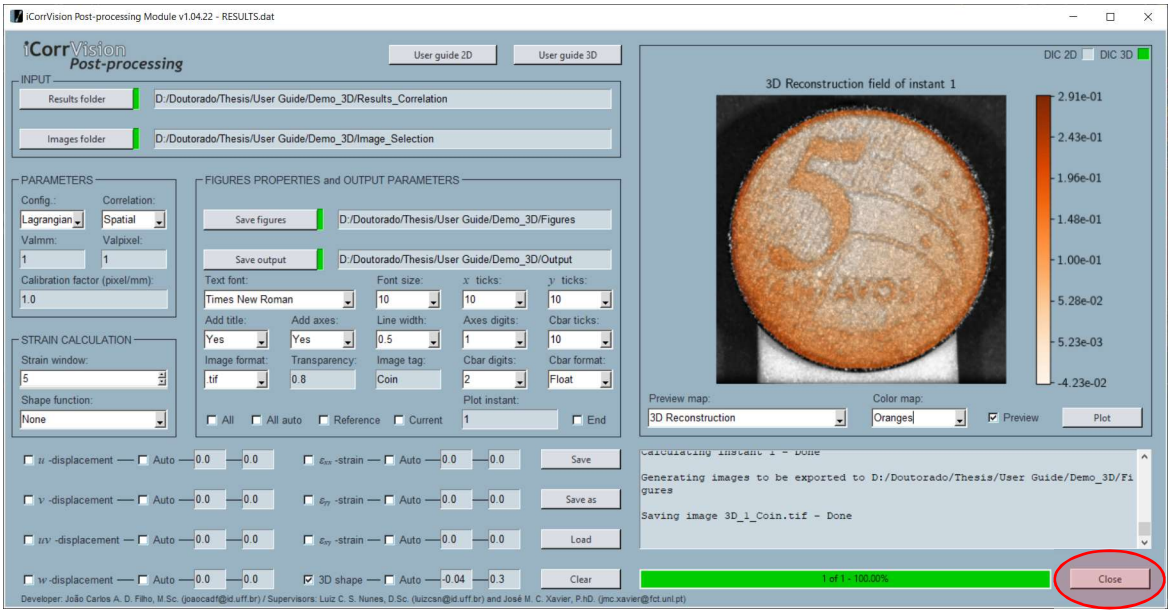
vii. Choose the preview field to be displayed on the screen. The user can select between all displacement and strain maps. Also, the color map can be selected between **Blues**, **Greens**, **Greys**, **Oranges**, **Reds**, **Afmhot**, **Autumn**, **Bone**, **Copper**, **Hot**, **Hsv**, **Jet**, **Winter** gradients. Then, select the **Preview** checkbox.




viii. Choose the instant to be plotted in **Plot instant**. Click on the **End** checkbox to automatically detect the last instant. NOTE: For more than 1 instant, use the following illustrative structure: 2, 3, 10, 20, 30 to plot the instants 2, 3, 10, 20 and 30, for instance. Press the **Plot** button to start the post-processing calculation and output generation. If it is a new post-processing study, a window will pop up in the screen. Inform a **.dat** file to save the results settings.



ix. Press the **Close** button to close the ***iCorrVision Post-processing*** **Module**.




x. Go to the directory where the figures were saved to visualize all results.