

Supplementary Material

A Tutorial Guide to Tribology Plug-in

Tribology

An ImageJ Plugin for surface topography analysis of laser textured surfaces.

General Description

This plugin presents an easy-to-use analysis tools for the evolution of the laser textured surfaces recorded by a high magnification camera.

It allows the user to visualize and analyze the laser textured surfaces in various ways:

- Display of the same location under different lightening conditions
- Display of the same location over all cycles for a given lightening condition
- Display of the all sample for a given cycle
- Display of the same location with bubble elimination
- Various statistical tools

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1. Tribology

This option is the main part that offers the main analysis tools and it can be selected as shown in Figure 1.

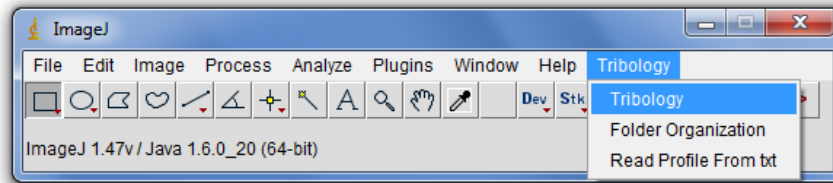


Figure 1: ImageJ main bar with Tribology plug-in

After selecting this option, a user interface as shown in Figure 2 comes out.

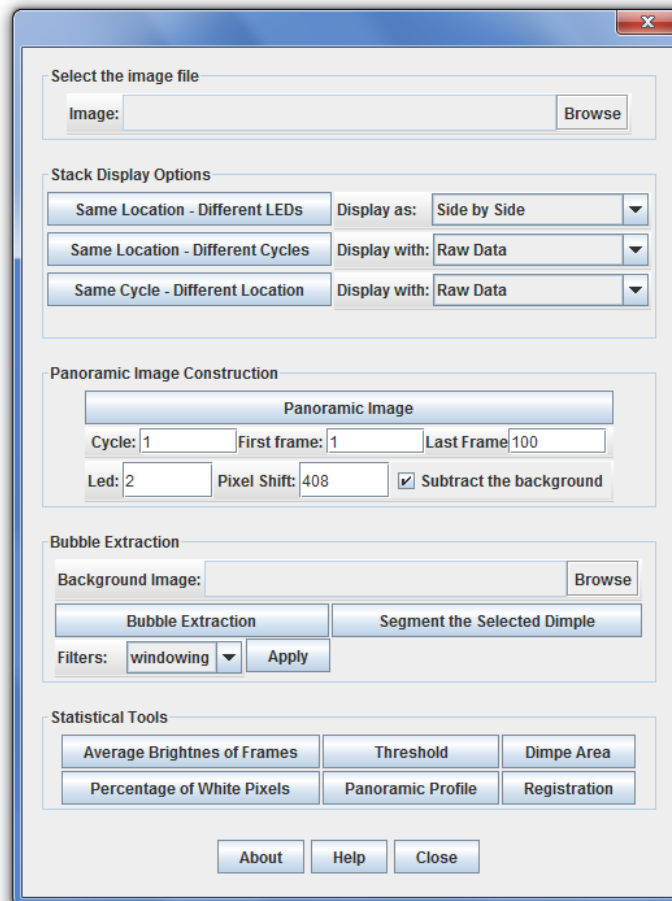


Figure 2: The user interface of 'Tribology'

1.1. Select the image file

The user can select the image file of interest by browsing. The important thing is that the folders that contain this image file should be organized as shown in Figure 3.

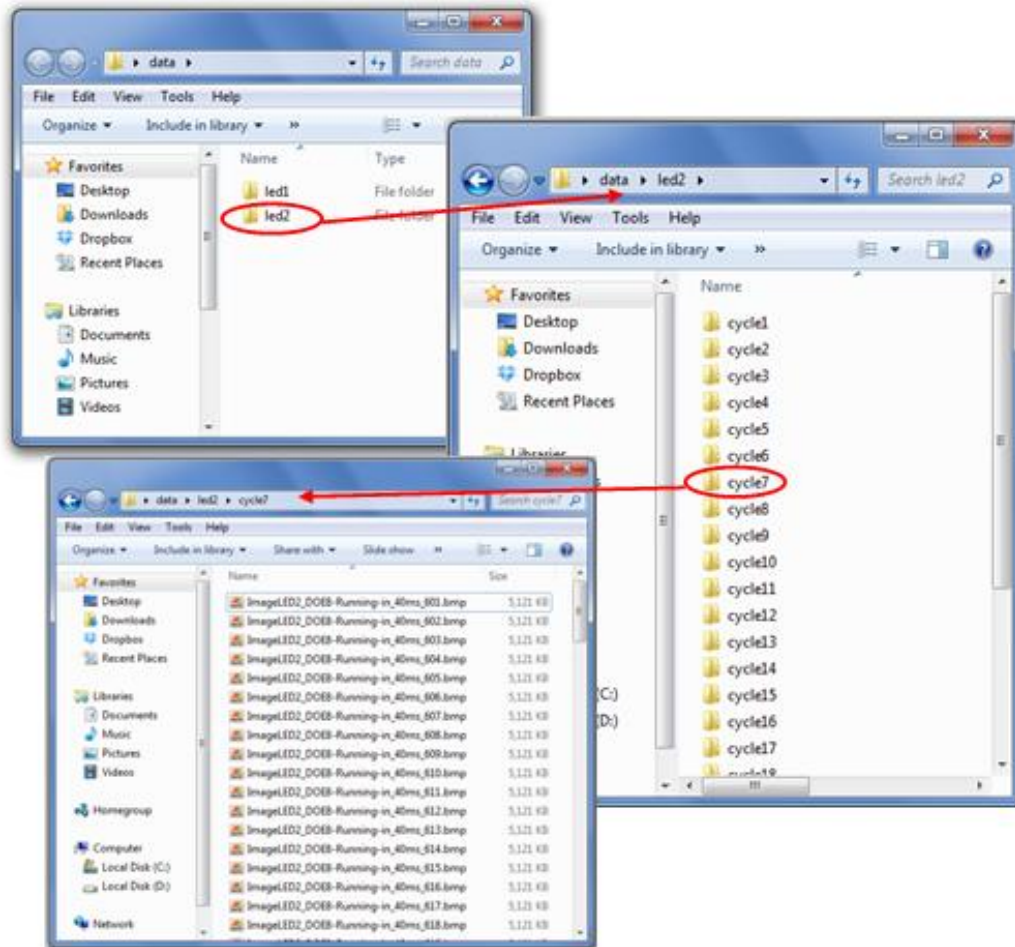


Figure 3: The organization of the folders

The folders for the LED 1 and LED 2 should have the names strictly as 'led1' and 'led2' respectively. The names of the folders that have the images of a specific cycle should have a name as 'cycleX' where X represents the number of the cycle. This organization can be made manually or the 'Folder Organization' option can be used which is explained in part 2.

1.2. Stack Display Options

1.2.1. Same Location – Different LEDs

With this option, the user can display two images of the same section and the same cycle with different LEDs according to the selection. The images can be displayed side by side, as a stack or in red and green channels. For the colored image, the data of LED1 is fed into the red channel and the data of LED2 is inverted and fed into the green channel.

1.2.2. Same Location – Different Cycles

With this option, the user can display the all images of a section in three ways. Firstly, the images of the section can be viewed for the selected LED. The LED is selected automatically with the selection of the image file. Secondly, the images can be viewed with background subtraction. Since lightening is not homogenous, it may be useful to subtract the background before analyzing the images. The background image is calculated by calculating the mean of the images in time axis and smoothing with a Gaussian filter. Lastly, the images can be viewed in red and green channels of the stack as in the previous section. It is important to note that for the colored image, the image file should be chosen from the folder of 'led1'.

After clicking the related button a dialog box appears as shown in Figure 4.

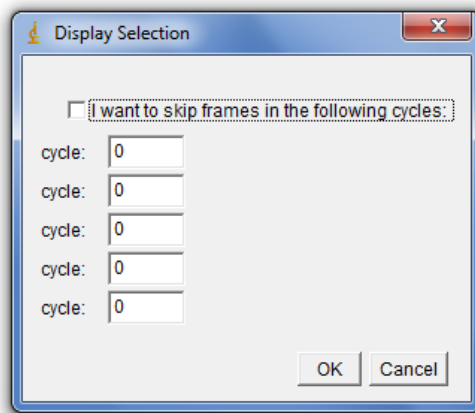


Figure 4: Dialog box for Same Location – Different Cycle Option

The user can skip the frames of the cycles that he/she does not want to see. The user can skip at most five frames. The numbering of the frames should be entered in to the boxes one by one with turning the checkbox to on mode. In this way, the resulting stack will not contain the images of the entered cycles.

1.2.3. Same Cycle – Different Location

With this option, the user can display the all images of the sample for the selected cycle and lightening. The cycle and the lightening are determined with the selection of the image file. The stack can be displayed as raw data with the background subtraction. Again, the background image is calculated by calculating the mean of the images in time axis and smoothing with a Gaussian filter.

1.3. Panoramic Image Construction

The user can display the panoramic image of the sample for any of the cycles. The input parameters should be entered correctly. The user can select the light mode, the cycle number and the coverage of the panoramic image by selecting the first and last frame numbers. Another important parameter that should be given by the user correctly is the pixel shift amount between two consecutive images. For a scan of 100 images, this value is 408 pixels. For other scan settings, this should be calculated by the user and entered correctly.

There is also a checkbox for background subtraction option which is set to on by default.

1.4. Bubble Extraction

This option only works for LED 2 images. Before selecting this option, the user should have selected a background model to eliminate the effect of inhomogeneous illumination. The example background model is created by averaging and smoothing the images of a non-textured sample. This result can be multiplied by a constant to fit the background better. After selecting a proper background model, a dialog box as shown in Figure 4 appears for the same reasons. The user can skip some of the frames. Then, the plugin calls all the images of the selected section, except the indicated ones, by the using the information of the first image file bar. The plugin subtracts the background and registers the images so that the camera slight movements between the cycles are eliminated. After the registration the plugin eliminates the bubbles.

The elimination of the bubbles happens with various assumptions. Firstly, it is assumed that the bubbles are always dark. Secondly, it is assumed that the images are getting brighter as sliding continues. With these two assumptions, the plugin uses the values of the previous or next frame for the pixels that are covered with bubbles.

After the elimination of bubbles, the user can take a closer look at a selected dimple by clicking 'Segment the selected dimple'. Before clicking this button, the user should have selected the center of a dimple by the point selection tool of ImageJ main bar. After the selection of the center and clicking on this button, a dialog box appears as shown in Figure 5.

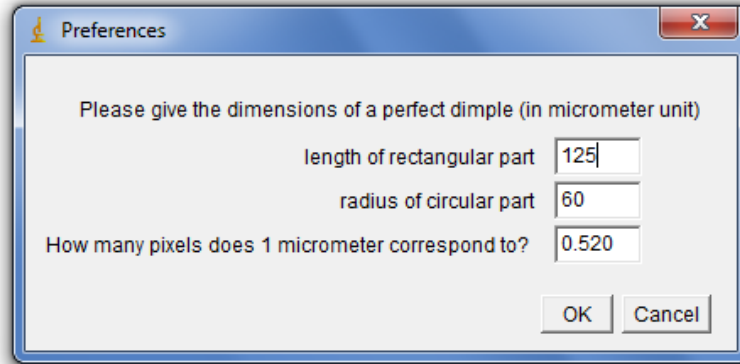


Figure 5: Dialog box for dimple segmentation preferences

In this dialog box, the user is expected to give the dimensions of a perfect dimple in the unit of micrometer and the correspondence of 1 micrometer in terms of pixel. The length and the radius parameters are shown in Figure 6.

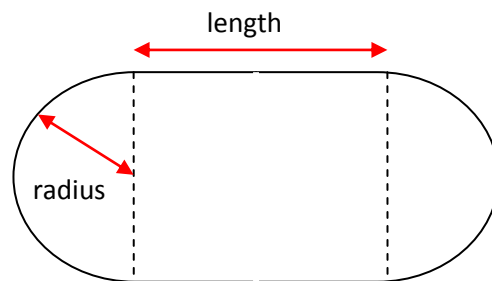


Figure 6: Dimensions of a dimple

After entering these parameters, the plug-in copies the region around the dimple as a stack, segments the inside area and convert the stack into binary.

The edge detection algorithm works with the gradient values of the simple. Due to low SNR, sometimes it is possible to have some pixels alone as the edge which may lead wrongly. Therefore another dialog box appears that asks for the elimination of these edges as shown in Figure 7. After the elimination of these edges, the rest is connected with straight lines.

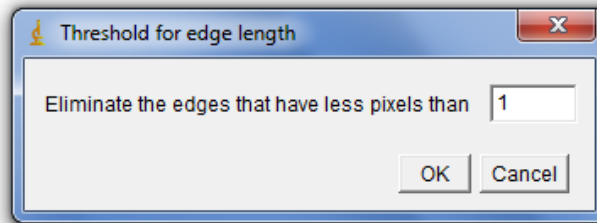


Figure 7: Threshold for the edge length

After the segmentation of the dimple, the user may want to apply a temporal filter that will compensate the missing edges are represented with straight lines after the edge elimination. The temporal filter named as 'windowing' uses only the data of the previous frame and the next frame for the correction of the current frame. The other temporal filter named as 'minimum' uses the information from all previous frames by putting a restriction for the decrease of area over time.

1.5. Statistical Tools

1.5.1. Average Brightness of Frames

This option calculates the average pixel intensity values for each frame and draws the graph over cycle (time) axis. It is important to note that before clicking button for this option, the desired stack of gray images should have been selected by mouse.

1.5.2. Threshold

This option lets the user to set a threshold on the gray images. The threshold value can be set by manually by dragging the bar or automatically by clicking on the 'Auto' button on the dialog box shown in Figure 8.

After selecting the threshold value and clicking on 'Apply' button, a new dialog box appears as shown in Figure 8.

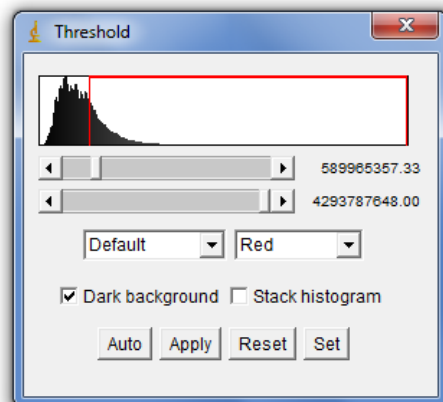


Figure 7: Threshold for the edge length

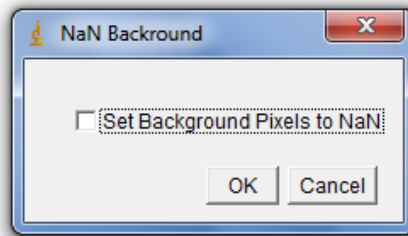


Figure 8: Background selection for Threshold

The checkbox for 'Set Background Pixels to NaN' should be turned to off mode. After clicking OK, another dialog box appears as shown in Figure 9.

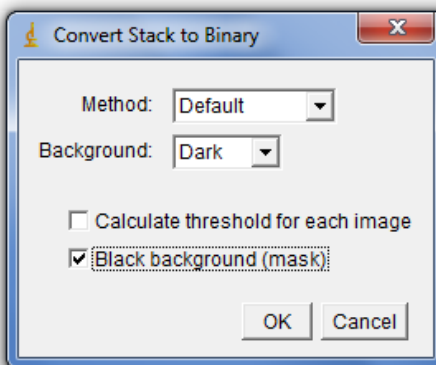


Figure 9: Conversion for Threshold

The selections for this new dialog box should be as shown in Figure 9. After clicking OK, the user obtains the binary version of the thresholded version.

1.5.3. Dimple Area

This option uses a binary stack of the dimple as an input which is obtained by 'Segment the Selected Dimple' option. The plug-in calculates number of the white pixels which correspond to the inside area of the dimple. The plot of the number of white pixels over the frame number of the stack is obtained as the output.

1.5.4. Percentage of White Pixels

This option uses any binary stack as an input. The plug-in calculates the percentage of the white pixels over all pixels. The plot of the percentage of white pixels over the frame number of the stack is obtained as the output.

1.5.5. Panoramic Profile

This option can be used with the panoramic image as an input which is obtained by 'Panoramic Image' option. When this button is clicked, a dialog box comes out as shown in Figure 10.

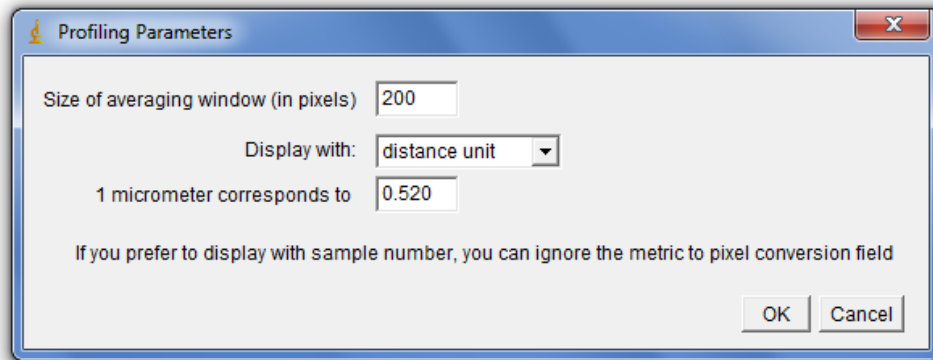


Figure 10: Parameters of Panoramic Profile

The plug-in calculates the average brightness of each row of the panoramic image by sampling that row. The amount of samples is determined by the first field in the dialog box shown in Figure 10. The average brightness of the rows is plotted as the output. The x-axis determined the section 'Display with' of the dialog box. The user can select the distance unit to convert the unit of x-axis to micrometers. Alternatively, the user can select 'sample number' to have an x-axis with the numbering of the rows. For the distance unit, the user should enter how many pixels 1 micrometer corresponds to correctly in the last field of the dialog box.

1.5.6. Registration

This plug-in requires a stack as an input. For example you can use the output of the 'Same Location – Different Cycles' option. After clicking the button for 'Registration', the plug-in starts to slice-to-slice alignment. Therefore, an indifferent slice in the stack can ruin the output where the slices after the indifferent slice would not be registered correctly. This is why skipping some images during display options may be necessary.

A more detailed explanation for 'Registration' option can be found at:

<http://bigwww.epfl.ch/thevenaz/stackreg/>

2. Folder Organization

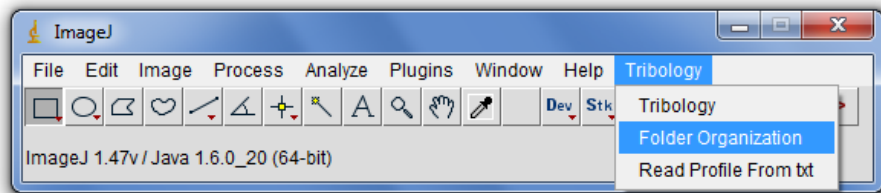


Figure 11: Folder Organization

To be able to use “Displaying and Processing” the images should be organized manually or with “Folder Organization” option. This option organizes the images inside a folder by creating necessary folders and copying the images in to them properly.

This option brings out a dialog box as shown in Figure 12, where the user should give some information about the organization.

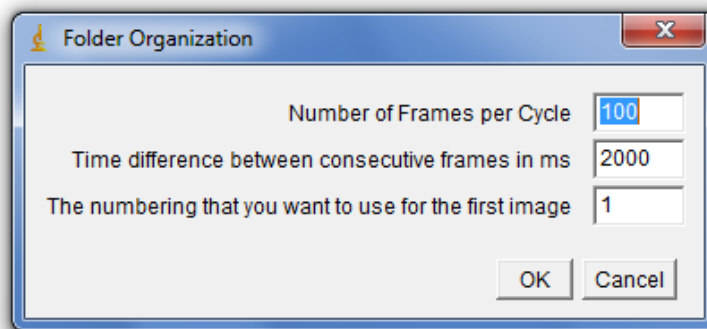


Figure 12: Dialog Box for Folder Organization

In the first field which is next to ‘Number of Frames per Cycle’, the user should enter how many pictures are taken by the machine in one cycle ideally. In the second field which is next to ‘Time difference between consecutive frames in ms’, the user should enter the ideal timing between two consecutive frames of the same cycle. In the last field which is next to ‘The numbering that you want to use for the first image’, the user should enter the numbering of the first frame which will be used in the organized folder.

After clicking ‘OK’, a browser comes out for the user to select the data folder. This folder should have contained all the images of the same type of lightening, for all cycles. After selecting this source folder, another browser comes out for the selection of the target folder. This target folder should have contained no files or folders. It should be completely empty.

After the selection of the data folder and the target folder, the plug-in starts to copy the images of the data folder into the target folder by creating new sub-folder for each cycle.

3. Read Profile From txt

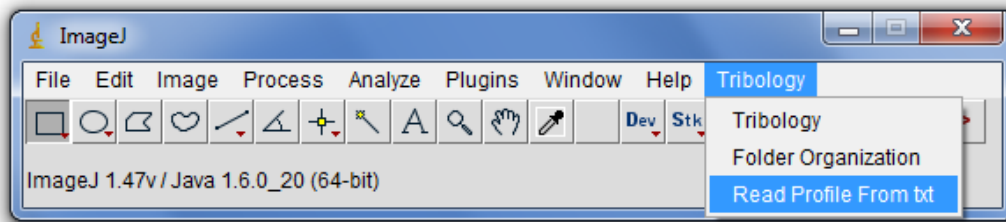


Figure 14: Read Profile from txt

This option can be used to display one or multiple images whose x-y-z information is in txt form. After selecting this option a dialog box appears as shown in Figure 15.

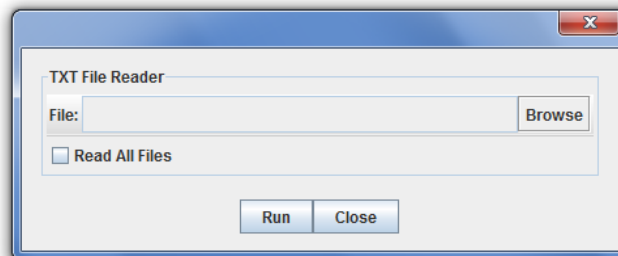


Figure 15: Dialog box for txt file reader

The user should select the txt file by using the browser. If the user wants to display only the selected image, 'Run' button should be clicked. If the user wants to display all the txt files in the folder of the selected file, the checkbox for 'Read All Files' should be turned on. Then the user should click 'Run' button that will cause a new dialog box as shown in Figure 16 comes out.

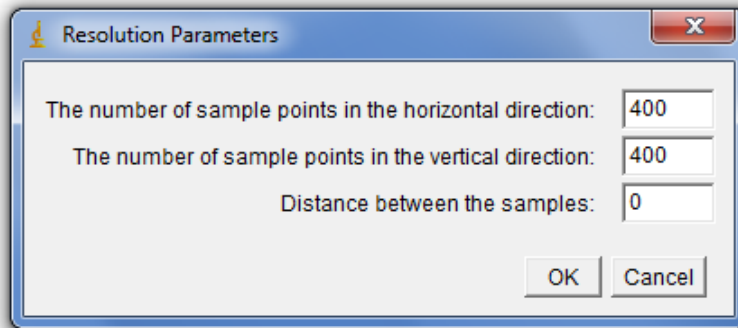


Figure 16: Dialog box for txt file reader

To be able to display the images without any problem, the resolution parameters should be entered correctly. Another important thing to note that is the files that are inside the folder of the selected file should have the same resolution parameters. In this way, images of all files in that folder can be displayed as a stack without any problem.