Aracne
Version 3.2.0

A Software Tool for Thread Counting in Fabrics of Canvases

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A Software Tool for Thread Counting in Fabrics of Canvases

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If you or your institution find it useful, we encourage you to write us with your feedback. Besides, we kindly suggest cooperating in this project with funding to further improve this software's usability and develop new tools. You may contact us at murillo@us.es.

Diseño de maquetación: F. Javier Payán Somet © 2024.

Contents

1 Installation

We provide a version for microsoft windows. This version was tested with Microsoft Windows 11, it should work with this and previous version of this operating systems.

To install and use the software we need two steps.

1. Save the application AracneV3.19.exe in some folder.
2. Then you should install the software MCR v9.9 from MATLAB® at http://es.mathworks.com/products/compiler/mcr/?refresh=true.

Important: Make sure you choose software for microsoft windows and that the version is 9.9 for Matlab2020b.

Upon request, at murillo@us.es, we may provide a version for max XOS, but it is valid for computers with intel processors. The software obtained from Matlab, used to develop Aracne, is not working properly with new metal CPUs.

2 A quick start

A complete processing of an image involves loading the image, selecting an area or the whole image to process, setting the parameters, running the thread counting algorithm, visualizing the results, and saving them as a project.

In this chapter, we go over these steps most simply by loading an image, selecting the whole of it, using the default parameters, running the algorithm, and visualizing the results.

In the following chapters, we go over these steps more deeply to fully explain, among other details, the meaning of the parameters and the visualization options.

2.1 Opening the tool

If correctly installed, after clicking the application icon we should get the window included in Figure 2.1, where we observe three main areas from top to bottom. First, we have the menu area, then some buttons as shortcuts to some options in the menus. Finally, the visualization zone where the load image (Original image panel) and the results (Results panel) panels of the tool will be observed.

2.2 Load an image

The first step is loading an image. This can be performed by simply clicking on the first icon from the left,  or by using the Project menu and there the submenu New Project/Load Image. In Figure 2.2 it can be observed the result of loading a sample image.

The images allowed are in .tif format, in greyscale, with image size, in pixels, and resolution value and resolution unit (either in inches or centimeters). We work here with an image of an X-ray plate, but a picture of the fabric, in greyscale, could be used instead. Please, make sure your image meets these requirements, otherwise, it will not be loaded, or sizes will be loaded improperly. In Apendix A it has been included an example of the format of an image with compliance parameters.

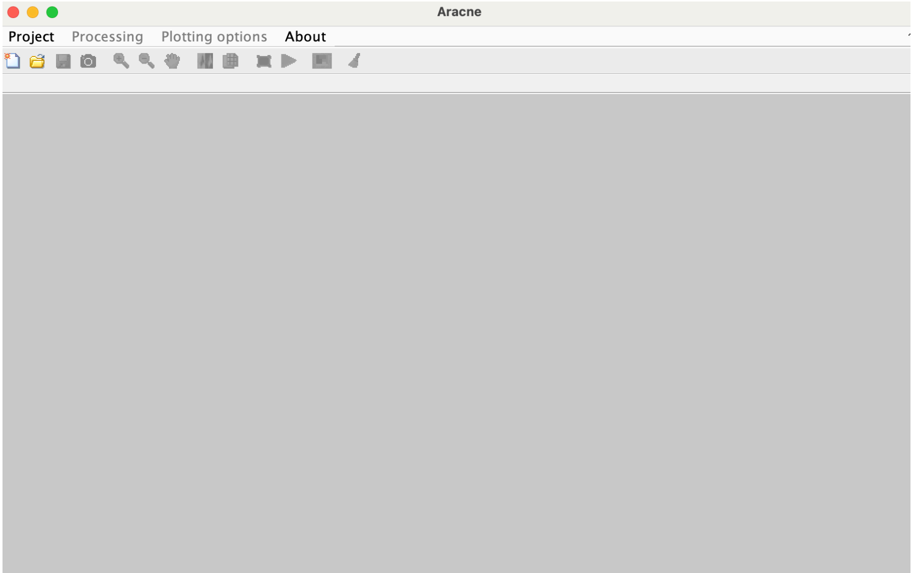

Figure 2.1 Opening the tool.

We provide an example of an image to play with, P07905RX.tif, that will be used in the following.

Figure 2.2 Loaded image.

2.3 Selecting an area of the image

With Aracne one may process an area of a loaded image or the whole image. We can go to the menu Processing/Processing Region/Select Whole Region to select the entire image. In this case, you would observe that the full image is copied to the right, and to the left the processed image is depicted with the selected area in blue color. The area in blue is the one to be processed. To select a given area either click on the icon or use the menu Processing/Processing Region/Select Image Region. A new window will show up where we must select a square area by clicking on the left upper corner first and then on the right lower. Then we can redefine the square, see Figure 2.3, by selecting its sides and moving them. When finished, we just double-click. The window will close and now the selected area to process turns into blue and will be shown to the right, see Figure 2.4. You may repeat the process to select another area. In the following, we will work on the whole image, see Figure 2.5.

Figure 2.3 Window to select the to-be-processed selected area of the image.

2.4 Running the thread counting algorithm

To run the algorithm, with default parameters, we just click on the play icon, or use the menu Processing/ Begin. This will start the algorithm, by showing a progressing bar that includes a button to cancel the process if needed. At the end of the algorithm the Results panel is automatically selected and the results are shown. See Figure 2.6, where we find three main areas in this panel.

To the left, we observe one image and four taps to change from one image to another. The first two taps correspond to the thread counting for the vertical and horizontal threads. A color legend helps translate the color image into values of threads per cm. Indicating

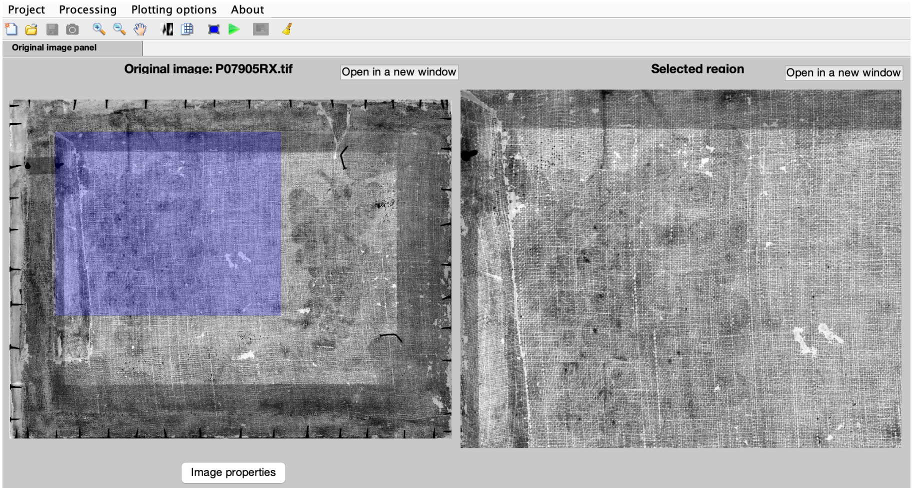

Figure 2.4 The selected to-be-processed area of the image, blue area to the left indicates the selected area.

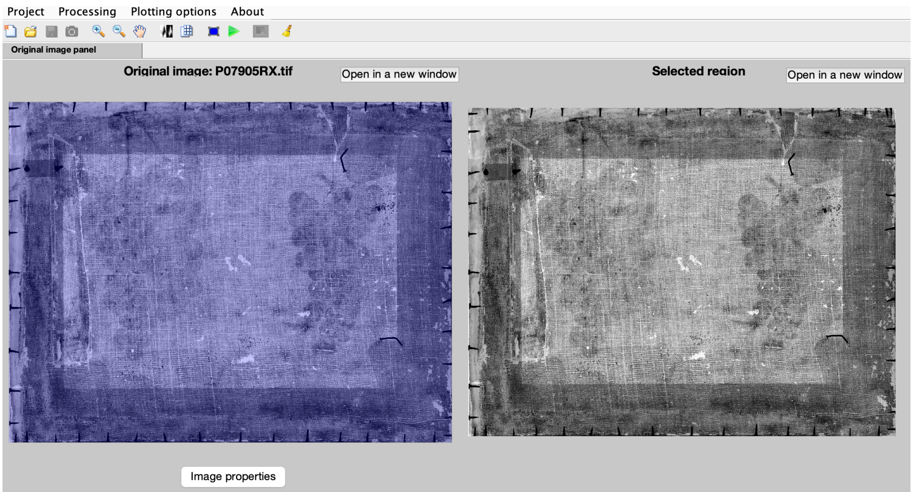

Figure 2.5 To-be processed area of the image when the whole image is selected.

the result along the selected area. Each pixel color results from the counting in a square window around it. The default value is a 2 cm side square. The other two images show the thread angle deviation. Again, each pixel color encodes the resulting value of the computation of the angle for a square window around it. Deviation from the vertical is shown for the vertical threads and from the horizontal for the horizontal ones. A positive value means a clockwise deviation. To better observe the result by locating every color pixel within the selected area you may use the overlap option, by clicking on and described in Subsection 3.1.1.

On the upper right part, we find the resulting histograms for the thread counting, for the vertical and the horizontal threads. This is just a plot of the number of times a thread counting value is found along the processed image. Below the histograms, we find some statistical values for the thread countings, the mean, mode, and statistical deviation for both the vertical and horizontal thread counting.

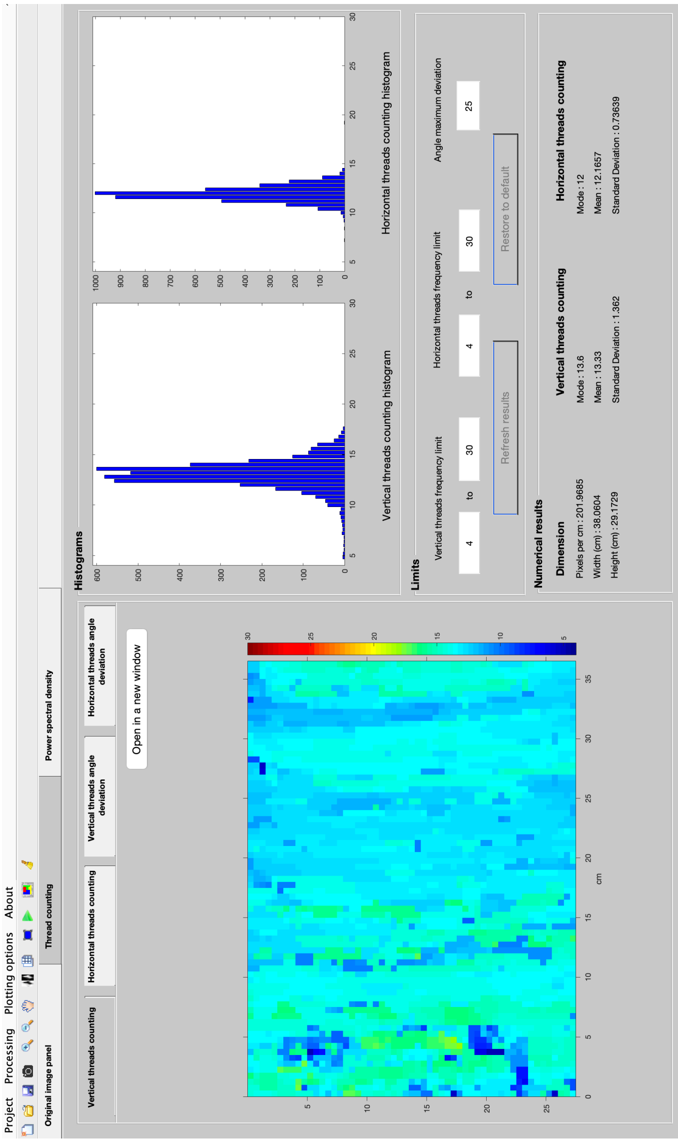

Figure 2.6 Result of the tread counting algorithm for the whole image, showing the image with the color density map for the vertical threads.

2.4.1 The Power Spectrum Density

In the tap "Power spectral density" you will observe a result as the one in Figure 2.7. The power spectrum density (PSD) is depicted using contour lines to the left and a 3D mesh figure to the right. Information about the maximum points found is included at the bottom. The maxima at the horizontal and vertical axis are related to the thread densities.

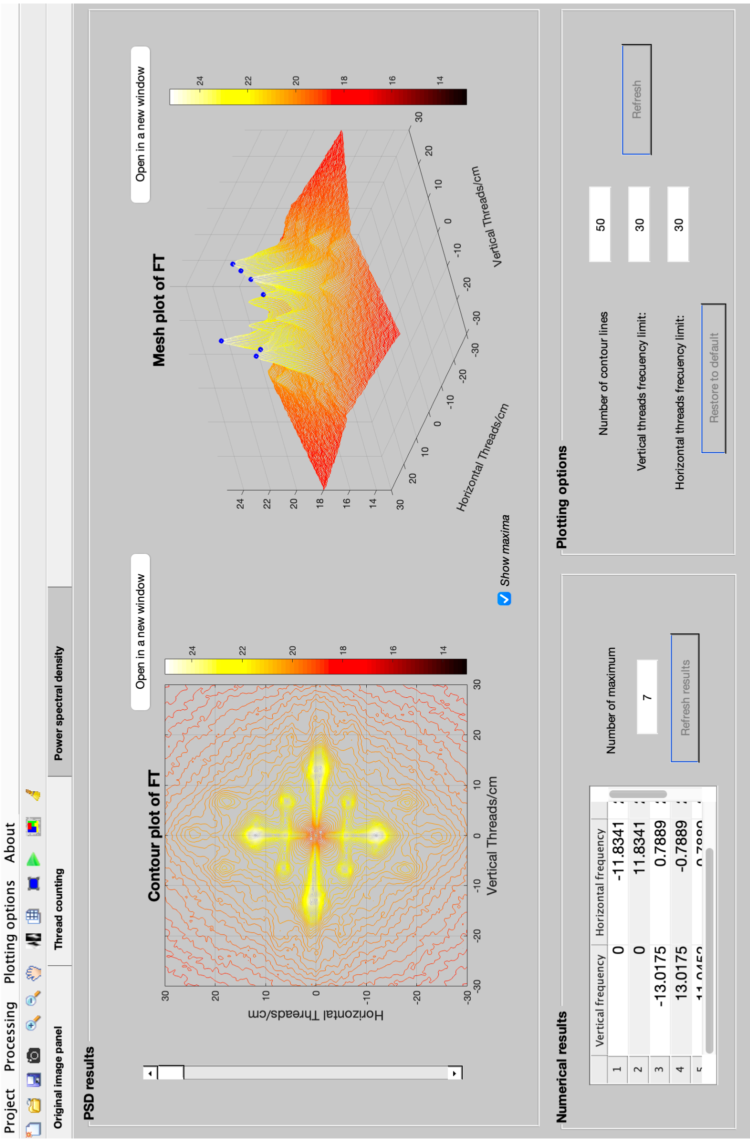

Figure 2.7 Result of the tread counting algorithm, showing the PSD both from an upper view using contour lines to the left, and in a mesh graphic, to the right.

3 Visualization options

THERE are some options that help visualizing the results and the original loaded image. These options are as follows.

3.1 Visualization of the results

3.1.1 Overlapping results and original image

To better locate the result of the thread counting or angle deviation within the selected area you may use the option overlap. After running the thread counting algorithm, you just click on the icon or using the menu Plotting options/Overlap results with processing area. In Figure 3.1 we include an example of this overlap, where the color image with the thread counting and the angle deviation results are plotted with transparency on top of the selected area of the original image. In these new images, every color pixel is surrounded by the area used to compute the value it encodes.

3.1.2 Setting the axis for the histograms

Under the histograms, one finds some boxes with the limits for the x-axis of the histogram. In the example in Figure 2.6 we better observe the histogram if we set these limits to 10-15 for the vertical and horizontal threads. Once you introduce the limits, just click on the Refresh histogram results. Note that the numerical results under the histograms will be recomputed for this range.

3.2 Visualization of the original image

Some tools have been included to improve the user experience when dealing with the original image, as follows.

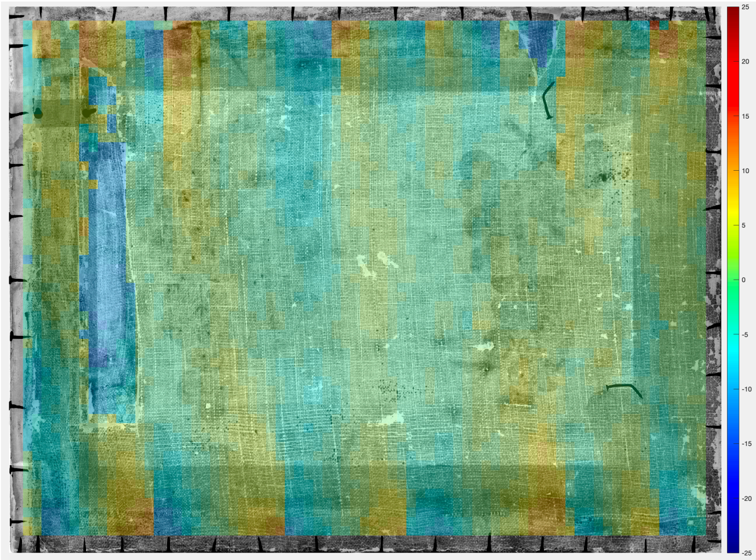

Figure 3.1 Overlap of the results with the original image for the angle deviations of the horizontal threads.

3.2.1 Zoom

In the top left corner, you will find the icons to zoom in or out the images. Also, both the loaded image and the selected area can be opened into a new window where to zoom them. A snapshot of the popped-up window is included in Figure 3.2.

3.2.2 Invert gray levels

It can be preferred to use the original image with the intensity levels inverted, as threads could be better observed. To accomplish this, just click on the icon or use the menu Plotting options/ invert gray levels.

3.2.3 Grid

A grid can be overlapped to the original and selected area images. Just click on the icon or use the menu Plotting options/ add a grid. The result is a red cross every D cm, where D is introduced in a dialog box. This allows for, e.g., a counting by visual inspection. In Figure 3.4 it can be observed the result, with red crosses arranged in a grid on the image.

3.2.4 Image properties

The properties of the loaded image can be observed by clicking on the button Image properties below the image to the left. In Figure 3.5 we include a snapshot of the program with the property window.

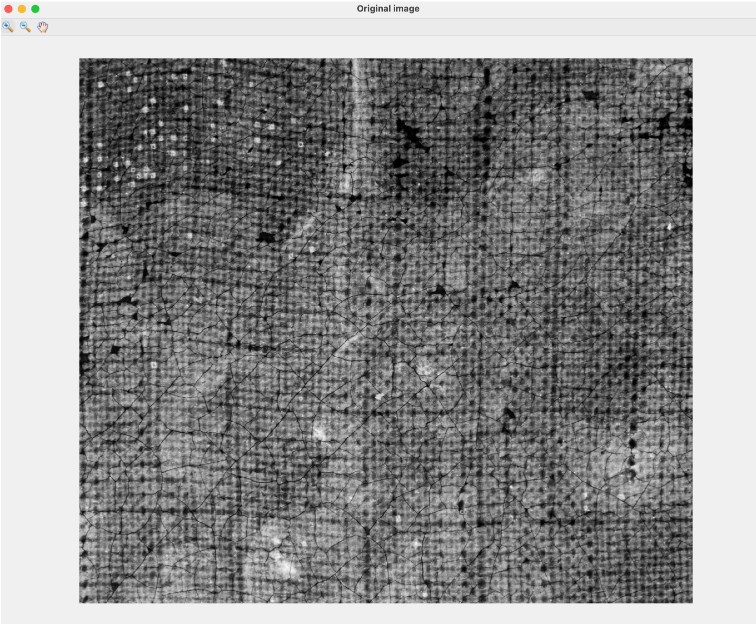

Figure 3.2 Zoom of the loaded image.

Figure 3.3 Loaded Image after inverting gray levels.

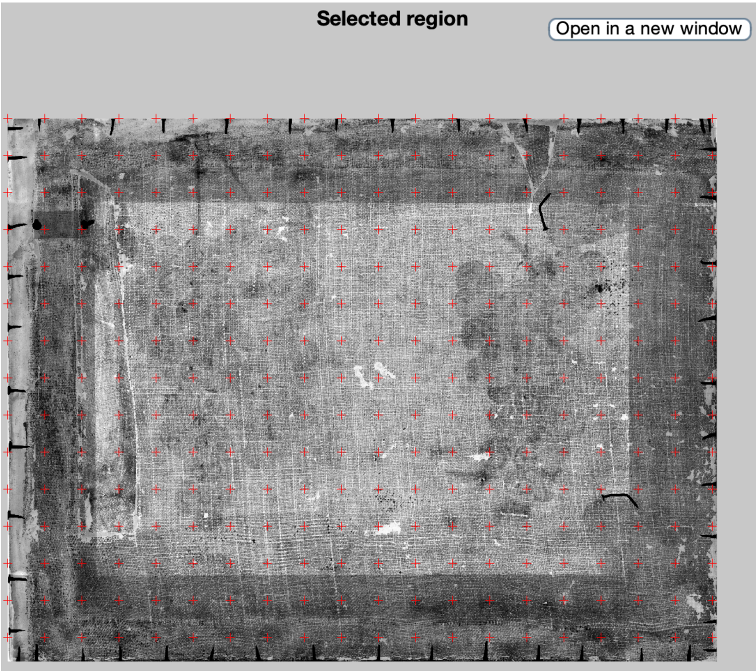

Figure 3.4 Showing the grid of 2 cm side on the image once we have selected a region.

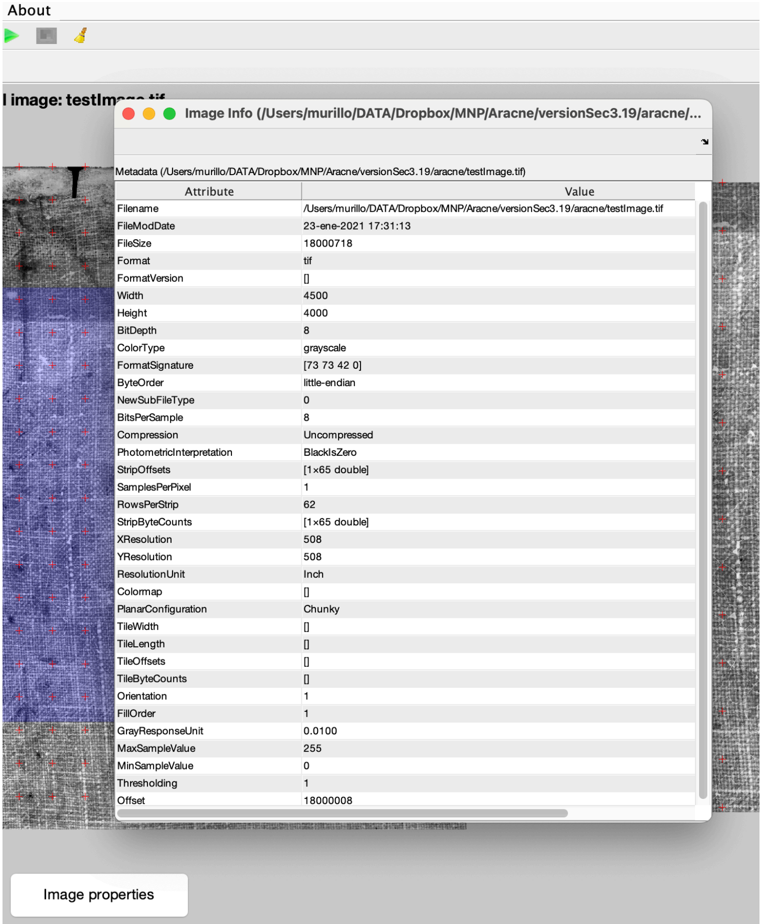

Figure 3.5 Properties of the format of the loaded image.

4 Saving results, projects

ONCE an image has been loaded and the thread counting algorithm has been run one may wish to save both the results and the configuration used. This can be easily done by saving the so-called project.

4.1 A project

When we load an image to be processed the program creates a project. This project is an environment where it includes the path to the image and the parameters used to run the thread counting algorithm. Once run, this project can be saved and then reloaded to visualize the results or event to modify and rerun it.

4.1.1 Saving a project

To save a project use the icon  or go to the menu Project / Save/ Save project. A dialog box will pop up to indicate a folder where to save the project. The name of the project will be automatically associated with the name of the image. In the folder, two files are saved. The file names start with the prefix “aracne_” followed by the name of the image. One is a program file, .mat ended, that cannot be opened with standard tools. The other file is a text file, .txt ended, that can be easily imported into an Excel-type program. You may try, for example, to open it with Microsoft Excel and say yes to all default import settings. It can be also opened with any text editor. In the file, you will observe the information about the image used, what region it was processed, and the parameters used. Then, the results of the thread counting, the histograms, are included next. The statistical values are stored along with the values of the histogram for both the vertical and horizontal threads. To save space the original processed image is not saved into the folder but the path of the image is used instead.

Note: The software is designed to save every project in a new folder. However, you may wish to save all projects in the same folder. In that case, if you already saved a project for a given image in the folder, make sure to change its name first. Otherwise, it will be overwritten.

Important: do not save two projects in the same folder

4.1.2 Loading a project

To load a project you may use the icon or the menu Project/ Existing project/ Load project. Then you select the folder containing the files of the project, then the name of the "aracne_*.mat" file of interest. If the image is not found in the path that was stored in the project file, you may indicate another path. After loading the project the program returns to the state it was when the project was saved.

4.1.3 Plain text file

Loading a full project can be cumbersome if we are interested in retrieving some information, such as the mode of the tread densities. For this reason, Aracne also saves a plain text file with the main numeric results of the analysis. The file is saved in .txt format, which can be easily loaded with Excel or similar. In Table 4.1 we include the first fields or the results of the processing of P07905RX.tif image. Other information not included in the table and saved in the .txt file are the values of the histograms for the thread densities, that can be useful if you wish to plot them, and the positions of the maxima of the PSD.

4.2 Saving results images

You may be interested in saving the images with the obtained results. To accomplish this task you should use the menu Project/ Save/ Save actual images. The program saves the images in the folder indicated, which can be the same one used to save the project. In Table 4.2 we include a description of the saved images. All image names start with "aracne_name" followed by the text included in the left column in Table 4.2, where name is the name of the original image processed. If the overlapping option ( ) is activated, then the overlapped images are saved. A description of the names of the images saved with overlap is included in Table 4.3. Also, take care not to save images in a folder where other results from the same image were saved, as they will be overwritten.

Table 4.1 Image data and processing parameters for P07905RX.tif.

Parameter	**Value**
Image name	P07905RX.tif
Whole image	Yes
Min row	1
Max row	5893
Min column	1
Max column	7688
Pixels per cm	201.97
Width (cm)	38.06
Height (cm)	29.17
Vertical threads Mode	13.60
Vertical threads Mean	13.33
Vertical threads Deviation	1.36
min - max vertical values to compute statistics	4.00 - 30.00
Horizontal threads Mode	12.00
Horizontal threads Mean	12.17
Horizontal threads Deviation	0.74
min - max horizontal values to compute statistics	4.00 - 30.00
Scale FFT	4
Shift Fraction	0.25
Number of windows	2.00
Rotation angle	0.00
Maximum deviation angle (degrees)	25.00
Type of window	hamming
Type of pre-processing	STD + Mean

Table 4.2 Description of the saved images.

Image name termination	Image description
_HorizontalThreadsAngle	Image with the angle deviation of the horizontal threads
_HorizontalThreadsCount	Image with the thread counting of the horizontal threads
_HorizontalThreadsCountHist	Image with the histogram of the thread counting for horizontal threads
_VerticalThreadsAngle	Image with the angle deviation of the horizontal threads
_VerticalThreadsCount	Image with the thread counting of the horizontal threads
_VerticalThreadsCountHist	Image with the histogram of the thread counting for horizontal threads
_original	Original image
_selectedProcessedRegion	Selected area of the original image processed

Table 4.3 Description of the saved images if the overlap option is activated.

Image name termination	Image description
_HorizontalThreadsAngleOverlap	Image with the angle deviation of the horizontal threads
_HorizontalThreadsCountOverlap	Image with the thread counting of the horizontal threads
_VerticalThreadsAngleOverlap	Image with the angle deviation of the horizontal threads
_VerticalThreadsCountOverlap	Image with the thread counting of the horizontal threads

5 Parameters

PARAMETERS are quite important for a correct performance of the algorithm. However, to understand their impact one must first know how the algorithm works. We next provide an overview of it including and explanation of the parameters involved at every step.

5.1 Algorithm overview

The software centers a square window of size $(m \cdot 1) \times (m \cdot 1)$ cm in the X-ray to compute the counting and the angle deviation. This window is shifted $n \cdot m$ cm each time in both horizontal and vertical directions, where n is a fraction of the window size m. For each shift, it computes the thread counting and angle deviation within the $m \times m$ square. The result will be one color pixel in the results images: horizontal and vertical thread counting and angle deviation.

A thread counting and angle deviation estimation algorithm is used in the computations for every $m \times m$ square. One important parameter of this algorithm is the number of points, p, computed. A low value for the number of points computed, p, involves less computational demanding operations but provides a worse resolution. On the contrary, a high value for p provides a good resolution but leads to a larger execution time.

The algorithm returns an estimated value for every thread counting value. Then the maximum values for vertical and horizontal threads are searched and these values are the ones showed in the results and used in the histograms. The algorithm searches for the maximum values within a given range, $[v_{min}, v_{max}]$ and $[h_{min}, h_{max}]$ for the vertical and horizontal threads respectively.

The thread counting for vertical threads is performed studying variations along the horizontal axis. However, the fabrics usually exhibit a rotation that slightly varies along the image. Hence, the algorithm first computes the angle around the horizontal axis that presents the maximum vertical thread counting. This angles is searched within a $\pm\alpha$ degree range. Since the whole image may have a rotation, the program allows for a rotation,

β, of the whole processed window before looking for these maximum. All angles are in degree units and are positive counter-clockwise.

5.2 Possible and Defaults values

The program include a set of default values. These values can be customized in the menu Processing parameters / User's parameters. The description, default values and possible values are included in Table 5.1. These values are discussed in the following.

- **Resolution scaling.** The resolution of the thread counting, that can be observed as the base width of the bars in the histograms, depends on this parameters, denoted as p. The obtained resolution can be computed as $s/(p \cdot 128)$ where s is the number of pixels per centimeter in the image. As p grows we have a better resolution, but the computing times increase. The default value is 4, and possible values are in the range 1 to 16. Powers of two are recommended to optimize the computing time, hence recommended values are 1,2,4,8,16.
- **Side of the window.** The size of the square window used as a moving mask to study the threads frequencies is allowed to change in steps of 1 cm, hence it can be viewed as the number of 1×1 cm. Accordingly, parameter m can be a integer between 1 and 10, and the default value is $m = 2$.
- **Shift fraction.** In every step of the algorithm the window of size m is shifted $n \cdot m$ to compute new values. The default value for $n = 0.25$ and it should be in the range $0.01 \leq n \leq 1$. Note that the maximum shift is 1, meaning that no overlap is performed.
- **Minimum and maximum vertical and horizontal counting.** By default, the software performs the thread counting for default values between 4 and 25 threads/cm. Points out of this selected range are regarded as meaningless points, i.e. regions where the counting could not be performed. Note that later, in the histogram the user can further limit the visualization range. But this is just to adjust, by zooming, the observed range. To change the computation range you must change the parameters in the program menu.
- **Maximum deviation angle.** The counting algorithm looks for the maximum frequency in the horizontal and vertical directions. However, if the image is distorted by a rotation this maximum frequencies are found in some directions ρ where ρ should be a low value. The algorithm looks for the maximum in any direction from $-\alpha$ to α for the horizontal direction and from $90-\alpha$ to $90+\alpha$ in the vertical one. The default value for this angle is *ese* degrees, and it should be in the range 5 to 45. Notice that this value should not be larger than this value.
- **Rotation angle.** If all the image is rotated by an angle $-\beta$, in the processing we can indicate to rotate it by β. The default value is $\beta = 0$.

Important: If you change any value do not forget to click on the Accept button.

Table 5.1 Parameters.

Parameter description	**Default**	**Range**
Resolution scaling (p)	4	$p = 1,2,...,16$
Shift fraction (n)	0.25	$0.01 \leq n \leq 1$
Side of the window, (m in cm)	2	$m = 1,2,...,10$
Maximum deviation angle, (α, degrees)	5	$\leq \alpha \leq 45$
Rotation angle, (β, degrees)	0	$-45 \leq \alpha \leq 45$
Minimum vertical thread counting, (v_{min} in thread/cm)	4	$0 \leq v_{min} \leq v_{max}$
Maximum vertical thread counting, (v_{max} in thread/cm)	25	$v_{min} \leq v_{max} \leq 100$
Minimum horizontal thread counting, (h_{min} in thread/cm)	4	$0 \leq h_{min} \leq h_{max}$
Maximum horizontal thread counting, (h_{max} in thread/cm)	25	$h_{min} \leq h_{max} \leq 100$

Hint: you could set the resolution scaling to a low value first, to perform some first trials, and then, for the final counting estimation, increase its value. You can also use a high value for the shift fraction first, then set it to a lower value for the final counting estimation.

In Figure 5.1 we include the results of the analysis as in Figure 2.6 but changing the Shift fraction parameter to 0.1. Hence, in the color image, when we move from one pixel to the next one, we are shifting 0.2 cm in the canvas. Besides we set to 8 the Resolution scaling. In the histograms it can be observed that we have double the bars we got for 4.

5.3 Preprocessing

Preprocessing is a crucial step in the thread counting with frequency analysis. We performed a local equalization of the mean followed by the standard deviation (STD). If results are somehow below expected, you might try to select the Pre-processing type field to "None" or just to the mean-based equalization (Mean).

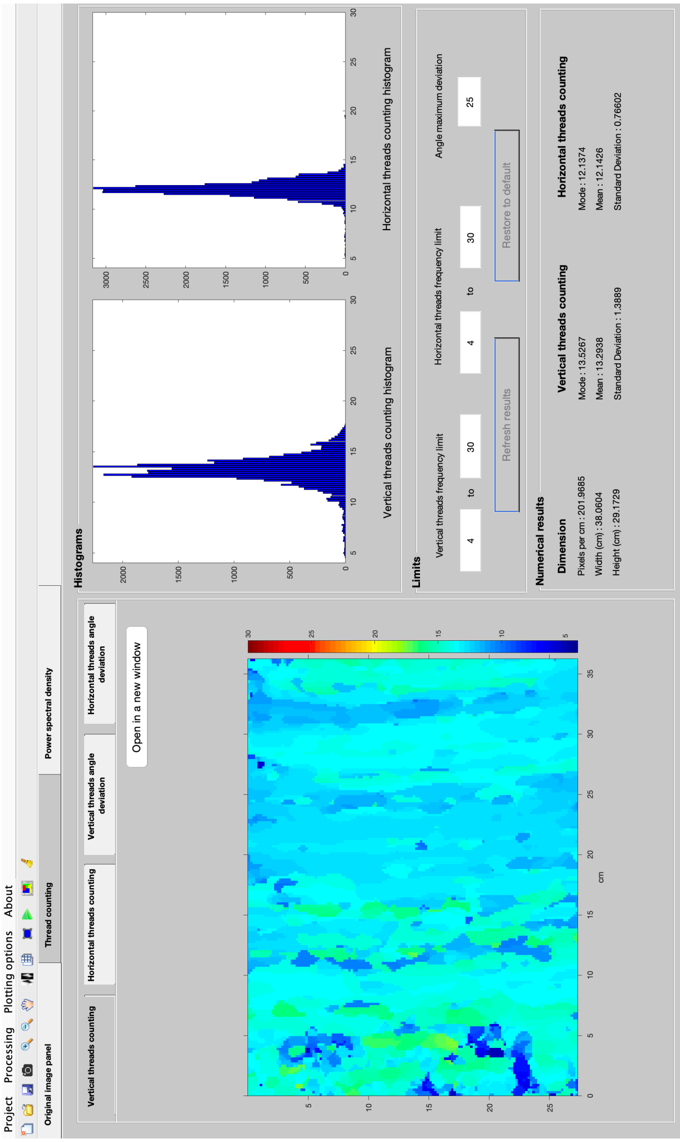

Figure 5.1 Result of the tread counting algorithm for the whole image, showing the image with the color density map for the vertical threads. Parameter Resolution scaling was set to 8 and Shift fraction to 0.1.

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- F. J. Simois-Tirado, J. J. Murillo-Fuentes, "On the power spectral density applied to the analysis of old canvases," Signal Processing, 2017, Vol. 143, pp. 253-268.

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6.11 Miscellaneous

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The possible invalidity or ineffectiveness of any provision of this license under applicable law will not affect the overall validity or effectiveness of the license. In such cases, the provision will be interpreted or reformulated as appropriate to make it valid and effective.

The MNP and the University of Seville may publish other or new versions of this license as necessary and reasonable without reducing the scope of the rights granted by the license. The new versions of the license will be published with a unique version number. All versions of this license are of equal value.

6.12 Competent Courts

Acceptance of this license entails the waiver by the licensee of any claim or litigation. In any case, disputes relating to the interpretation of this license that arise between the parties will be submitted to the Spanish Courts for the resolution of any divergences not amicably resolved that may arise from the interpretation or execution of this contract.

6.13 Applicable Law

Without prejudice to any specific agreement between the parties, this license will be governed by Spanish law.

Appendix A
Image Format

In Table A.1 we include some the fields of the format of an example image.

Table A.1 Fields of the format of an example image.

Field	Value
Filename	[1x88 char]
FileModDate	'05-jun-2014 17:26:28'
FileSize	47857960
Format	'tif'
FormatVersion	[]
Width	7848
Height	6095
BitDepth	8
ColorType	'grayscale'
FormatSignature	[73 73 42 0]
ByteOrder	'little-endian'
NewSubFileType	0
BitsPerSample	8
Compression	'Uncompressed'
PhotometricInterpretation	'BlackIsZero'
StripOffsets	24356
SamplesPerPixel	1
RowsPerStrip	6095
StripByteCounts	47833560
XResolution	508
YResolution	508
ResolutionUnit	'Inch'
Colormap	[]
PlanarConfiguration	'Chunky'
TileWidth	[]
TileLength	[]
TileOffsets	[]
TileByteCounts	[]
Orientation	1
FillOrder	1
GrayResponseUnit	0.0100
MaxSampleValue	255
MinSampleValue	0
Thresholding	1
Offset	8
Software	'Adobe Photoshop CS3 Windows'
DateTime	'2013:08:06 09:29:15'
Artist	[1x43 char]
XMP	[1x15295 char]
ITPC	[11x1 double]
Photoshop	[8642x1 double]
DigitalCamera	[1x1 struct]