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‘Fourier App’ Braid Angle Measurement App

This document is a walkthrough of how to use the FourierApp, an image processing tool that allows for the braid angle of a mesh structure to be measured from an image.

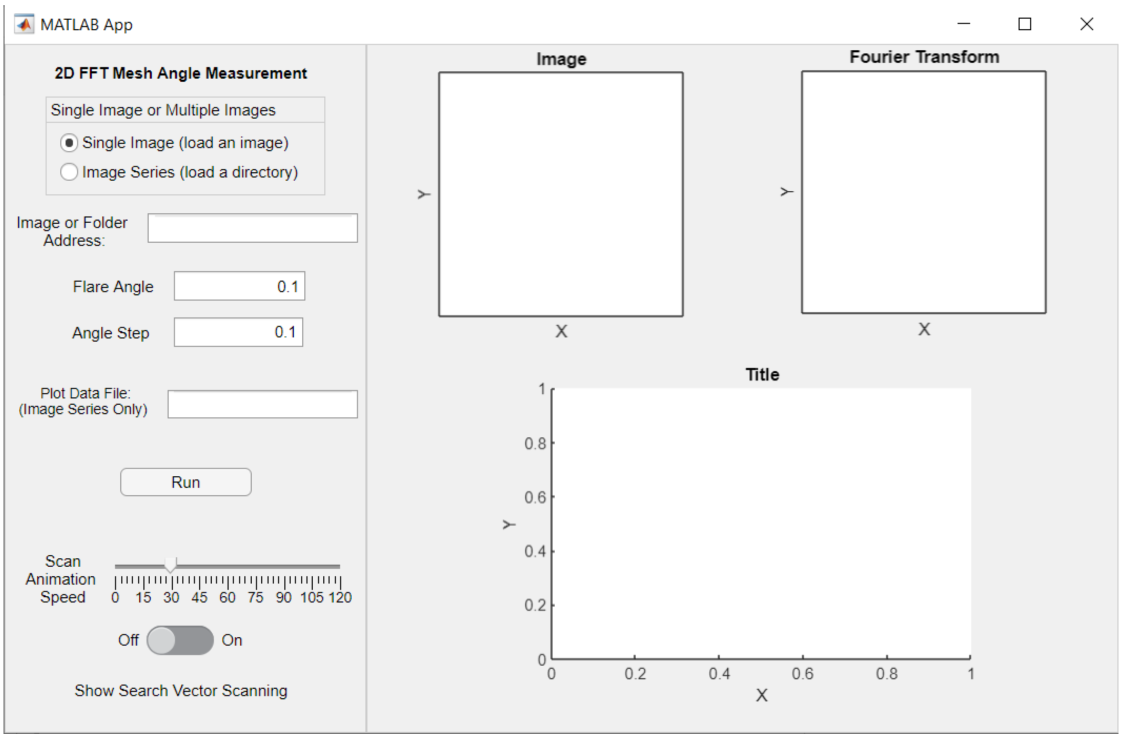

Figure 1. App View.

There are two modes of use:

I. Single Image
II. Image Series

I. Single Image Walkthrough

This mode allows a single image to be ran. The output of this mode is a plot which shows the distribution of the mean pixel intensity for each direction 0-180 degrees and displays the braid angle.

First, view the image to ensure that it is properly oriented. The following is the proper orientation:

Figure 2. Proper image orientation.

The braided structure should be oriented such that the angle between the fibers which the user desires to measure is bisected by the horizontal. If it is not, rotate the image until the braided structure runs horizontally.

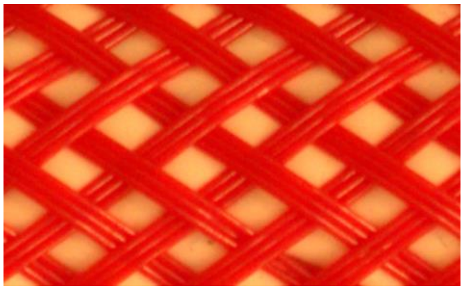

Figure 3. Zoomed in view of proper orientation.

The angle which this app will measure will be defined as half that angle between the fibers, and the variable name is the Braid Angle, α. This is effectively the same as the angle between the fiber direction and the horizontal, which is the proper definition of the Braid Angle.

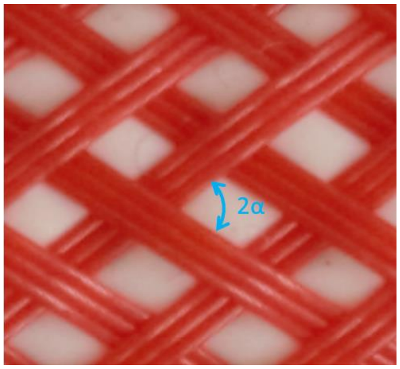

Figure 4. Braid Angle.

After the image is oriented properly, copy and paste the image file path into the text edit field labeled: 'Image or Folder Address'.

The image is now ready to process. If the user desires to see an animation of how the search vector sweep or "scan" works, the 'Show Search Vector Scanning' switch can be set to 'On' and the 'Scan Animation Speed' can be chosen using the slider. This will affect the processing speed, so it should be left off if the user wants to quickly process the image.

Press 'Run'.

A pop-up window of the image which the user chose to run will show up. Click and drag to create a square section of the region of the image to process. Double click the section to continue. In examples such as Figure 2, this is useful as the whole image is not needed, rather just a small square section. **The aspect ratio of the section will be locked so the user can only create a square. If the aspect ratio is not 1, the measurement of the braid angle will not be accurate.**

Three figures will show up on the App's RHS panel.

1. Image of the selected square section
2. Image of the Frequency Spectrum (created by the 2D Fourier Transform) of the selected section.
3. Plot of the Mean Pixel Intensity vs Angle showing the mean pixel intensity in each direction detected by the search vector as it swept around 0-180 degrees. **Note: only sweeps 0-180 degrees as the frequency spectrum is axially symmetric.**

If the animation is turned 'On', the animation will play over the Frequency Spectrum image.

The Braid Angle will be displayed on the plot also.

II. Image Series Walkthrough

The process used for the image series mode is similar to the Single Image Mode. This mode is useful for portraying the behavior of a braided structure (artificial muscle) throughout the duration of a test or something similar. For example, if one wanted to measure what happened to braid angle as the pressure was increased incrementally, pictures could be taken every 5 psi and then a plot of the braid angle vs pressure could be made. The same could be done for braid angle vs stress, braid angle vs strain, etc.

The run mode is set to ‘Image Series’ for this function.

First, put the images in a folder and ensure the nomenclature of the images will allow MATLAB to determine the order. Something like ‘DSC_4111.png’, ‘DSC_4112.png’, etc. will work. This folder must contain only the images.

Second, verify the orientation of the images and ensure the artificial muscle (or other) is in the same location in all pictures. That is, if you were to crop a section of any image to view a close up of the braid, the cropped section location should allow proper analysis of any other image in the folder.

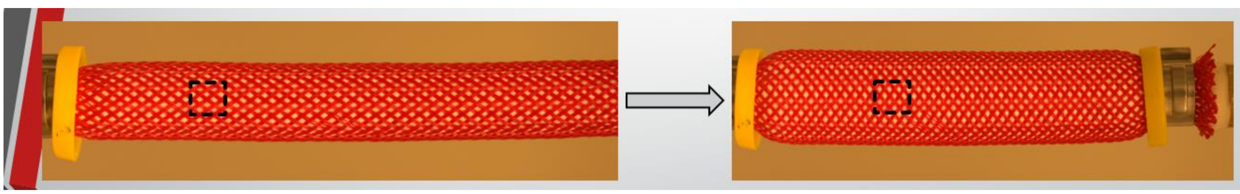

Figure 5. Cropped Section As the muscle contracts, the cropped section location (marked by the square) is stationary from image to image relative to the left end of the muscle, and still resides in the middle of the muscle to allow for useful information to be gathered.

Once the images are confirmed to be oriented properly, copy the address of the directory containing the images, and paste it in the ‘Image or Folder Address’ text field.

Next, create a text file that details the data you would like to plot against the braid angle. If one took three images during a quasi-static test of an artificial muscle at pressure values of 0,5,10 psi, the text file would look like this:

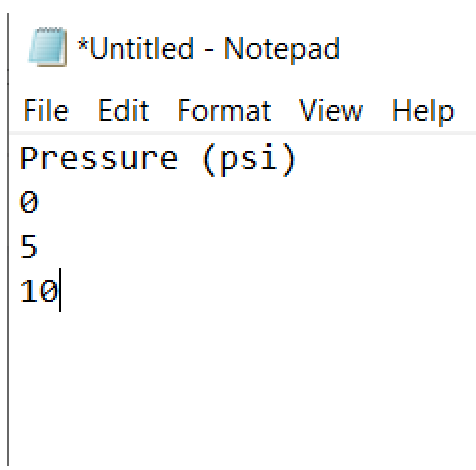

Figure 6. Text file.

This will be used later for plotting purposes. The first line of this file will be the x-axis label for a plot detailing the relationship between that braid angle and that variable.

Save the text file. Copy and paste the file address in the second edit text field, labeled 'Plot Data File'. **Note: length of data in this file and number of images must match.**

Now choose whether to add animation, and press 'Run'.

As with the single image mode, a pop up window of the first image in the folder will appear. Click and drag a square section on this image to process. This section size and location will be used on every other image in the folder, as the program assumes the muscle or other braided structure is held stationary (aside from contraction or expansion) between images.

The program will iterate through the images, showing the sections and corresponding frequency responses. Once it finishes running through the images, a plot showing Braid Angle vs <Plot Data File Variable> will show up.

For demonstration purposes, 11 images of a digital mesh structure with varying braid angle is run. The braid angle value increases from 31 to 51 degrees in steps of 2 degrees.

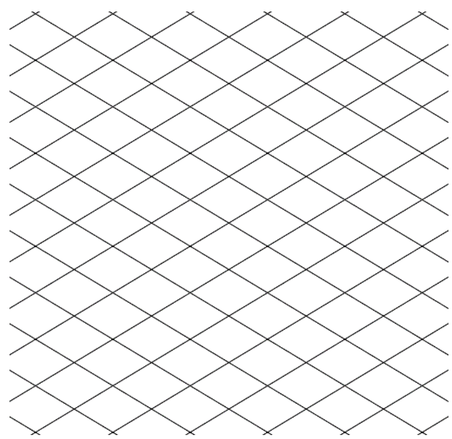

Figure 7. Digital Mesh Structure.

A plot data text file that looks as follows is created:

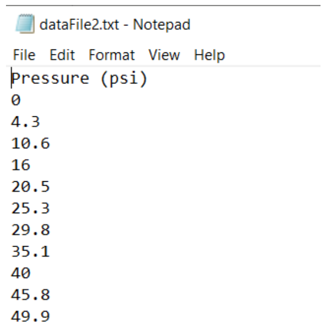

Figure 8. Data File. Random pressure values increasing from 0 – 49.9.

After running this data, the following plot is made.

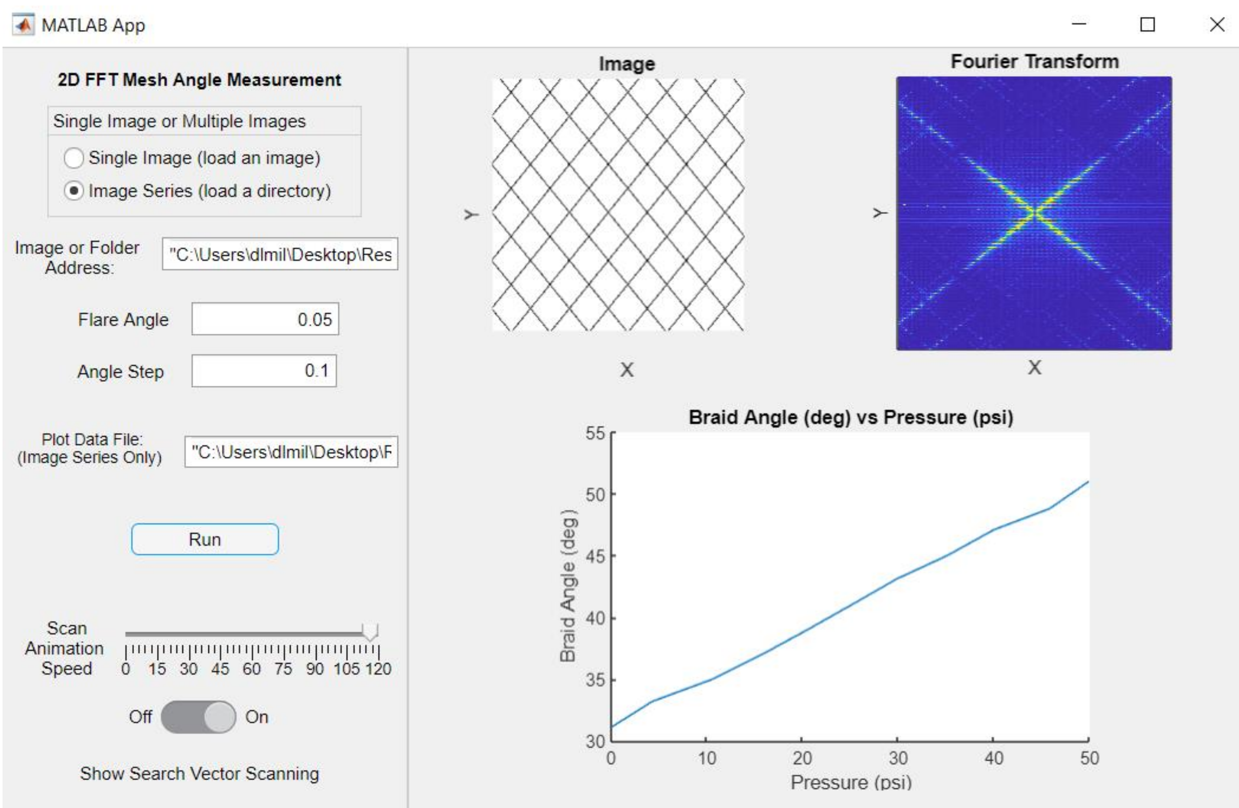

Figure 9. Image Series Test Plot.

From this plot, it can be seen that with the artificial data and digital mesh images, the braid angle increases approximately linearly with increasing pressure.

Limitations

The main limitation is resolution. The image resolution must be above around 250 dpi for reliable results. Anything lower than this and the precision of this program drastically falls off and can produce somewhat random results. With increasing resolution on the other hand, the precision increases, and the braid angle measurement converges.

Another limitation is that this program can only be used with braided structures that have braid angles less than about 70-80 degrees and more than 10-20 degrees. Most braided structures (especially artificial muscle braid materials) would meet this criteria, so it is not very problematic. This problem occurs because there is some non-physical response in the frequency spectrum along the horizontal and vertical directions which can alter the results of the angle measurement. These occur likely due to the fact that the image is square shaped and has flat sides. When the braid angle is between the boundaries mentioned, or between about 20 – 70 degrees, this is not an issue whatsoever as a cushion is programmed into the app which causes the non-physical responses near the 0,90, and 180 directions to not be considered in angle determination. Otherwise, there would be a spike in mean-pixel intensity in these directions which do not refer to anything real in the image.

Sources

Fuzhong Bai, Jun Kong, Tieying Zhang, Yongxiang Xu, Xingrong Shi, "Angle measurement for cross-line target image based on fourier-polar transform algorithm," Proc. SPIE 11053, Tenth International Symposium on Precision Engineering Measurements and Instrumentation, 110532D (7 March 2019); https://doi.org/10.1117/12.2511908

Hunt, A. J., & Carey, J. P. (2019). A machine vision system for the braid angle measurement of tubular braided structures. *Textile Research Journal*, *89*(14), 2919–2937. https://doi.org/10.1177/0040517518803792