Speckle Tool MATLAB App Documentation

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Contents

1 Introduction **3**

2 Quality measurement metrics **3**

2.1 Mean Intensity Gradient (MIG) 3

2.2 Speckle Size 4

2.3 Shannon Entropy 4

3 Instructions on usage **5**

4 Benchmark images **7**

4.1 Shannon entropy 7

4.2 Mean intensity gradient 7

5 Conclusions **8**

1 Introduction

The following app was designed on MATLAB for researchers to evaluate the quality of the speckle pattern used in digital image correlation (DIC).

DIC is an optical method used to measure surface deformation and strain of a body under load in various applications. In doing so, a black-and-white speckle pattern is applied to the body. Measurements of deformation use image-correlation algorithms to monitor the displacement of subsets in the pattern [4]. Therefore, it is important to have a uniquely varied speckle pattern with optimal gradient variation and speckle size. In order to measure these characteristics (as well as others), quantifiable metrics need to be devised.

2 Quality measurement metrics

The following metrics are used to evaluate the quality of the speckle pattern applied:

1. Mean Intensity Gradient (MIG)
2. Speckle Size
3. Shannon Entropy

These three metrics and their mathematical calculations shall be explained in brief below.

2.1 Mean Intensity Gradient (MIG)

Mean intensity gradient is a metric which measures globally the variation of the modulus of a intensity gradient vector [3]. It is defined as:

$$\delta_f = \sum_{i=1}^{W} \sum_{j=1}^{H} |\nabla f(x_{ij})| / (H \times W) \tag{1}$$

Where H is the height (in number of pixels) of the speckle pattern image and W is width (number of pixels) of the image. Here $\nabla f(x_{ij})$ is the modulus of the gradient vector [3], which in turn is defined as:

$$\nabla f(x_{ij}) = \sqrt{f_x(x_{ij})^2 + f_y(x_{ij})^2} \tag{2}$$

Here, $f_x(x_{ij})$ and $f_y(x_{ij})$ are directional derivatives of the pixel intensity in the x- and y-directions respectively. These derivatives are computed with the use of a finite difference method and a Sobel operator (normally used for edge detection).

2.2 Speckle Size

The next metric which can be determined takes a morphological approach. The app outputs the average speckle size of a grey-scale image, where speckle size is measured in number of pixels.

In order to do this, first the image must be binarised, with all speckles falling below a threshold value (from between 0 to 255 for an 8-bit image) forming the background, while speckles with intensity value greater than this threshold form the foreground or main pattern. The threshold value for binarisation is determined using Otsu's thresholding algorithm.

The optimal threshold value is the one that maximises variance of grey-level distribution between background and speckle pixels [2]. This inter-class variance is calculated as:

$$\sigma_B^2 = \omega_0\omega_1(\mu_1 - \mu_0)^2 \tag{3}$$

Here, ω_0 is the cumulative probability of all pixels in the background (that is, with a grey level intensity higher than the threshold value). Similarly, ω_1 is the cumulative probability of all pixels darker than the threshold value [2].

μ_0 and μ_1 are the weighted mean class levels of background and speckle pattern respectively. These are given as:

$$\mu_0 = 1/\omega_0 \sum_{i=1}^{k} ip(i) \tag{4}$$

$$\mu_1 = 1/\omega_1 \sum_{i=k+1}^{L} ip(i) \tag{5}$$

Where the k^{th} grey level is the proposed threshold and there are L grey levels in total in the image [2].

2.3 Shannon Entropy

Shannon entropy is a concept borrowed from information theory, where it associates the amount of 'information', which is equal to the logarithm of the probability of an event occurring [1]. In terms of a discrete random variable such as the distribution of grey levels among the pixels of a speckle pattern, the Shannon entropy of the image is given as:

$$H(X) = -\sum_{i=0}^{255} p(a_i) * log_2(p(a_i)) \tag{6}$$

In other words, for a random variable, the 'entropy' is the sum of log of probability multiplied by the probability. This entropy value is an expected value $E(X)$. Here, $p(a_i)$ is the probability of each grey level occurring (i.e. however many pixels possess this grey level out of the total number). For an 8-bit image, grey levels will range from 0 to 255 [1]. The minus sign ensures that the entropy value is always a positive (or zero) value.

3 Instructions on usage

The app is simple and intuitive to use and has some supplementary features for extra information. It can be run as follows:

1. On opening the app, the screen will look like shown in Figure 1. The load view window is blank because a speckle pattern image has not been uploaded yet.

2. Select load and the current path folder will appear. From this folder, select the speckle pattern you choose to evaluate. This should be *saved as a .jpg or .png file.* The selected image will load in the 'Loaded Image' window.

3. If so desired, this image can be cropped by pressing the 'Crop' button. This will open another window with the image. The cursor can be used to select a sub-region of the image.

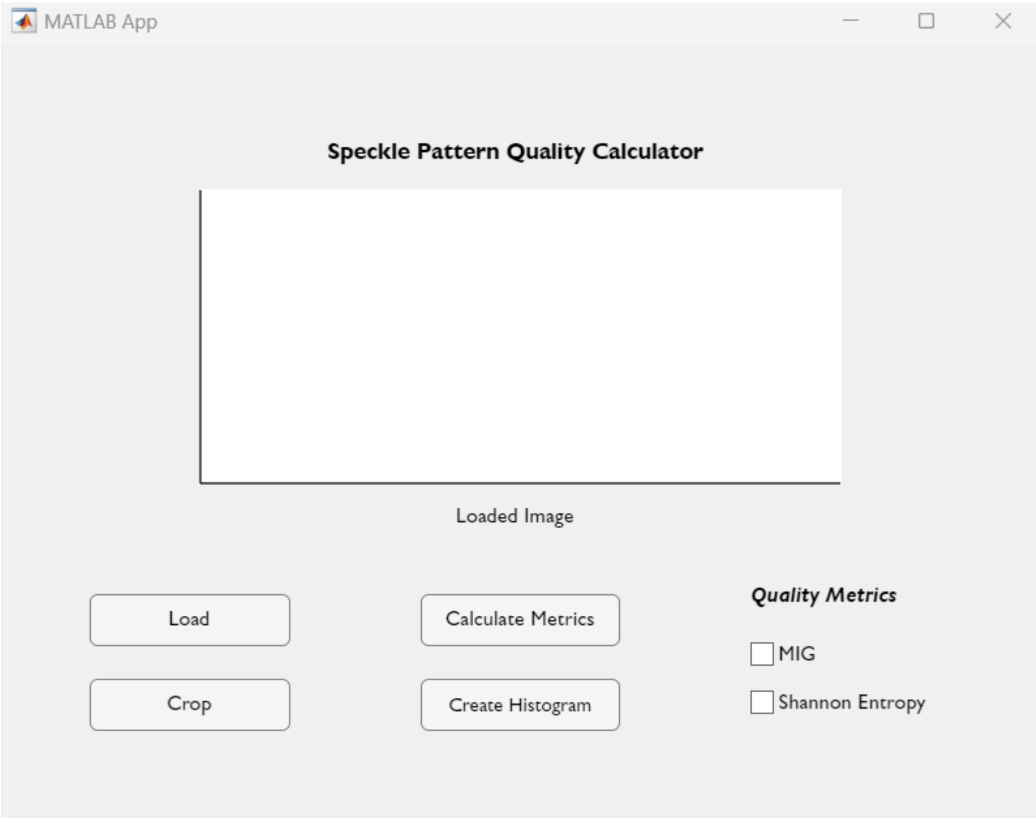

Figure 1: *Load view window upon immediately opening the app.*

4. Under 'Quality Metrics' option on the right hand side, whichever metrics the user wants can be selected. Then 'Calculate Metrics' is pressed to calculate the results. Results will appear in the Command Window.

5. Finally, the 'Create Histogram' button in the central column of buttons enables the user to generate a grey-value histogram of the image (with grey values from 0 to 255). The generated histogram is automatically saved in the current path folder under the name 'Filename_histogram.fig', where 'Filename' is the name of the speckle pattern file selected.

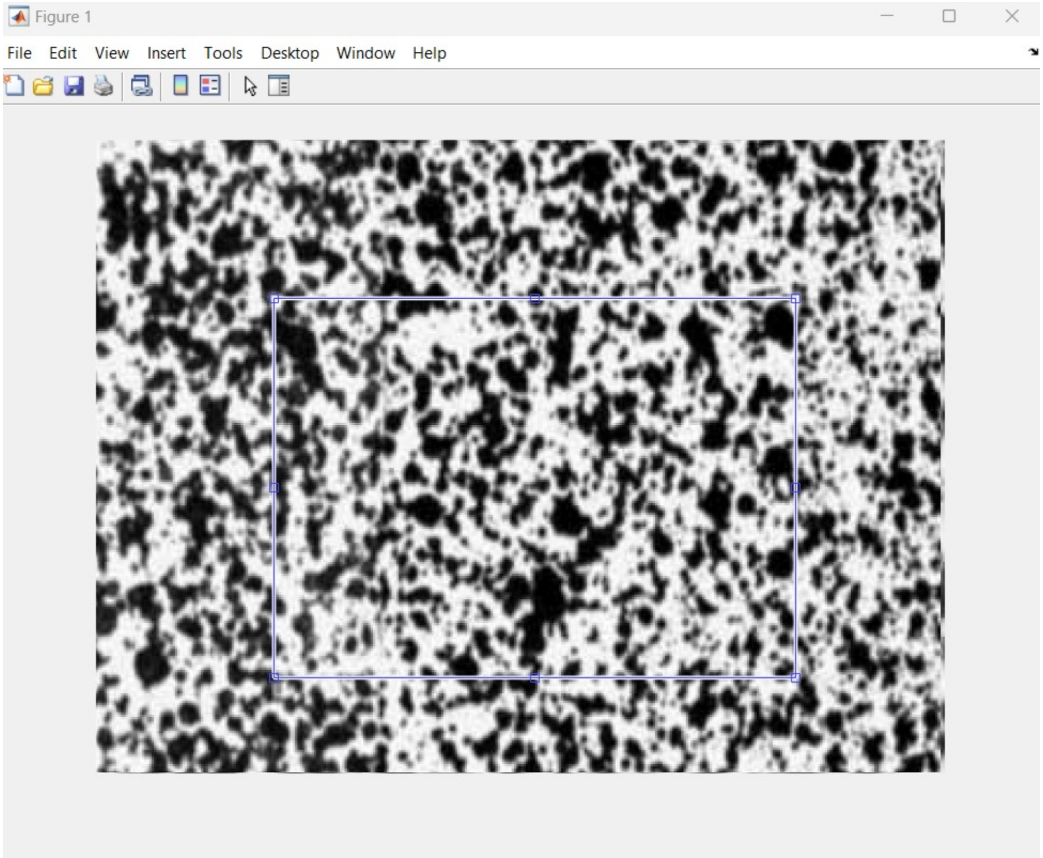

Figure 2: *Crop view window with a sub-region selected.*

4 Benchmark images

4.1 Shannon entropy

The benchmark image is taken from reference [1], Figure "Shannonspeckle.jpg". The current version of the app calculates 7.5249, while the original paper reports 7.2985. The relatively small difference may be due to the fact that we downloaded and cropped the speckle from the image file available online, which might result in lossy data compression.

4.2 Mean intensity gradient

The benchmark image is taken from reference [5], Figure 7. The current script calculates 25.92, as per the value reported in the paper.

5 Conclusions

This app hopes to combine several quality metrics in one accessible package in such a way that is easy and intuitive for researchers to use. In doing so, several metrics can be determined simultaneously, thus enabling comparisons between each other. This should compensate for some of the drawbacks of each metric taken individually.

Furthermore, the app includes some additional functionality for the user to tailor the image to the desired result, such as a cropping tool.

References

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