Assignment 6

This assignment is due by 11:59 p.m. on Friday, March 20. All reports should be submitted as PDFs. Only one report must be submitted per team, but all team member's names must appear on the report.

Part 1: Detecting Image Contrast Enhancement

In many scenarios, it is important for a forensic investigator to understand how a digital image has been processed. One family of image processing operations which we studied earlier in this course is contrast enhancement operations. These operations apply a nonlinear mapping to the pixel values of a digital image to effectively increase they dynamic range of pixel values. This has the effect of increasing the visual contrast of a digital image.

In class, we examined how contrast enhancement operations introduce fingerprints into a digital image's pixel value histogram. For a number of reasons, we can model the pixel value histogram of an unaltered digital image as some "smooth" function. Contrast enhancement fingerprints take the form of impulsive peaks and gaps into an image's pixel value histogram.

- Visually examine the pixel value histograms of the images **imageCE1.tif**, **imageCE2.tif**, **imageCE3.tif**, and **imageCE4.tif**. Based off of your knowledge of contrast enhancement fingerprints, which of these images are likely to have been contrast enhanced?

  Note: It may be useful to use the Matlab command *imhist* to calculate the image's pixel value histogram. When plotting the histogram, however, it is often more useful to use the *bar* functin to display the histogram rather than *imhist* which displays the histogram as a stem plot.

- Examine the pixel value histograms of the unaltered images **unaltIm1.tif**, **unaltIm2.tif**, and **unaltIm3.tif**. Next, apply gamma correction with $\gamma = 0.7$ to each of these images and examine the pixel value histograms of the gamma corrected images. Repeat this procedure again, but this time modify each of the unaltered images using with $\gamma = 1.3$.

  What influence does the unaltered image's pixel value histogram have on the location and amplitude of the contrast enhancement fingerprints in each of the gamma corrected images. What influence does the contrast enhancement mapping (in this case specified by the value of γ) have on the location and amplitude of the contrast enhancement fingerprints in each of the gamma corrected images. Include the pixel value histograms of each of the unaltered and contrast enhanced images in your report.

- In class, we discussed the unique artifacts introduced into a "smooth" pixel value histogram by both contractive and expansive mappings. The image **imageCE5.tif** has been contrast enhanced using gamma correction. Examine its pixel value histogram and identify which regions of the contrast enhancement mapping are locally expansive and which are locally contractive. Based off of this information, is γ greater than 1 or less than 1?

Part 2: Detecting Image Resampling and Resizing

Image resampling operations are another family of image processing operations which a forensic investigator may wish to detect. Most commonly, image resampling occurs when a digital image is resized. In class, we discussed how image resampling fingerprints can be detected using the method proposed by Popescu and Farid which makes use of the Expectation-Maximization (EM) algorithm, as well as the more computationally efficient algorithm proposed by Kirchner.

Rather than making use of the computationally expensive EM algorithm to estimate the relationship between pixels, Kirchner's resampling detection algorithm uses a fixed linear prediction filter to approximate this relationship. Kirchner was able to demonstrate that the variance of the resulting prediction error will be periodic, regardless of the linear prediction filter used. As a result, an approximation of an image's p-map can be computed without needing to use the EM algorithm to calculate the optimal prediction filter.

Kirchner's algorithm for efficiently approximating an image's p-map can be summarized as follows:

1. Obtain a prediction $\hat{I}(x,y)$ of the value of each pixel on the basis of its neighboring pixel values by filtering the image $I(x,y)$ using the linear prediction filter

$$\alpha^* = \begin{bmatrix} -0.25 & 0.50 & -0.25 \\ 0.50 & 0 & 0.50 \\ -0.25 & 0.50 & -0.25 \end{bmatrix} \tag{1}$$

2. Calculate the resulting prediction error $e(x,y)$ according to the formula $e(x,y) = I(x,y) - \hat{I}(x,y)$.

3. Calculate the approximate p-map p using the equation

$$p(x,y) = \lambda \exp\left(-\frac{e(x,y)^\tau}{\sigma}\right). \tag{2}$$

- Write a Matlab function that uses Kirchner's algorithm to calculate an image's p-map. This function should accept the image to be examined as an input and a matrix corresponding to the image's p-map as the output. When calculating the image's p-map, set $\lambda = 1$, $\tau = 2$, and $\sigma = 1$. Please fully comment your code and append it to your report.

- Use your Matlab function to calculate the p-maps of the images **resampIm1.tif**, **resampIm2.tif**, **resampIm3.tif**, and **resampIm4.tif**. Visually examine these p-maps and include them in your report. Which of these p-maps exhibit periodic properties that are indicative of image resampling?

  Note: It may be useful to use the function *imagesc* to display each image's p-map.

- Use the Matlab function *showFreqPmap* provided on the course's Blackboard page to plot the magnitude of the Fourier transform of the image's p-map. Which of these plots contain resampling fingerprints? Include the plot of the magnitude of the Fourier transform of each image's p-map in your report. If contrast enhancement fingerprints are present in an image, clearly label these fingerprints.