Image Enhancement

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1. **Introduction**

Computer assignments aim to study the effects of various image processing methods such as contrast enhancement, spatial filtering, median filtering, and edge sharpening. All goals were accomplished using MATLAB code [1].

2. **Theory**

   a. **Contrast Enhancement**

The contrast enhancement method uses histogram equalization [2] for mapping the image. There are two ways to accomplish this. It is histogram equalization and specification. The histogram equalization goal is to design a mapping that creates a uniform image histogram. The formula for the new y_l image is (1)

$$y_l = Int[\frac{(y'_l - y'_{min})}{1 - y'_{min}}(y_L - y_{L0}) + y_{L0} + 0.5]\ (1)$$

where y_L, y_{L0}- is smallest and largest intensity in the mapped image. Also $y_L - y_{L0}$ is a number of bins in the histogram of the new image.

The histogram specification is the method to design the histogram and tries to fit the image's histogram.

   b. **Spatial Filtering**

Spatial filtering is the method to use 2-D low-pass filters to decrease the noise of the image [3]. Using a mask is like in formula (2)

$$y(m, n) = \sum_{k,l \in W} \sum h(k, l)x(m - k, n - l)\ (2)$$

where $h(k, l)$ is filter.

   c. **Median Filtering**

Median filtering is a non-linear filtering process. The median filter operation involves sliding a window spanning an odd number of pixels like spatial filtering. Then the center pixel in the window is replaced by the median of the pixels in the window, as in (3)

$$y(m, n) = median[x(m - k, n - l)]\ (3)$$

d. Edge Sharpening

The edge sharpening images using the HPF operator or 2D gradient. A portion of this image with a gradient or high pass filter is added to the original image to sharpen or emphasize edges (4).

$$y(m,n) = x(m,n) + \lambda g(m,n) \quad (4)$$

g(m,n) is a suitable gradient computed for the mask centered at (m,n) and $\lambda > 0$ is a proportionality constant. The edge detection operators presented in the report are the Roberts, Prewitt, Sobel, and 2-D discrete Laplacian operators.

Robert operators is based on two 2x2 diagonal gradients (5).

$$g(m,n) = |x(m,n) - x(m+1,n+1)| + |x(m+1,n) - x(m,n+1)| \quad (5)$$

The Prewitt and Sobel operators are similar to the Roberts. It is based on approximating the first derivatives and detecting edges with different orientations.

The Laplacian operator is similar to Prewitt and Sobel but based on second oder derivatives. The edge operator is (6)

$$g(m,n) = 4x(m,n) - [x(m-1,n) + x(m+1,n) + \quad (6)$$
$$+ x(m,n-1) + x(m,n+1)]$$

3. Results and discussion

a. Contrast Enhancement

The Matlab code provides algorithmics for the histogram equalization with 16, 32, 64 bits on the "Pepsi" images. The result of processing the image is presented in Figure 1.

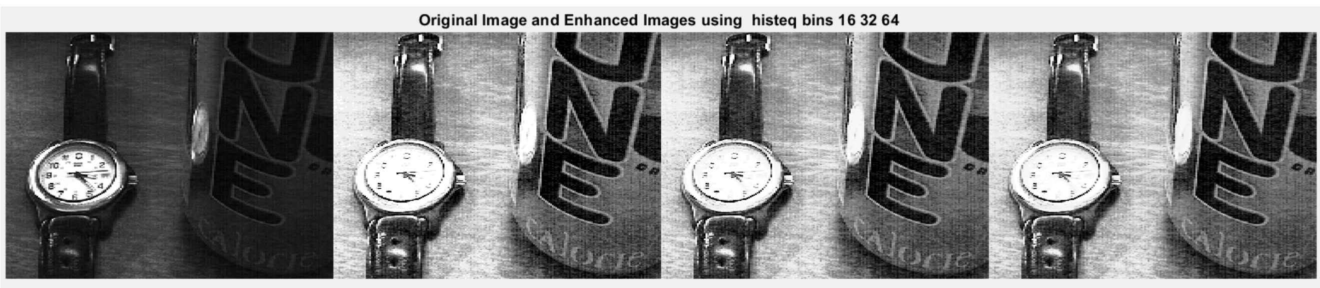

Figure 1 The original and process image with different bit histogram equalization.

The histogram of these images is presented in Figure 2.

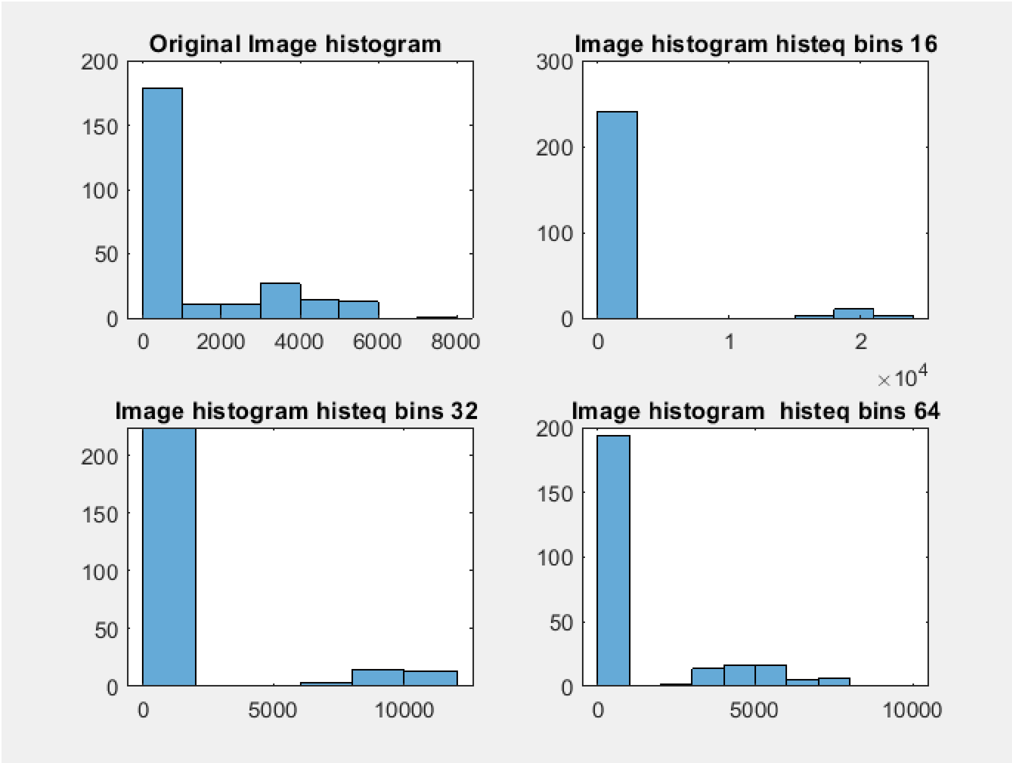

Figure 2 The original and process image equalization histograms.

The histogram is not uniform, and equalization decreases the number of high-frequency bars, increasing the image's brightness. The visual appearance of the new images is worth more than the original. A custom histogram was designed to increase the contrast and visuality, presented in Figure 3.

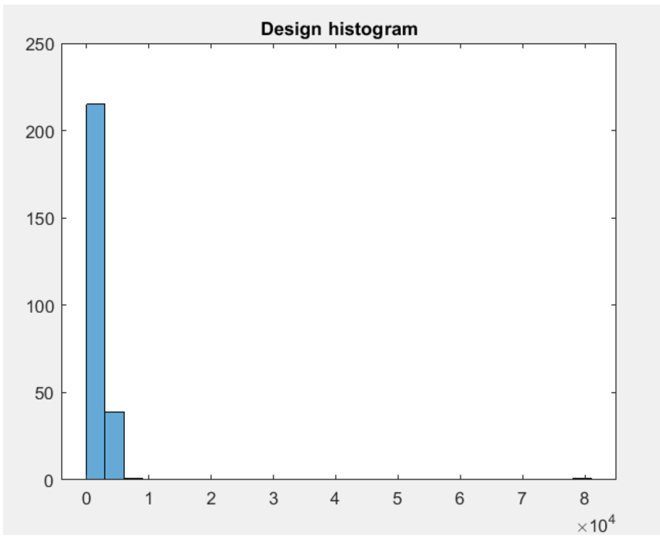

Figure 3 The design histogram

The histogram specification with the design histogram of the image is presented in Figure 4.

Figure 4 The original image after histogram specification.

The contrast of the image becomes better than the original image, but the quality of the image does not change. This method generally increases the overall contrast of many images, primarily when close contrast values represent the image data used. Also, the method allows for better distribution of the intensity on the histogram. Moreover, histogram equalization allows areas with lower contrast to receive higher contrast, which could be used on medical x-ray images to increase the poorly visible parts of the image. However, the method may increase the contrast of background noise while decreasing the usable part of the image.

b. Spatial Filtering

The Matlab code provides an algorithm for reducing noise by using different filters 2x2, 4x4, and 8x8. The result is presented in Figure 5.

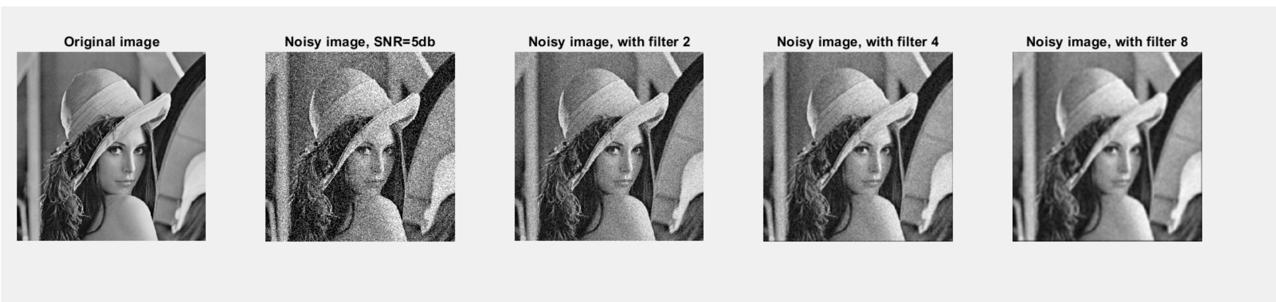

Figure 4 The original image, noise image, and filtering image.

The noise of filtering images with the two first filters decreased without bluring the image. The SNR of all three images is presented in Table 1.

Filter	2x2	4x4	8x8
SNR	2.4525	0.5611	0.1380

Table 1 The SNR of differnt filters.

All three filters reduce the noise of the images. The frequency selectivity characteristics are presented in Figure 5.

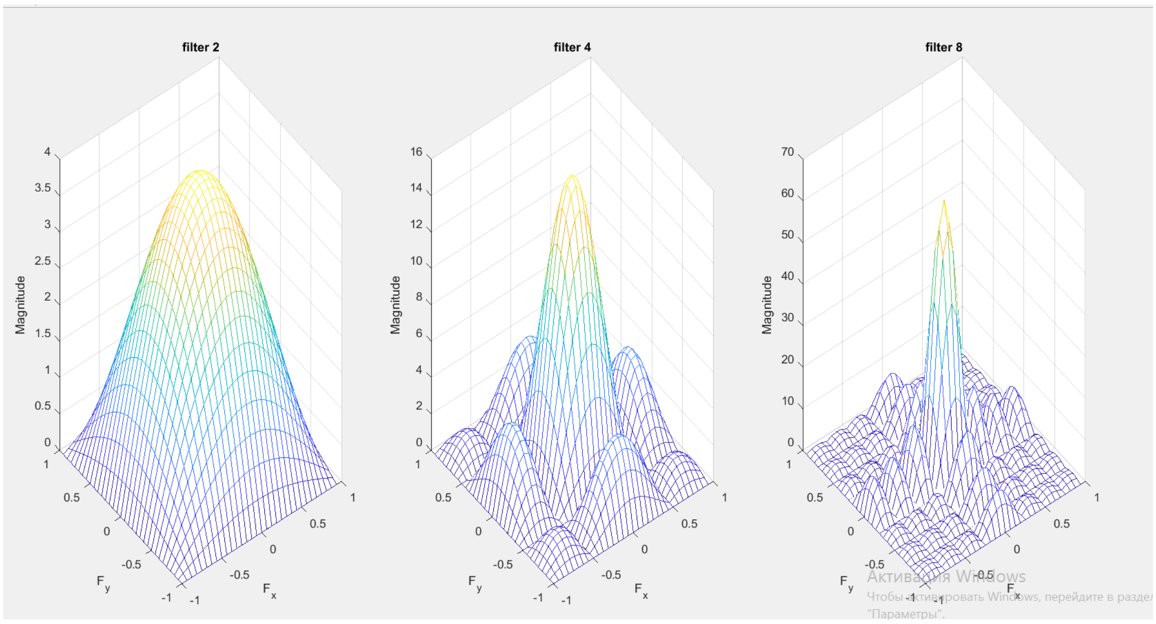

Figure 5 The frequency characteristic of filters.

The second and third masks have smaller bandwidth, hence better noise removal ability and more blurring artifacts. This method could significantly reduce the noise of the image. However, to get the best result, a low bandwidth filter needs to be used, which leads to blurring images, i.e., finding a balance between noise and image clarity. In some cases, a more effective way of decreasing noise could be found without losing the information.

c. Median Filtering

The Matlab code provides an algorithm for reducing “salt and pepper” noise by using different median filters 3x3, 5x5, and 7x7. The process of increasing the noise is presented in Figure 6.

Figure 6. The median filters of different noisy images

The 7x7 filters are best to decrease the noise of the image, but it most blurs the image because of the bandwidth. The 3x3 is the most clarity filter, but it does not handle the much noise images. The properties of 5x5 are between these two filters. Median filters reduce random noise, especially when the noise has periodic patterns. A significant advantage of the median filter over other filters is that the median filter can eliminate the effect of input noise values with huge magnitudes.

d. Edge Sharpening

The Matlab code provides an algorithm for edge sharpening of the image presented in Figure 7.

Figure 7. The original image.

The edge extraction is presented in Figure 8.

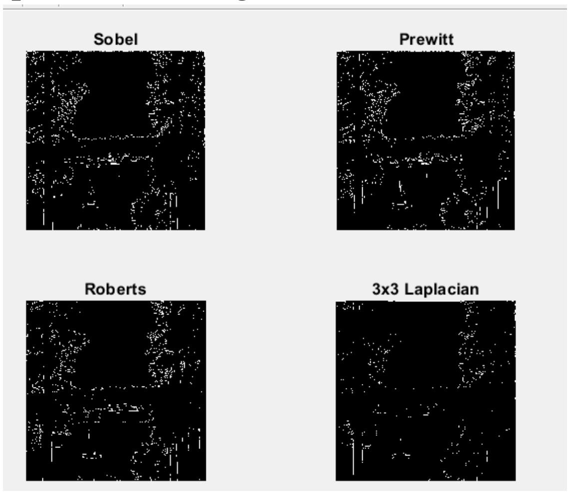

Figure 8. The edge of the image.

The combination of the original image and edge without saturation is presented in Figure 9.

Figure 9. The combination of the image.

The best filter is the Sobel, and after the combination, the images become more explicit and make an image appear sharper. Moreover, it looks like the resolution increased. Also, the viewers could clearly see the background and foreground parts of the image. However, high-pass filtering amplifies noise. That is why the noise could overwhelm the image. High-pass filtering can also cause small, faint details to be greatly exaggerated. The reprocessed image will look grainy and unnatural, and dark donuts will appear around the point sources. So while high-pass filtering can often improve an image by sharpening details, being overzealous can degrade image quality significantly.

4. Conclusion

The computer assignments show enhanced images differently. The computer assignments provide a method of decreasing the noise of the image. Also, assignments show how to change the image's contrast to select an object or improve image visibility. Moreover, the task provides a way to image quality by emphasizing the object shapes.

Reference

1. The official MATLAB site: https://www.mathworks.com/
2. The professor M.R Azimi lecture 17-18
3. The professor M.R Azimi lecture 19-20