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Entry Number - 2017MT10748
COL783 - Digital Image Analysis

DENOISING AND DEBLURRING
(Assignment - 2)

To demonstrate the results of the first 3 parts of the assignment, the image "Barbara.png" has been used.

BASIC DENOISING

In order to generate gaussian noise, random points following normal distribution with mean = 0 and standard deviation = 50 have been used so that 99.99% points lie in the range [-255,255]. Similarly, for creating salt and pepper noise, Pa = Pb = 0.25 has been used.

Finally, the noise has been added to the given image and the output has been clipped within the range [0,255] and converted to unsigned integer.

For denoising, mean and median filters of kernel varying from 1 to 20 (odd values only) has been used. The PNSR value has been calculated according to the formula on the next page and its variation with kernel size has been plotted for mean as well as median filters.

(a.) Original image

(b.) Gaussian Noise

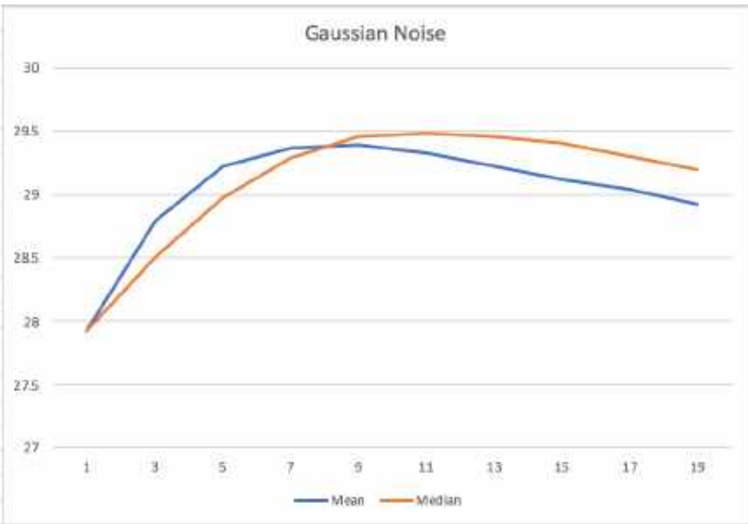
(c.) Salt and Pepper Noise

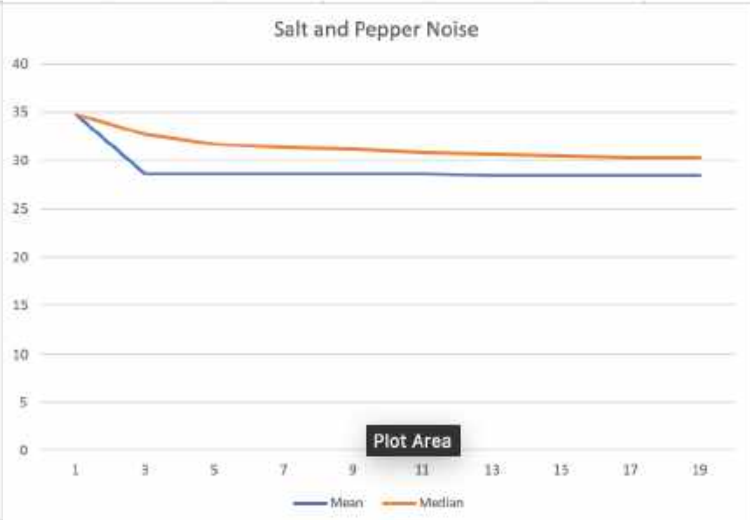
Mean (left) vs Median Filter (right) on Gaussian (left) vs Salt and Pepper Noise (right)

Kernel sizes are 3 (top), 5, 7 and 9 (bottom) and MAX_I = 255

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

$$\begin{aligned} PSNR &= 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \\ &= 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \\ &= 20 \cdot \log_{10}(MAX_I) - 10 \cdot \log_{10}(MSE) \end{aligned}$$





1. Greater PNSR value indicates greater closeness to the original image.
2. Mean and median filters work almost similarly on gaussian noise but mean filter shows highest PSNR value.
3. For salt and pepper noise, median filtering works noticeably well.
4. PSNR value is not always a very accurate indicator of how closely the new image resembles the original.

EDGE-PRESERVING SMOOTHING

Non - local means has been implemented in this section. Value of standard deviation has been set to 50 for gaussian noise. Since standard deviation of salt and pepper noise does not make sense, standard deviation in this case has been set to 50 after experimenting.

NonLocal means on (a.) Gaussian noise and (b.) Salt and Pepper noise

DEBLURRING

Derivation of N(u , v) spectrum in terms of noise function

$$\eta(x) \cdot g(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-1/2\left((x-u)^2/\sigma^2\right)}$$

$\mu = 0$ (mean)

$\sigma = 5$ (standard deviation).

$$|\eta(x)|^2 = \left(\frac{1}{5\sqrt{2\pi}} e^{-x^2/25}\right) = \frac{1}{5\sqrt{2\pi}} e^{-1/25(x^2)}$$

N = fourier transform of $\eta(x)$

$$N(k) = \int_{-\infty}^{\infty} \frac{1}{5\sqrt{2\pi}} e^{-x^2/25} e^{-2\pi i k x} \, dx.$$

odd function

$$= \frac{1}{5\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{-x^2/25}\left(\cos(2\pi k x) - i \sin(2\pi k x)\right) dx$$

$$= \frac{1}{5\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{-x^2/25} \cos(2\pi k x) \cdot dx$$

$$= \frac{1}{5\sqrt{2\pi}} \cdot \sqrt{25\pi} \; e^{-\pi^2 k^2 (25)}$$

Transforms to another Gaussian.

$$|N(k)|^2 = \left(\frac{1}{2} e^{-50\pi^2 k^2}\right) = \frac{1}{2} e^{-50\pi^2 (k^2)}$$

$$\therefore \; |N(k)|^2 \propto |\eta(x)|^2$$

where proportionality is a function of σ.

Estimation of |F(u , v)| for Wiener Filtering

Three types of functions have been used for estimating the noise spectrum of the un-degraded image. The first approximation gives the best results.

a. Ground-truth spectrum for original image

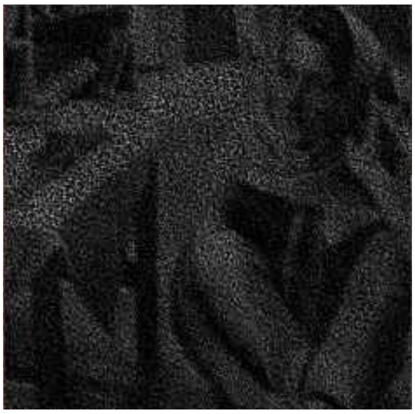
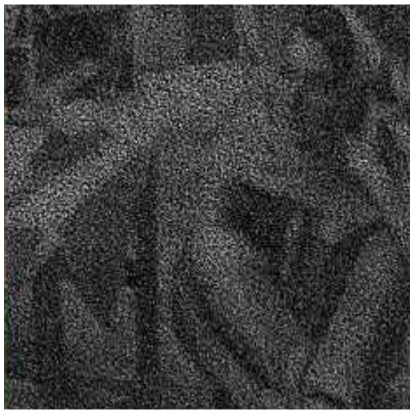
Since the original image is given, |F(u , v)| is taken as noise spectrum of original image.

b. Constant value

|F(u , v)| is set to constant value matrix with the values 1e06, 1e07 and 1e08 (left to right) respectively as shown below.

c. Proportional to L2 Norm of pixel location

|F(u , v)| is set to L2 norm of pixel location with the values of alpha as 3.25, 3.5 and 3.75 (left to right) respectively as shown below.

REAL WORLD IMAGE RESTORATION

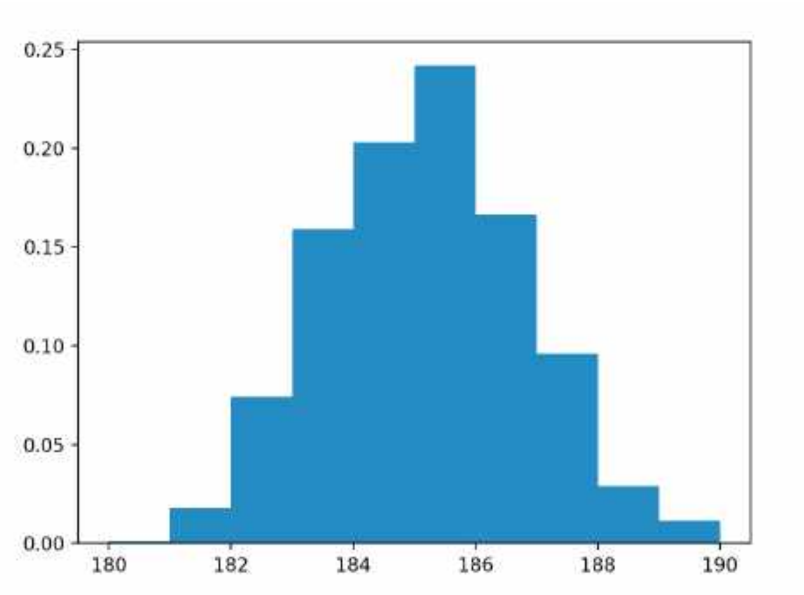
Shan.png and Bharti.png have been selected for this section. For both the coloured images, Luminance values of each pixel as per Assignment - 1 have been used to apply the image restoration techniques. Later on, the luminance values have been undone.

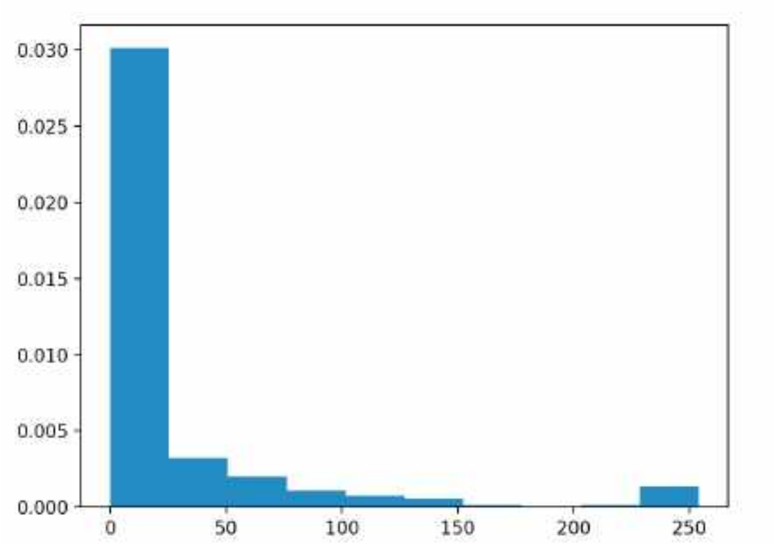
The steps followed are -

1. A nearly constant intensity region is studied to approximate the noise distribution.
2. A point illumination is studied to approximate the blur function.
3. Wiener filtering is applied after approximating the degradation function and noise.
4. The results are enhanced further using smoothing and sharpening filters.

Shan.png

Original Input image converted to Luminance Domain

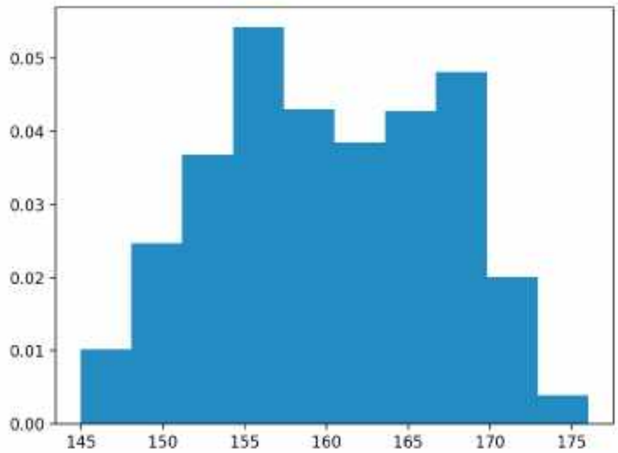




Noise distribution is assumed to be gaussian with standard variation between 1-2. The blur function is assumed to be a Gaussian Kernel. Further, spectrum of F (original image) is taken to be the same as G (degraded image).

Post Wiener Filtering, laplacian sharpening filter has been applied to the second image. Finally, the colour image is obtained by reversing the luminance value calculations.

Bharti.png



Original input is converted to grayscale image using luminance values.

Noise distribution is assumed to be gaussian with standard variation between 5-7. The blur function is assumed to be a disc-shaped Point Spread Function. Further, spectrum of F (original image) is taken to be the same as G (degraded image).

Weiner filtering gives a sharper image but also introduces lot of noise. Median filtering with 7-sized filter was efficient in removing the noise. Sharpening of the image was also done before reversing the luminance operation to get the coloured image back.