Digital Image Processing
Assignment 1

By

Seelapureddy Venkata Rama Aditya Reddy
IMT2014047
Aditya.seelapureddy@iiitb.org

1. Implement different smoothing techniques on different natural images

A. Smoothing techniques causes blurring an image and reduces noise.

- **Averaging:**

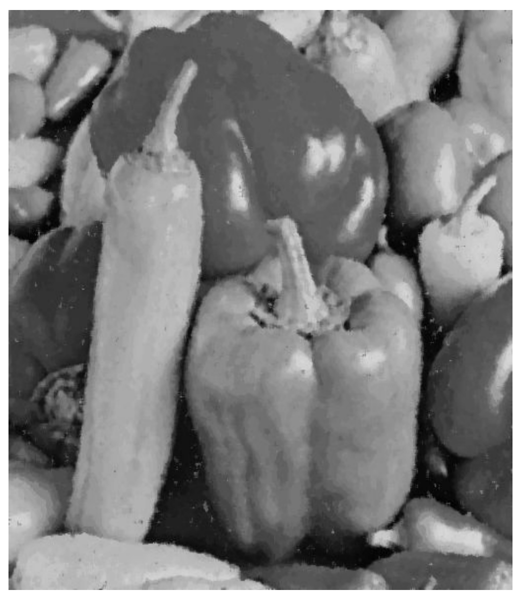
  Blurs an image and reduces some noise. Causes Ringing Artifacts.

- **Gaussian smoothing:**

It is nothing but weighted averaging. Does not Ringing Artifacts as frequency response of gaussian does not have zero crossings which is also a gaussian.

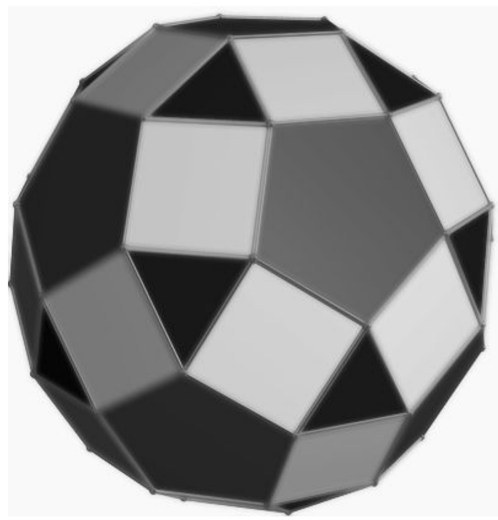
- **Median Blurring:**

It reduces salt and pepper noise effectively.



- **Bilateral Filtering**:

  It keeps the edges sharp. Bilateral filter also takes a gaussian filter in space, but one more gaussian filter which is a function of pixel difference. Gaussian function of space make sure only nearby pixels are considered for blurring while gaussian function of intensity difference make sure only those pixels with similar intensity to central pixel is considered for blurring. So it preserves the edges since pixels at edges will have large intensity variation [1].



- **Wiener Filtering:**

  It helps in improvising images degraded by additive noise and Blurring or linear motion.

- **Closing:**

  It is nothing but dilation followed by erosion.

  The pepper noise has been completely removed with only a little degradation to the underlying image [2].

2. Name different point transformations (6 techniques) and neighbourhood transformations(6 techniques min.)

A. Point transformation techniques are.

- **Image Negatives:**

$$v = L - u,$$

u is Initial Intensity,V is new value, L is maximum intensity in the dynamic range.
This is useful when black areas are more, by finding negative It is easier to analyze it. Can be used in Medical Applications.

- **Log Transformations:**

$$v = c \log (1+u), \text{ c is a constant}$$

After applying Log Transformations the High Intensities are compressed and lower Intensities are stretched i.e helps in compressing dynamic range.

Useful while displaying magnitude of fourier transform of an image.

- **Power-Law(Gamma) Transformations:**

$$v = cu^{\gamma}, \text{ c is a constant}$$

Can be used in Medical Applications, aerial images($\gamma > 1$).

When $\gamma < 1$ the High Intensities are compressed and lower Intensities are stretched.

When $\gamma > 1$ the High Intensities are stretched and lower Intensities are compressed.

- **Thresholding:**

For Binarizing the image.

- **Intensity-level Slicing:**

  To highlight a specific range of Intensities in an image.

  Highlighting water bodies in satellite images.

- **Bit Plane Slicing:**

  Each Pixel value intensity is 8 bit value. By plotting bit planes we can observe that most significant bits contribute to the image than least significant bits.

  Technique can be used in Steganography (hiding one image in another image), compression.

Neighbourhood transformation techniques are.

- **Average Filtering:**

  This filter replaces the Intensity value of the pixel by the average of values present in it’s neighbourhood.
  Useful in removing noise, smoothing(blurring) an image. Can cause ringing artifacts.

- **Median Filtering:**

  This filter replaces the Intensity value of the pixel by the median of values present in it’s neighbourhood. It is useful for removing isolated lines or pixels i.e helpful in removing impulse noise / salt and pepper noise.

- **Gaussian Filtering:**

  It is nothing but weighted averaging. Gives more weight at the central pixels and less weights to the neighbors.The farther away the neighbors, the smaller the weight. There will be no ringing artifacts due to the apply of this filter because fourier transform of gaussian curve is also a gaussian and it does not have zero crossings. Helps in removing noise.

- **Bilateral Filtering:**

  It keeps the edges sharp.

- **Prewitt Operator:**

  Useful in finding gradient of an Image. With gradient we can do edge mapping.

- **Sobel Operator:**

  Useful in finding gradient of an Image. With gradient we can do edge mapping.

3. Interpolate

A. Using the following Original Image

Type of Interpolation	**$\lvert E_{original} - E_{interpolated} \rvert$**	**MSE**
Nearest Neighbour	8211	356.661331177
Bilinear	4231	334.722518921
Bicubic	13486	263.356658936
Linear spline	414	454.881293297
Bicubic spline	116	436.848929479

Original Image

Type of Interpolation	$\|E_{original} - E_{interpolated}\|$	MSE
Nearest Neighbour	7902	111.175537109
Bilinear	3814	92.0262145996
Bicubic	7938	65.874786377
Linear spline	11179	144.076230049
Bicubic spline	11120	136.023681503

Of all the above observations we can conclude that for interpolation Bilinear, Bicubic Interpolations are better.

Assumption: Energy of an image is sum of intensity values of all pixels in an image.

4. Write a short note on Histogram Equalization (motivation & logic behind it) and different variants of it.

A. Histogram Equalization(HE) is a technique used for contrast Enhancement. It stretches the dynamic range of gray levels by using Cumulative Distributive function of image. After applying the Histogram Equalization the number of gray levels remains same. It flattens the histogram of input image [3].

Histogram Equalization performs contrast enhancement globally. This may cause over enhancement.

Variants of Histogram Equalization are Adaptive Histogram Equalization(AHE), Contrast Limited Histogram Equalization(CLAHE). These variants are local enhancement techniques [3].

In AHE different histograms are calculated for each subsection of an image (almost equal size). Therefore it enhances the image locally. Problem is in Homogeneous regions it over amplifies the noise in that region. In order to counter this a clip limit is introduced. This method is known as CLAHE [3].

5. Write a short note of different noise models and methods to counteract or nullify it

A. Different Noise models are:

- **Additive Gaussian Noise:**

  The noise model is additive in nature and follows Gaussian Distribution. It means that each pixel in a noisy image will have intensity equal to sum of actual pixel Intensity value and random noise which follows gaussian distribution.

  Can be countered using Gaussian Smoothing Filter.

- **Impulse Noise (Salt and Pepper Noise):**

  Black and White dots appears in the image because of this noise.

This noise can be overcomed by using median filters.

- **Poisson Noise:**

  Poisson or shot photon noise is the noise that can cause, when number of photons sensed by the sensor is not sufficient to provide detectable statistical information. The noise follows poisson distribution [4].

  This noise can be overcomed by Wiener filter.

- **Rician Noise:**

  Noise in Magnitude Magnetic Resonance Images is modeled by Rician Distribution [5].

  Some methods to remove noise are based on wavelet based methods, maximum likelihood based approach etc [5].

- **Gamma Noise:**

  The Noise added follows a gamma distribution.

  Arithmetic Mean filter can reduce the noise to some extent.

- **Exponential Noise:**

  The Noise added follows an exponential distribution.

  No specific filter, can use average filter to reduce noise to some extent.

References used for theory and code:

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6. Summary Wiener Filter - wiener7-2.pdf

7. Morphology - Closing

8. scipy.interpolate.interp2d — SciPy v0.14.0 Reference Guide

9. Image Filtering — OpenCV 3.0.0-dev documentation

10. Noise and Signal Estimation in Magnitude MRI and Rician Distributed Image

11. Noise Models: Gaussian and Gamma noise - AI Shack - Tutorials for OpenCV, computer vision, deep learning, image processing, neural networks and artificial intelligence.

12. Digital Image Processing by Rafael C. Gonzalez, Richard E. Woods