جامعة المستقبل
AL MUSTAQBAL UNIVERSITY

كلية العلوم
قســم الانظمة الطبية الذكية

Lecture (9): Image Restoration

Subject: Image Processing
Level: Third
Lecturer: Asst. Lecturer Qusai AL-Durrah

1. Image Restoration:

Image restoration methods are used to improve the appearance of an image by application of a restoration process that use mathematical model for image degradation.

Example of the type of degradation:

1. Blurring caused by motion or atmospheric disturbance.
2. Geometrics distortion caused by imperfect lenses.
3. Superimposed interface patterns caused by mechanical systems.
4. Noise from electronic source.

2. What is noise?

Noise is any undesired information that contaminates an image. Noise appears in image from a variety of source. The digital image an acquisition process, which converts an optical image into a continuous electrical signal that is then sampled is the primary process by which noise appears in digital images.

At every step in the process there are fluctuations caused by natural phenomena that add a random value to exact brightness value for a given pixel. In typical image the noise can be modeled with one of the following distributions:

1. Gaussian ("normal") distribution.
2. Uniform distribution.
3. Salt _and _pepper distribution.

(a) original (b) with Gaussian noise (variance=0.005)

(c) with salt and Pepper noise (p=1%)

Figure (1): Image Noise

2.1 Noise Removal using Spatial Filters:

Spatial filtering is typically done for:

1. Remove various types of noise in digital images.

2. Perform some type of image enhancement.

[These filters are called spatial filter to distinguish them from frequency domain filter].

The three types of filters are:

1. Mean filters.

2. Median filters (order filter).

3. Enhancement filters.

Mean and median filters are used primarily to conceal or remove noise, although they may also be used for special applications. For instance, a mean filter adds "softer" look to an image. The enhancement filter high lights edges and details within the image. Spatial filters are implemented with convolution masks. Because convolution mask operation provides a result that is weighted sum of the values of a pixel and its neighbors, it is called a linear filter. Overall effects the convolution mask can be predicated based on the general pattern. For example:

• If the coefficients of the mask sum to one, the average brightness of the image will be retained.

• If the coefficients of the mask sum to zero, the average brightness will be lost and will return a dark image.

• If the coefficients of the mask are alternatively positive and negative, the mask is a filter that returns edge information only.

• If the coefficients of the mask are all positive, it is a filter that will blur the image.

The mean filters, are essentially averaging filter. They operate on local groups of pixel called neighborhoods and replace the center pixel with an average of the pixels in this neighborhood. This replacement is done with a convolution mask such as the following 3X3 mask

Arithmetic mean filter smoothing or low-pass filter.

$$\begin{pmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{pmatrix}$$

Not that the coefficient of this mask sum to one, so the image brightness will be retained, and the coefficients are all positive, so it will tend to blur the image. This type of mean filter smoothes out local variations within an image, so it essentially a low pass filter. So, a low filter can be used to attenuate image noise that is composed primarily of high frequencies components.

a. Original image

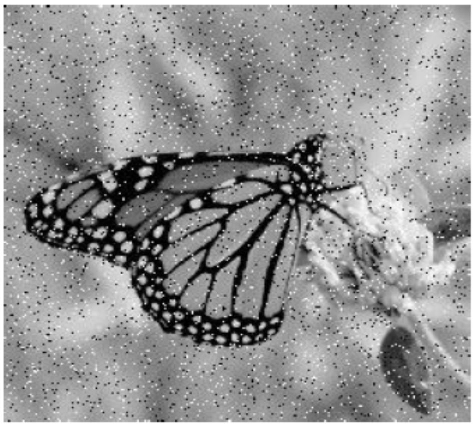
b. Mean filtered image

Figure (2): Mean Filter.

The median filter is a nonlinear filter (order filter). These filters are based on as specific type of image statistics called order statistics. Typically, these filters operate on small sub image, “Window”, and replace the center pixel value (similar to the convolution process). Order statistics is a technique that arranges the entire pixel in sequential order, given an NXN window (W) the pixel values can be ordered from smallest to the largest.

$$I1 \le I2 \le I3.........................< IN$$

Where **I1, I2, I3………, IN** are the intensity values of the subset of pixels in the image.



a. Salt and pepper noise

b. Median filtered image (3x3)

Figure (3): Median Filter

Example:

Given the following 3X3 neighborhood

$$\begin{pmatrix} 5 & 5 & 6 \\ 3 & 4 & 5 \\ 3 & 4 & 7 \end{pmatrix}$$

We first sort the value in order of size (3,3,4,4,5,5,5,6,7); then we select the middle value, un this case it is 5. This 5 is then placed in center location. A median filter can use a neighborhood of any size, but 3X3, 5X5 and 7X7 are typical. Note that the output image must be written to a separate image (a buffer); so that the results are not corrupted as this process is performed. (The median filtering operation is performed on an image by applying the sliding window concepts, similar to what is done with convolution).

The window is overlaid on the upper left corner of the image, and the median is determined. This value is put into the output image (buffer) corresponding to the center location of the window. The window is then slides one pixel over, and the process is repeated.

When the end of the row is reached, the window is slide back to the left side of the image and down one row, and the process is repeated. This process continues until the entire image has been processed.

Note that the outer rows and columns are not replaced. In practice this is usually not a problem due to the fact that the images are much larger than the masks. And these "wasted" rows and columns are often filled with zeros (or cropped off the image). For example, with 3X3 mask, we lose one outer row and column, a 5X5 mask we lose two rows and columns. This is not visually significant for a typical 256X256 or 512X512 images.

The maximum and minimum filters are two order filters that can be used for elimination of salt- and-pepper noise. The maximum filter selects the largest value within an ordered window of pixels values; whereas the minimum filter selects the smallest value.

The minimum filters work best for salt- type noise (High value), and the maximum filters work best for pepper-type noise.

In a manner similar to the median, minimum and maximum filter, order filter can be defined to select a specific pixel rank within the ordered set. For example, we may find for certain type of pepper noise that selecting the second highest values works better than selecting the maximum value. This type of ordered selection is very sensitive to their type of images and their use it is application specific. It should note that, in general a minimum or low rank filter will tend to darken an image and a maximum or high rank filter will tend to brighten an image.

The midpoint filter is actually both order and mean filter because it relies on ordering the pixel values, but then calculated by an averaging process. This midpoint filter is the average of the maximum and minimum within the window as follows:

$$\text{Order set} = I_1 \le I_2 \le I_3 \ldots\ldots\ldots \le I_{N^2}$$

.

$$\textbf{Midpoint} = (I_1 + I_{N^2})/2$$

The midpoint filter is most useful for Gaussian and uniform noise.

2.5.3 The Enhancement filter:

The enhancement filters are:

1. Laplacian type.

2. Difference filter.

These filters will tend to bring out, or enhance details in the image.

Example of convolution masks for the Laplacian-type filters are:

$$\begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix} \quad \begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix} \quad \begin{pmatrix} -2 & 1 & -2 \\ 1 & 5 & 1 \\ -2 & 1 & -2 \end{pmatrix}$$

The Laplacian type filters will enhance details in all directions equally.

a. Original image b. Laplacian filtered image

Figure (4): Laplacian Filter.

The difference filters will enhance details in the direction specific to the mask selected. There are four different filter convolution masks, corresponding to lines in the vertical, horizontal and two diagonal directions.

Vertical

$$\begin{pmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 0 \end{pmatrix}$$

Horizontal

$$\begin{pmatrix} 0 & 0 & 0 \\ 1 & 1 & -1 \\ 0 & 0 & 0 \end{pmatrix}$$

Diagonal 1

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

Diagonal 2

$$\begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \end{pmatrix}$$

a. Original image

b. Difference filtered image

Figure (5): Difference Filter