Image processing

Image Analysis

Ch2 – part 3

Image Noise

Noise is any undesired information that contaminates an image. Noise appears in image from a variety of source. The digital image a 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 distribution:

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

Noise Removal Using Spatial Filters

Spatial filters can be effectively used to remove various types of noise in digital images and Perform some type of image enhancement.. These spatial filters typically operate on small neighborhoods 3*3 to 11*11, and some can be implemented as convolution masks.

There are three primary categories of spatial filters

1. Mean filters
2. Median filters (order filter)
3. Enhancement filters

Original Image

Image with S&P Noise

Image Denoising

Noise Removal Using Spatial 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.

Noise Removal Using Spatial Filters

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.

Mean Filters

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.

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

$$\text{arithmetic Mean} = \frac{1}{N^2} \sum_{(r,c)\varepsilon w} d(r,c)$$

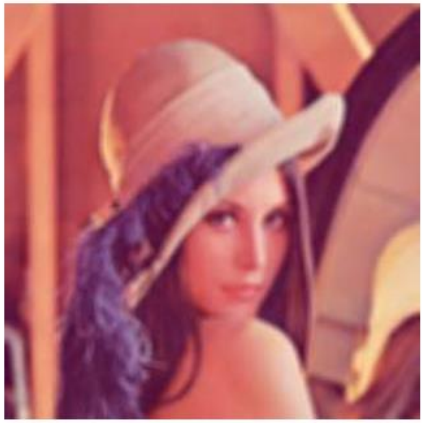
where N^2= the number of pixels in the N*N window.

Mean Filters

The arithmetic mean filter smoothes out local variations with an image, so it is essentially a low-pass filter. It can be implemented with convolution mask where all the mask coefficients are $1/N^2$. This filter will tend to blur an image while mitigating the noise effects.

This type of filter works best with Gaussian and uniform noise. The blurring effect which reduces image details is undesirable, and the other mean filters are designed to minimize this loss of detail uniform.

Original Lena image



Lena image filtered with 5x5 Meanfilter

Mean Filters

Note: The blur rate in the resulting image increases with the size of the Mask.

- Image smoothed with 3×3, 5×5, 9×9

and 11 ×11 box filters

Linear Image smoothing

Median Filter

The median filter is a non-linear 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), the median filter work best with salt-and-pepper.

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.

$$I_1 \leq I_2 \leq I_3 \leq \ldots \leq I_{N^2}$$

where $\{ I_1, I_2, I_3, \ldots, I_{N^2} \}$ are the intensity (gray-level) values of the subset of pixels in the image, that are the N*N window.

Median Filter

Image with S&P Noise

Median Filter

Example: Given the following 3X3 neighborhood

5	5	6
3	4	5
3	4	7

We first sort the value in order of size (3,3,4,4,5,5,5,6,7) ; then we select the middle value ,in this case it is 5. This 5 is then placed in center location.

Median Filter

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 slide 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.

Median Filter

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.

0	**0**	**0**	**0**	**0**
0	75	66	78	0
0	39	98	78	0
0	55	77	88	0
0	0	0	0	0

75	**66**	**78**
39	98	78
55	77	88

After applied median filter filled buffer with zeros (or cropped off the image).

Median Filter

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

The midpoint filter is actually both order and mean filter because it rely 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, The midpoint filter is most useful for Gaussian and uniform noise.

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 Enhancement Filter

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

Original image

Laplacian filtered image

The Enhancement 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.

Original image

Difference filtered image

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

Vertical

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

Horizontal

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

Diagonal 1

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

Diagonal 2