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# Smoothing of a Noisy Image Using Different Low Pass Filters

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**ABSTRACT**

One picture is worth more than ten thousand words. An image is nothing more than a two dimensional signal.[1] It is defined by the mathematical function f(x,y) where x and y are the two co-ordinates horizontally and vertically. The value of f(x,y) at any point is gives the pixel value at that point of an image. If image contains noise, results are unexpected. So, to enhance the quality of an image - low pass filters are used. Low pass filters are basically used for removing noise from image.

***Keywords:*** **—**Image, Noise, Filter, Smoothing.

## I. INTRODUCTION

Image processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. A digital image is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels.[1] Pixel values typically represent grey levels, colours, and distance from camera, etc. Pixel is the smallest element of an image. Each pixel corresponds to any one value. In an 8-bit grey scale image, the value of the pixel between 0 and 255. The value of a pixel at any point corresponds to the intensity of the light photons striking at that point. Each pixel stores a value proportional to the light intensity at that particular location.

## II. HOW IT WORKS


Fig.1 Working of Image Processing

Image noise is random (not present in the object imaged) variation of brightness or colour information in images, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is an undesirable by-product of image capture that adds spurious and extraneous information.

The original meaning of "noise" was and remains "unwanted signal"; unwanted electrical fluctuations in signals received by AM radios caused audible acoustic noise ("static"). By analogy unwanted electrical fluctuations themselves came to be known as "noise". Image noise is, of course, inaudible.

The magnitude of image noise can range from almost imperceptible specks on a digital photograph taken in good light, to optical and radioastronomical images that are almost entirely noise, from which a small amount of information can be derived by sophisticated processing (a noise level that would be totally unacceptable in a photograph since it would be impossible to determine even what the subject was).

## III. TYPES OF NOISE

### *A. Gaussian noise*

Principal sources of Gaussian noise in digital images arise during acquisition e.g. sensor noise caused by poor illumination and/or high temperature, and/or transmission e.g. electronic circuit noise.[4]

A typical model of image noise is Gaussian, additive, independent at each pixel, and independent of the signal intensity, caused primarily by Johnson–NY Quist noise (thermal noise), including that which comes from the reset noise of capacitors ("kTC noise").Amplifier noise is a major part of the "read noise" of an image sensor, that is, of the constant noise level in dark areas of the image. In colour cameras where more amplification is used in the blue colour channel than in the green or red channel, there can be more noise in the blue channel. At higher exposures, however, image sensor noise is dominated by shot noise, which is not Gaussian and not independent of signal intensity.[

### *B. Salt-and-pepper noise*

Fat-tail distributed or "impulsive" noise is sometimes called salt-and-pepper noise or spike noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. This type of noise can be caused by analog-to-digital converter errors, bit errors in transmission, etc. It can be mostly eliminated by using dark frame subtraction, median filtering and interpolating around dark/bright pixels.[4]

Dead pixels in an LCD monitor produce a similar, but non-random, display.

### *C. Shot noise*

The dominant noise in the darker parts of an image from an image sensor is typically that caused by statistical quantum fluctuations, that is, variation in the number of photons sensed at a given exposure level.[4] This noise is known as photon shot noise. Shot noise has a root-mean-square value proportional to the square root of the image intensity, and the noises at different pixels are independent of one another. Shot noise follows a Poisson distribution, which except at very low intensity levels approximates a Gaussian distribution.

In addition to photon shot noise, there can be additional shot noise from the dark leakage current in the image sensor; this noise is sometimes known as "dark shot noise" or "dark-current shot noise". Dark current is greatest at "hot pixels" within the image sensor. The variable dark charge of normal and hot pixels can be subtracted off (using "dark frame subtraction"), leaving only the shot noise, or random component, of the leakage. If dark-frame subtraction is not done, or if the exposure time is long enough that the hot pixel charge exceeds the linear charge capacity, the noise will be more than just shot noise, and hot pixels appear as salt-and-pepper noise.

### *D. Quantization noise (uniform noise)*

The noise caused by quantizing the pixels of a sensed image to a number of discrete levels is known as quantization noise. It has an approximately uniform distribution.[4] Though it can be signal dependent, it will be signal independent if other noise sources are big enough to cause dithering, or if dithering is explicitly applied.

## IV. FILTERING

### A. *Low pass filters (Smoothing)*

Low pass filtering (aka smoothing), is employed to remove high spatial frequency noise from a digital image. The low-pass filters usually employ moving window operator which affects one pixel of the image at a time, changing its value by some function of a local region (window) of pixels.[2] The operator moves over the image to affect all the pixels in the image. Useful for reducing noise and eliminating small details.

### B. *High pass filters (Edge Detection, Sharpening)*

A high-pass filter can be used to make an image appear sharper. These filters emphasize fine details in the image - the opposite of the low-pass filter. High-pass filtering works in the same way as low-pass filtering; it just uses a different convolution kernel.

### *C. Filters in spatial domain*

Spatial filters used different masks (kernels, templates or windows).There is a one-to-one correspondence between linear spatial filters and filters in frequency domains. Spatial filters can be used for linear and nonlinear filtering. (Frequency domain filter just for linear filtering).The mechanics of spatial filtering spatial filters consists of: Neighbourhood (small rectangle).Predefined operation that is performed on the image pixel.

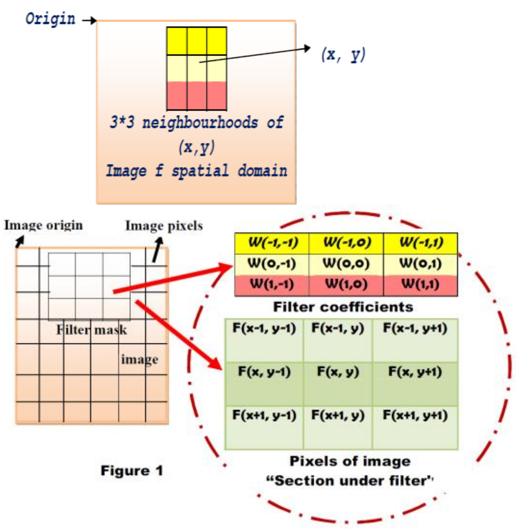


Fig. 2 Spatial Domain Filtering Process

### *1) Mean filter:*

- Mean filter is also known as Box filter and average filter. A mean filter has the following properties.[1]
- It must be odd ordered
- The sum of all the elements should be 1
- All the elements should be same

| | | |
|---|---|---|
| 1/9 | 1/9 | 1/9 |
| 1/9 | 1/9 | 1/9 |
| 1/9 | 1/9 | 1/9 |

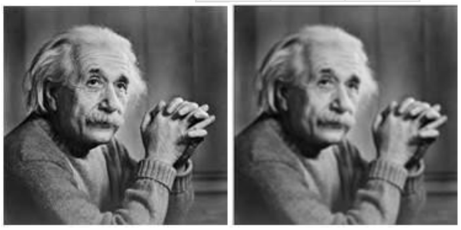

Fig. 1 The result of a mask of 3x3 on an image

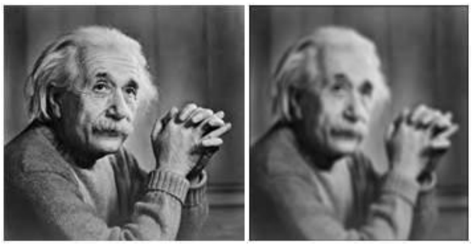

Fig. 4 The result of a mask of 5x5 on an image

### *2) Weighted average filter:*

In weighted average filter, we gave more weight to the centre value. Due to which the contribution of centre becomes more than the rest of the values. Due to weighted average filtering, we can actually control the blurring.[1]

- Properties of the weighted average filter are.
- It must be odd ordered
- The sum of all the elements should be 1
- The weight of center element should be more then all of the other elements
- The two properties are satisfied which are (1 and 3).
- But the property 2 is not satisfied. So in order to satisfy that we will simple divide the whole filter by 10, or multiply it with 1/10.

| | | |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 2 | 1 |
| 1 | 1 | 1 |

- Mask size determines the degree of smoothing (loss of detail).

Original Image 3X3 5X5 7X7

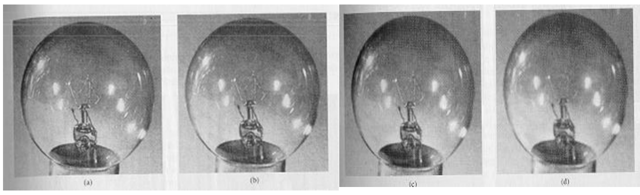

Fig. 5 Example of Weighted Average Filter

### *3) Gaussian Filter:*

A linear smoothing spatial filter, whose coefficients are determined bya gaussian function.[1]
It assigns more weight to the position near the center, and less weight to the positionsfar away from the center.
It is given by:

$$G_\sigma(x,y) = \frac{1}{2\pi\sigma^2} \exp^{-\frac{x^2+y^2}{2\sigma^2}}$$

7 × 7 Gaussian mask

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 2 | 2 | 1 | 1 |
| 1 | 2 | 2 | 4 | 2 | 2 | 1 |
| 2 | 2 | 4 | 8 | 4 | 2 | 2 |
| 2 | 4 | 8 | 16 | 8 | 4 | 2 |
| 2 | 2 | 4 | 8 | 4 | 2 | 2 |
| 1 | 2 | 2 | 4 | 2 | 2 | 1 |
| 1 | 1 | 2 | 2 | 2 | 1 | 1 |

- σ controls the amount of smoothing
- As σ increases, more samples must be obtained to represent the Gaussian function accurately.

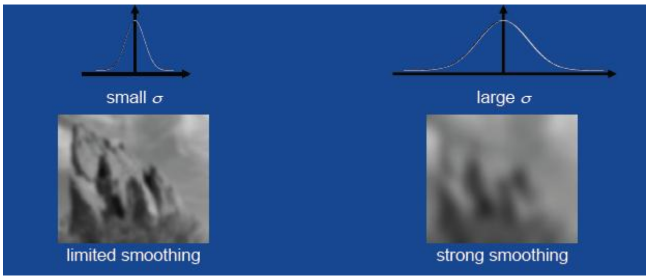


Fig. 6 Example of Gaussian Filter

Fig. 7 Example of Box filter vs. Gaussian Filter

4) ***Median Filtering:***
Very effective for removing "salt and pepper" noise (i.e., random occurrences of black and white pixels).[2]


Fig. 8 Example of Median Filter

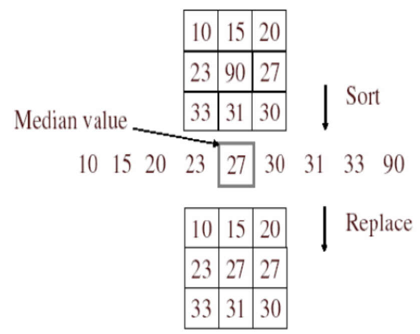


Fig. 9 Working of Median Filter

Replace each pixel by the median in a neighbourhood around the pixel.

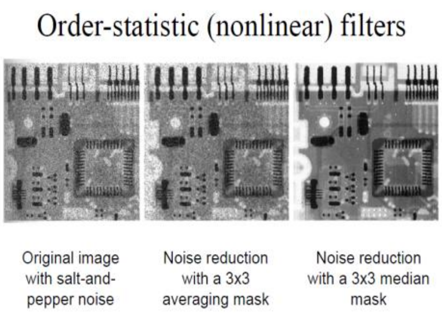


Fig. 10 Example of Average vs. Median Filter

***5) Bilateral filter:***

A bilateral filter is a non-linear, edge-preserving and noise-reducing smoothing filter for images.[3] The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight can be based on a Gaussian distribution. Crucially, the weights depend not only on Euclidean distance of pixels, but also on the radiometric differences (e.g. range differences, such as color intensity, depth distance, etc.). This preserves sharp edges by systematically looping through each pixel and adjusting weights to the adjacent pixels accordingly.

# IV. CONCLUSIONS

Filtering is perhaps the most fundamental operation of image processing and computer vision. In the broadest sense of the term "filtering", [1] the value of the filtered image at a given location is a function of the values of the input image in a small neighbourhood of the same location. Mean filter is the basic filter for blurring image. Gaussian blur is the fastest of the three options and is usually good for most applications.

Median filtering is a non-parametric operation which is really useful when you want to get rid of things like speckle noise.[2]

Neither Gaussian nor median filters preserve edges, meaning after applying the filter the location of edges in your image will move. A bilateral filter is edge preserving, but it is slower than a Gaussian filter.[3]

# REFERENCES

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[3] https://en.wikipedia.org/wiki/Bilateral_filter.
[4] https://en.wikipedia.org/wiki/Image_noise