

Performance Analysis of Different Filters for Digital Image Processing

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Abstract: Digital image processing is one of the drastically growing areas used in various real-time industries like medical, satellite, remote sensing, and pattern recognition. The output of the image processing depends on the quality of the image. Filters are used to modify the images, such as removing the noise and smoothing the images. It is essential to suppress the high-frequency values in the image for smoothing and improving the low-frequency values to enhance the image of strengthening else it doesn't provide good output. This paper discussed various filters and their functionalities concerning digital image processing. Here linear, as well as non-linear filters, are presented. It is easy to decide about the better filter for improving the image processing output from the discussion.

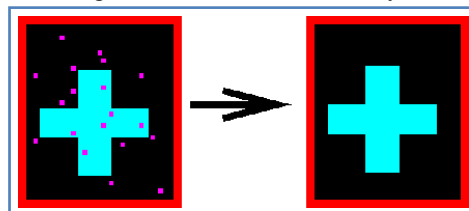
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1. Introduction

When an imaging system captures an image, then the idea seems to have some noises. Normal images are ignored before processing. Medical images need to be examined or processed before any diagnosis. Medical images often not usable because of their illumination variations, poor contrast, etc. This paper explains the image enhancement methods using filters. In images, the image's high frequencies are suppressed by using filters such as smoothing the image and detecting the edge in the image. Many steps are involved in image processing, such as transforming the image into the frequency domain and then multiply this using a frequency filter. Many images often contain many gray values and are eliminated using histogram modification and equalization. Modification on the histogram is used for image reconstruction. Equalizing the histogram is used for improving the contrast by distributing the gray values more evenly. Many types of filters are used in image processing, such as linear filters, non-linear filters, digital filters, etc. Image smoothing is an important process in image processing. It will eventually reduce the noise level. The below image Figure-1 represents the image filtering process.

2. Related Works

Image processing is done for image enhancement. It is done to maintain the original clarity of the image [1, 2, 3]. Image enhancement is used for improving the details of the image for viewing. It provides better results after implementing automated image processing techniques. The main goal is to modify the image without losing its image characters. The attributes of the images are preserved even after modification. Digital image processing is the advanced technique used for image reconstruction [4]. Many filter methods are used for image modification or image enhancement. Mainly linear and non-linear filter methods are used for ideal transformations [5]. An advanced model for image transformation is spatial filter usage for better results [6]. These filters are used for removing noise in the image. Many problems are associated with image processing. Example: X-ray enhanced image is not suited for microscopic studies. In this paper, the filters and the properties of the filters are used for enhancing the image. The resultant image from this model is merely free from noises



(a):input image (b):output image

Figure-1. Before and after noise removal of the sample image

Filters are mainly used to filter a user-required pattern, odd data from a whole dataset, or filter out the required pattern from the input data. Various types of filters exist in the computing and electronics industry applications. In image processing, filters are used for noise removal and image enhancement. In other fields, filters are used to filter out specific data from the group of data. Some of the filter types are:

- Filters.
 - Linear Filters.
 - Linear Filter Properties.
 - Non-linear Filters.
- Filters

Filters are applied to the image for modification purposes. The filter operation's main specialty is that it uses more than one pixel to generate the pixel value. Example: smoothing filter replaces its own pixel value by half the size of its neighbor pixel value. Generally, filters are categorized into two parts.

- Linear filter.
- Non-linear filter.

Linear Filter

The linear filter is a type of filter that uses the pixel value in the support region. The values used are in the form of linear such as weighted summation. "Filter Matrix" is used to specify the support region, and it is represented by $H(i, j)$. H denotes the filter region, i and j are column index and row index, respectively. This hotspot location is illustrated in Figure-2. The filter region owns a coordinate system. The hotspot is located in the center of the origin location.

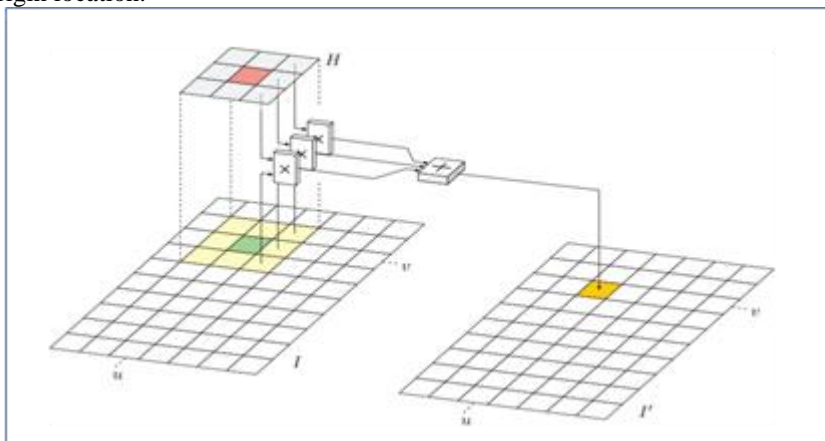


Figure-2. Representation of Hotspot Location.

Filters and its Functionalities

A set of all filters used mainly in image processing is described here.

General steps need to be followed for applying filters

1. The filter matrix is moved over the image I and $H(0, 0)$. The current image position (u, v) is moving along with the filter matrix.
2. Each filter coefficient $H(i, j)$ is multiplied with its own corresponding image element $I(u+i, v+j)$.
3. From the previous step, all the results are averaged, and the current location of $I(u, v)$ is revealed.

Below equation is described from the above steps:

$$\begin{aligned}
 &I' u, v \leftarrow i=1 \\
 & \quad j=1 \\
 & \quad j=-1 \\
 & I u + i, v + j . H i, j \quad (1)
 \end{aligned}$$

In the above equation, " I " represents the input location, " I' " represents the output location,

H represents the coefficient, " u, v and i, j " represents the coefficients' location. The types of Linear filters are given below.

Smoothing Filter

This filter only contains positive integers. These filters are used for smoothening the input image by removing the noise available in the image.

Box Filter

All the filter members for this type are the same. The sample 2D model, 2D structure, and the Box filter example are shown in Figure-3(a).

Gaussian Filter

The member location depends on the weight of the filter member. The center takes the maximum weight, and it gradually decreases in weight by moving away from the center. The sample 3D model, 2D structure, and the example for the Gaussian filter is shown in Figure-3(b)

Laplace or Mexican Hat Filter

Not all the filters are positive. Some of them are negative. They are calculated by the summation of all positive and negative filter members. The sample 3D model, 2D structure, and the Laplace filter example are shown in Figure-3(c).

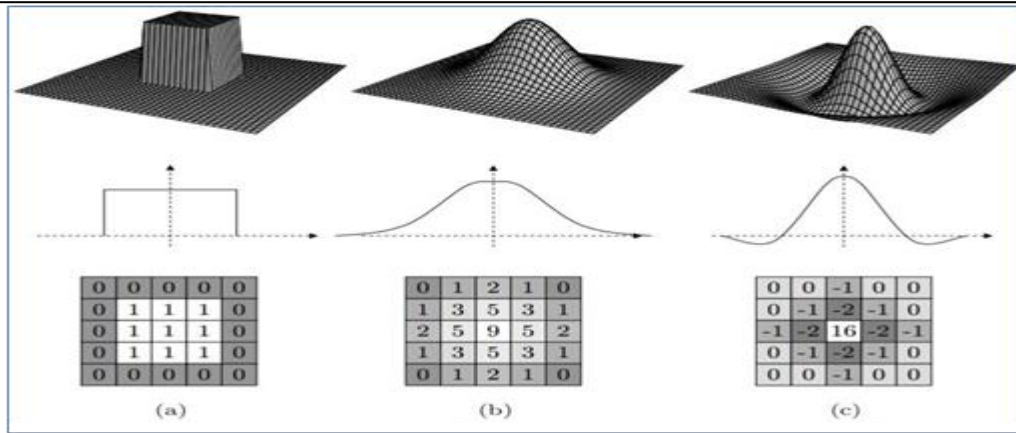


Figure-3. The optimal 3D structure, 2D structure, and example of filter (a) Box filter (b) Gaussian filter and (c) Laplace filter.

Properties of Linear filter

Linear Convolution is a unique operation that is associated with a linear filter. The below equation represents the convolution operation for the two-dimensional function of I and H.

$$I'_{u,v} = \sum_{i=-\infty}^{\infty} \sum_{j=-\infty}^{\infty} I_{u-i, v-j} * H(i, j)$$

$$I' = I * H$$

(2)

The "*" represents the convolution operation. The above gives the same results with the linear filter. The filter function from the linear filter is the same on both the horizontal and vertical axis. The kernel is the other name for the convolution matrix (H). Some of the properties of the filters are:

- Commutativity
- Linearity
- Associativity
- Separability:

Multiple kernels are separated into a pair of dimensional kernels x and y.

Non-linear Filters

Resultant images from the linear filter are associated with some problems such as image structure and edge. Such disadvantages are solved using a non-linear manner.

Types of non-linear filters Minimum and maximum Filters

The minimum and maximum value in the moving region R is the result of the minimum and maximum filter of the original image. In equation 2: the *min* and *max* represent the moving region R.

$$I'_{u,v} \leftarrow \min I_{u+i, v+j} | (i, j) \in R$$

$$I'_{u,v} \leftarrow \max I_{u+i, v+j} | (i, j) \in R$$

(2) Median Filter

In the moving region R, the median value of all values is the result of the median filter. It is the same as the min and max filter. This filter is specifically used for removing the pepper and noise in the image. In the below equation (3), "median" represents the median value.

$$I'_{u,v} \leftarrow \text{median } I_{u+i, v+j} | (i, j) \in R$$

(3)

From the above equation, I represent the input image, I' represents the output image after noise is removed using a median filter. The terms u, v, i, and j represent the index values of the images. This filter takes the median value of the input image, and this process is illustrated in Figure-4.

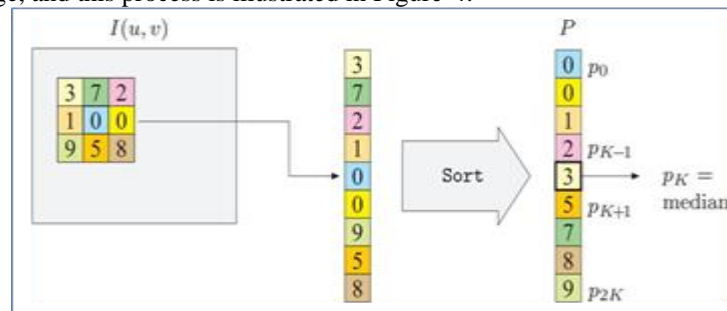


Figure-4. Median filter work.

Weight Median Filter

It is the same as the median filter. According to the Weight matrix W , each member's extension in the kernel is represented as "weight." The filter member near the hotspot region will get maximum weight than other members.

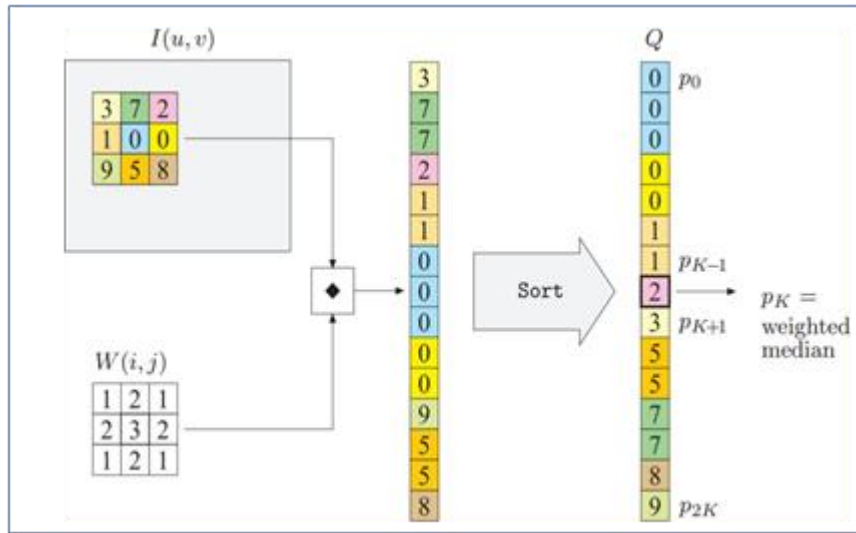


Figure-5. Weighted Median Filter

The weighted median filter takes the weighted median value from the image data I and weight matrix W , and it is illustrated in Figure-5. The image's original data is kept from the weighted median value, and the noise values are filtered.

3. Experimental Results

This paper verifies thevarious filters' performance is implemented and experimented with in MATLAB software. One hundred images are tested in the experiment and the results are verified in terms of MSE and SNR values and are calculated from the input and output images. From the MSE PSNR values, it is clear that the output images' quality is better than the input images. Table-1 represents the PSNR, SSIM, MSE values of all images used. N/A denotes that the image is not available during the process.



Figure-6. Results obtained from Various Filters

Each image in Figure-6 shows the input image, noise removed, and enhance images respectively for the input images. All the input images are taken from the MATLAB images folder, such as baboon, Barbara, Lena, pepper, Santiago, cameraman, and Elaine.

Table-1. Input Images with PSNR and MSE

Input Images	PSNR	MSE
Baboon	41.0983	5.0495
Barbara	43.8356	2.6885

Lena	43.4694	2.9251
Pepper	43.281	3.0548
Santiago	40.9769	5.1927
F16	44.5105	2.3016
Cameraman	42.86	2.138
Elaine	43.98	2.7319

The PSNR and MSE values for the set of all input values are calculated and given in Table-1. All the filters are implanted and tested on the input images and results obtained. Some of the images are not used in the earlier methods. The experiment is carried out on various threshold values, and the results are verified. The threshold values given in the processing influence the quality of the image. Thus, the images' threshold values are changed within two values, such as lower threshold value and a higher threshold value for verifying the PSNR and MSE. Based on these two values, the image quality is determined.

4. Conclusion

Filters are used to reduce the noise level and improve the contrast in the image. Filters are highly useful in medical image processing. Many imaging techniques and many types of filters are used for processing the image. From the above model, various filters are used for the image, reducing the image's noise level. Many types of filters are used and compared on different images. By determining the hotspot location and finding their coefficients are related to the noise level. The PSNR, SSIM, MSE values of all images are obtained using MATLAB, and they are compared. Not all the filters provide the exact same results, and the results are based on the image's noise level. Further improvements will be made using several imaging techniques, and this will provide a more enhanced image by reducing most of the noise level with great details.

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