International Journal on Emerging Technologies (Special Issue NCETST-2017) **8**(1): 509-515(2017)
(Published by Research Trend, Website: www.researchtrend.net*)*

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Methods of Spatial Domain Filtering for Image De-noising From Digital Images

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ABSTRACT: Lots of applications in computer graphics and computer vision involve the concept and methods of image processing to extract important image structures and/or to reduce noise. Simple Low Pass Spatial Filters and High Pass Spatial Filters/Kernels/Operators are widely used in image visibility, smoothing edge detection, blurring, feature extraction. In this paper we demonstrate that image processing filters are effective and efficient in a great variety of computer graphics and computer vision applications in different scenarios.

I. INTRODUCTION AND LITERATURE

Filtering and sorting visual data by computer has been acquiring a very important consideration of the scientists and professionals during the last few years. The methods of acquiring and judging visual meaningful data by the human creature is known to as sight, view, observation or perceiving. Same way, the events of acquiring and observing visual meaningful data by modern and digital computer is known as digital image processing..

The field of Image Processing or Filtering continues, as it has since the early 1970s, on a path of dynamic growth in terms of popular and scientific interest and number of commercial applications. Yiu-Fai Wong (1994) told that Image enhancement is important when the information of image or picture is lost due to diverse conditions or reasons. Then the solution is given by subtracting a mask from the image to improve it's information, this is the trick to enhance the details They told that edge preserving filter can be applied for obtaining a better mask that is smooth over region with fine details. [45.]. The joint bilateral filter extends this idea by computing the filter weights based on additional input images and not on the color image itself. Therefore, it directly correlates to the previously mentioned global illumination filtering methods, where this buffer consists usually of combinations of the normals, depth and/or noisy color image. Bakker, Vliet, Verbeek (1999), they proposed an advance method of collective adaptive filtering using orientation and filter of edge preserving. This filter ignore filtering over borders and accept local orientation. Using this method orientation of steering the filter is anticipated using a permanent window size that does not have two or more region of orientation. It may be got by filtering technique of Generalized Kuwahara. Using this filter a data set of permanent sized window is selected which has the recent pixel and the window orientation using heaviest anisotropy. They shown multi scale strategy method using comparison of fitters. [30.]. Michael Elad (2002) proposed such a bridge, and showed that using Bayesian approach bilateral filter can use emerging methods by useful and popular algorithm of iteration. He demonstrated by observation that the quality and technique of bilateral filtering may be enhanced to handle problems of reconstruction [24]. Segovia (2006) performs a Gaussian blur on the incident illumination by detected discontinuities in the geometry for deferred shading. Agaian [2007] recommended that global histogram equalization can be used for transform based enhancement methods, this technique changes spatial histogram of a picture for closely matching the uniform distribution. He proposed three methods of image enhancement first one is logarithmic transform histogram matching, and second one is logarithmic transform histogram shifting, and finally in third one he told by Gaussian Distribution the logarithmic transform histogram shaping. These all are depends on the histogram equalization and logarithmic transform domain histogram properties. [22]

Laine (2007) use a geometry-aware box filter for $n \times m$ pixel regions. They have also shown that bilateral filter may be broken into spatial filters of constant time. They have also shown that arbitrary range kernels and arbitrary spatial kernels can be constructed using bilateral filter of constant time. Dammertz (2010) proposed to approximate the cross bilateral filter by an edge-avoiding À-Trous wavelet transform. As we will show all approaches based on the idea of the cross bilateral filter may suffer from small outliers for which not enough samples are available for sufficient filtering results [13.]. Arun R, Madhu S. Nair, R. Vrinthavani and Rao Tatavarti (2011) told that the Adaptive histogram equalization produced a good result in terms of neighborhood pixels clarity that confirms command on the contrast of picture or image by method of transformation to remove the confinement of traditional method of transformation [11]. Pablo Bauszat, Martin Eisemann, Marcus Magnor (2011) proposed a method of pipeline tracing way depends upon filtration of edge using illumination that generates smooth consequences. This method is used for the picture or image that contain polluted path traced and also guides the filters that are used to combine features and other attributes which do not have noise. They illustrate the comparison between their approach and Monte Carlo Integral method and proved that their method is better approximation.[8]. D. Prasanthi propose a novel explicit image filter which is derived from a local linear model, this filter compute the output of filters using consideration of substance of guided picture or image, that may be any picture or image in the form of input. This filter may be used as an preserving of edges and smoothening operator as accepted bilateral filter with better behavior near edges as guided filter. This guided filter may convert the structures of guided picture or image to factorization output, by activating applications of new filtering like de-hazing and guided feathering. And here experiment shows that the guided filter is very efficient as well as effective in a immense range of HDR compression, de-hazing, computer vision, image matting, computer graphics application, sampling, etc. It is a work which accelerating the bilateral filter.[3.]. Yuxiang Yang, Zengfu Weng (2012) proposed a smooth technique of resolving problem of super resolution for range picture or image. If for input images resolution is low, it recovers a high resolution range image by a camera with high resolution for the scene that was captured with low resolution. It resolves the problem of super resolution for range picture or images using gathering the beneficial features of reconstruction constrain and image filter of guided images. Here guided image filter are applied to integrate the range data of image with image of high resolution for the generation of range picture of image with initial high resolution. And experiment demonstrates that this method may achieve range image with great high resolution in terms of spatial resolution and depth precision. [6.]. Jiahao Pang, Oscar C. Au and Zheng Guo propose a scheme which de-haze single image and it is based on haze removal on dark channel. The main benifit of using this filter to refine the transmission lies in its low computational cost; it also generates comparable dehazed result. [7.]. Zhi-Feng Xie, Yan Gui, Rynson W.H. Lau, (2012) propose a new sharpness characteristic effectively gradient-domain image reconstruction and gradient transformation with affinity-based.

II. FILTERING TECHNIQUES

SPATIAL MASK

let us assume an image $f(x, y)$ with N^2 size and neighborhood are defined for each and every pixel. Consider an example window of size 3×3.

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

Fig. 1. Spatial Masks 1
(Taken from *Digital Filters: Analysis and*

Here every pixel is replaced by average weight of neighbourhood pixels then we get the reply from the mask for pixels z_5 is $\sum_{i=1}^{9} w_i z_i$. and this process is repeated for complete image.

LOW PASS AND HIGH PASS SPATIAL FILTERING

A 3×3 mask (spatial) that perform operations on an image may generate
(b) This mask may suppress the information of constant background and may do edge enhancement.
Consider a mask in given below form

a	b	c
d	1	e
f	g	h

Fig. 2. Spatial Masks 2
(Taken from *Digital Filters: Analysis and*

To mea[illegible] coefficients a, b, c, d, e, f, g, h , let us assume one dimensional mask

d	1	e

Consider that we apply mask for a signal $x(n)$. Then this operation output can be $y(n)$ as :[17.]

$$y(n) = dx(n-1) + x(n) + ex(n+1) \Rightarrow Y(z) = dz^{-1}X(z) + X(z) + ezX(z) \Rightarrow$$

$$Y(z) = (dz^{-1} + 1 + ez)X(z) \Rightarrow$$

$\dfrac{Y(z)}{X(z)} = H(z) = dz^{-1} + 1 + ez$. Using domain of frequency we get

$H(e^{j\omega}) = d\exp(-j\omega) + 1 + e\exp(j\omega)$.

here for $\omega = 0$ and $\omega = \pi$ are:

$$H(e^{j\omega})\Big|_{\omega=0} = d + 1 + e$$

$$H(e^{j\omega})\Big|_{\omega=\pi} = -d + 1 - e$$

If there is a need of considering the affect of low pass filter then we get below condition

$$H(e^{j\omega})\Big|_{\omega=0} \geq H(e^{j\omega})\Big|_{\omega=\pi} = d + e \geq 0$$

If there is need of considering the effect of low pass filter then

$$H(e^{j\omega})\Big|_{\omega=0} \leq H(e^{j\omega})\Big|_{\omega=\pi} = d + e \leq 0$$

POPULAR TECHNIQUE FOR LOW PASS FILTERING

UNIFORM FILTERING:

If we consider low pass filter then a very popular mask will be that will have all of its positive coefficient and the value of all coefficient will be equal. below is the example of such type of filter

$\frac{1}{9}\times$

1	1	1
1	1	1
1	1	1

Fig. 3. Uniform Filtering
(Taken from *Digital Filters: Analysis and Design[41]*

Gaussian filtering

Gaussian mask is given by [28.]

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

The below mask illustrate a kernel with best considering integral values with a σ of 1.0.

$\frac{1}{273}\times$

1	4	7	4	1
4	16	26	16	4
7	26	41	26	7
4	16	26	16	4
1	4	7	4	1

Fig. 4. Convolution Kernel
(Taken from *Digital Filters: Analysis and Design[41]*

Median filtering

Median is the mid value of any given data set. In median filtering every and each pixels is replaced by the grey level median of neighborhood pixels.

We can understand it by $x(n)$ and $y(n)$ [17.]

$$\text{median}\{x(n) + y(n)\} \neq \text{median}\{x(n)\} + \text{median}\{y(n)\}$$

Below is the example.

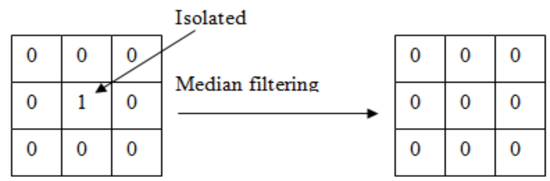

Fig. 5. Median Filtering
(Taken from *Digital Filters: Analysis and Design[41]*

DIRECTIONAL SMOOTHNING

Directional average filter is very important when there is a need to protect edges from blurring while smoothing. Spatial averages can be calculated $g(x,y:\theta)$ for considering lots of chosen directions. [28.]

$$g(x,y:\theta) = \frac{1}{N_\theta} \sum_{(k,l)\in W_\theta} \sum f(x-k, y-l)$$

and a direction θ^* is found such that $|f(x,y) - g(x,y:\theta^*)|$ is minimum. And replacement $g(x,y:\theta)$ with $g(x,y:\theta^*)$ desired result can be obtained.

HIGH BOOST FILTERING

(Highboost-image)= (A) (Original)-(Lowpass)= $(A-1)$ (Original)+(Original)-(Lowpass)

= $(A-1)$ (Original)+(Highpass)

below is the example.

$\frac{1}{9}\times$

-1	-1	-1
-1	$9A-1$	-1
-1	-1	-1

Fig. 6. Un-sharp Masking
(Taken from *Digital Filters: Analysis and Design[17.])*

POPULAR TECHNIQUES FOR HIGH PASS SPATIAL FILTERING:

Edge detection using derivative filters

ABOUT TWO DIMENSIONAL HIGH PASS FILTERS

Consider an image $f(x, y)$ and its locations at (x,y).

$$\nabla \underline{f}(x, y) = \begin{bmatrix} \dfrac{\partial f(x, y)}{\partial x} \\ \dfrac{\partial f(x, y)}{\partial y} \end{bmatrix}$$

where ∇f is given by following

$$\nabla f(x, y) = \text{mag}(\nabla \underline{f}(x, y)) = \left[\left(\frac{\partial f(x.y)}{\partial x} \right)^2 + \left(\frac{\partial f(x, y)}{\partial y} \right)^2 \right]^{1/2}$$

For the gradient's approximation:

$$\nabla f(x, y) \cong \left| \frac{\partial f(x, y)}{\partial x} \right| + \left| \frac{\partial f(x, y)}{\partial y} \right| \text{.............................(1)}$$

let us assume a pixel of interest $f(x, y) = z_5$ with a rectangular of size $3 \times 3 = 9$ as shown below.

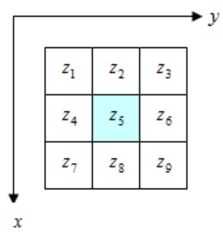

Fig. 7. High Pass Filter
(Taken from *Digital Filters: Analysis and Design[47.]*)

ROBERT OPERATOR

Equation (1) may be approximated with point z_5 using number of ways. The very common and usual method is the difference $(z_5 - z_8)$ with x direction and $(z_5 - z_6)$ with y direction. Such type of approximation is called Roberts operator, and it is illustrated below.[28.]

$$\nabla f \cong |z_5 - z_8| + |z_5 - z_6| \text{ ....(2)}$$

now as per cross differences

$$\nabla f \cong |z_5 - z_9| + |z_6 - z_8| \text{ ....(3)}$$

The implementation of Equations (2), (3) is given by following.

1	0
-1	0

1	-1
0	0

Roberts operator

1	0
0	-1

0	1
-1	0

Roberts operator

Fig. 8. Robert Filter
(Taken from *Digital Filters: Analysis and Design[47.]*)

PREWITT OPERATOR

Equation (1) can be approximated by 3×3 mask as below. [17.]

$$\nabla f \cong |(z_7 + z_8 + z_9) - (z_1 + z_2 + z_3)| + |(z_3 + z_6 + z_9) - (z_1 + z_4 + z_7)| \text{ .. ..(4)}$$

This method of approximation is called the **Prewitt** operator. The implementation of Equation (4) is given by following.

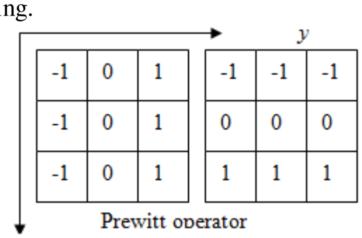

Fig. 9. Prewitt Filter
(Taken from *Digital Filters: Analysis and Design[47.]*)

SOBEL OPERATOR: Definition and comparison with the Prewitt operator

Equation (1) can be approximated by 3×3 mask as per following it is very popular method:

$$\nabla f \cong |(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)| + |(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)| \text{ ....(5)}$$

Such type of approximation is called the **Sobel** operator.

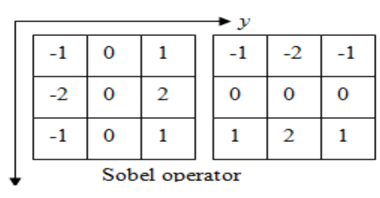

Fig. 10. Sobel Filter
(Taken from *Digital Filters: Analysis and Design[47.]*)

LAPLACIAN OPERATOR

The **Laplacian** of a 2-D function $f(x, y)$ is a second order derivative defined as[28.]

$$\nabla^2 f(x,y) = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2}$$

The other method of implementing it by a 3x3 mask as below:

$$\nabla^2 f = 4z_5 - (z_2 + z_4 + z_6 + z_8)$$

BILATERAL FILTER

Using average weighted of neighborhood pixels filter output is computed by bilaterel filter. It preserve edges when smoothes edges.[16].

GUIDED FILTER KERNEL

Here at first general linear translation variant filtering process is defined, that consist of input image p, a guided image I and q is am output image. I and p may be similar or identical. We can express filtered output at a pixel I in the form of weighted average[2]:

$q_i = \sum_j W_{ij} \ (I) p_j$ .... (6)

Here j is index of pixel and i is also an index of pixel. I is a guidance image, and function of I is the filter kernel W_{ij}, with respect to p, this function is linear.

A joint bilateral filter can be an example of above filter. To confirm that $\sum_j W_{ij}^{bf} = 1$ K_i is the normalizing parameter. For adjusting the range and spatial similarity the parameters σ_s σ_r are used. If we assume p and I are same or identical then the The joint bilateral filter degrades to the original bilateral filter.

In the mid way of filter output q and I the assumption of filter is a local linear model. Now if we consider that linear transform of I is q for a window w_k centered at the pixel k then [2.]:

$q_i = q_k I_i + b_k, \forall i \in w_k$ .... (7)

Here coefficient (a_k , b_k) are linear and considered to be constant for w_k . Let us consider a window that is square of a radius r. Here $\nabla q = a\nabla I$. It has been proved that this is the best suitable model for removal of haze, image super resolution and image matting.

Let us find a solution to (7) for determining linear coefficient and difference between p and q is minimized. Following is the function for minimizing:

$E(a_k, b_k) = \sum_{i\in w_k}((q_k I_i + b_k)^2 + \in a_k^2)$........................ (8)

The next solution to (8) may be illustrated by using following linear regression.

$a_k = \frac{\frac{1}{|\omega|}\sum_{i\in w_k} I_i p_i - \mu_k \bar{p}_k}{\sigma_k^2 + \varepsilon}$... (9)

$b_k = \bar{p}_k - a_k\mu_k$.. (10)

Here σ_k^2 and μ_k indicates the variance and mean of I in w_k , |w| is the number of pixels in w_k. Then linear model is applied to all local windows for the complete image. Then after having computed (a_k , b_k) for all patches w_k, filter output is computed by following:

$q_i = \frac{1}{|\omega|} \sum_{k:i\in w_k}(a_k I_i + b_k)$ ....(11)

$= \bar{a}_i I_i - \bar{b}_i$ ....(12)

where

$$\bar{a}_i = \frac{1}{|\omega|}\sum_{k\in w_i} a_k \ and \ \bar{b}_i = \frac{1}{|\omega|}\sum_{k\in w_i} b_k$$

In such type of situation we will be having $\nabla q \approx \bar{a}\nabla I$.

Now it is figure out that the relationship among q, p, and I can be given by (12), (10), and (9) are required in the form of image filtering (6). a_k can be rewritten in (9) can be rewritten as a weighted sum of p: $a_k = \sum_j A_{kj}(I) p_j$. If identical reason is consider, then $b_k = \sum_j B_{kj}(I) p_j$ from (10) and $q_i = \sum_j W_{ij}(I) p_j$ from (12). And it has been proved that the kernel weights may be illustrated by:

$W_{ij}(I) = \frac{1}{|\omega|^2}\sum_{k:(i,j)\in w_k} 1 + \frac{(I_i-\mu_k)(I_j-\mu_k)}{\sigma_k^2+\varepsilon}$ .... (13)

Further computations shows that $\sum_j W_{ij}(I) = 1$.

PERFORMANCE MEASURES

The below components of measuring performance are being applied for quantitative measurement of analysis and performance for the filtering technique.

Mean Square Error (MSE)

It is the cumulative squared error between the original image and the filtered image and is given by the following equation[36.]:

I(x,y) = Image before filtering,

I'(x,y) = Image after filtering
M, N = dimensions of the image
D = 255 (for unit8 data type) or 1 (for double data type)
Lower the value of the mean square error better.

$$MSE = \frac{1}{MN}\sum_{Y=1}^{M} \sum_{X=1}^{N}\left[\frac{I(x,y)-I^{I}(x,y)}{D}\right] \quad .... (14)$$

Peak signal to noise ratio (PSNR)

The term **peak signal-to-noise ratio (PSNR)** is a technique or method for the ratio between power of distorting noise and the maximum possible value that make impact on the quality of representation. Because many signals have a very wide **dynamic range**, (it is a ratio between smallest values of changeable quantity and the largest values). We can illustrate and express PSNR in the form of logarithmic decibel scale.

It is the measure of the peak error in the signal and is expressed mathematically by the following equation[36.]:

$$PSNR = 20\log_{10}\frac{D}{\sqrt{\mathrm{MSE}}} \quad .... (15)$$

Filters are Applied: Here comparision is being shown among various filters

BOAT IMAGE

Below Comparison of MSE and PSNR for Guided filter, linear and nonlinear filters on gray scale images.

Table 1: Comparison of MSE and PSNR for the Boat Image.

Image filter	Gaussian filter	Average filte	Sobel filter	Median filter	Guided ima
MSE	0.0027	0.0208	6.0369	0.0128	0.0015
PSNR	2110	16.82	-7.80	18.91	28.32

CONCLUSION

We studied here the various techniques of image filtering in this paper, the results show that guided filter is an edge preserving filter, non iterative, fast and accurate as compared to earlier developed filters for image enhancement. Other aspect which needs to be studied are image feathering, image smoothing, flash/no flash de-noising etc.

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