Various Filtering Techniques of Image Processing

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Abstract

Most applications in computer vision and computer graphics involve the concept of image filtering to reduce noise and/or extract useful image structures. Simple explicit linear translation-invariant (LTI) filters like Gaussian filter, Laplacian filter, Guided Filter and Sobel filter are widely used in image, blurring, Smoothing edge detection, and feature extraction. In this paper we demonstrate that all filters are e ective and e cient in a great variety of computer vision and computer graphics applications in different scenarios using MSE and PSNR parameters.

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. Processing of digital images are developed for answering to reply three main purposes that are concerned with images; these main concerned and purpose are Digitization of pictures and coding of images, Enhancement of images and image restoration and Segment of images.

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 classic bilateral filter by Tomasi and Manduchi (1998) is a weighted Gaussian filter that makes use of an intensity component in addition to the spatial component to reweight the Gaussian filter. 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. Even though various methods for accelerating the original bilateral filter exist it does not seem to be feasible to directly speedup the joint bilateral filtering [37.]. 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. Their idea was to detect interleaved sample patterns and computer them using non-interleaved deferred shading process. Agaian [2007] recommended that global [23.]. 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 × m pixel regions. N. Ahuja Q. and Yang, K.-H. Tan (2009) proposed computational complexity invariant to the kernel size of filter with a recent bilateral filter, called O(1). 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. While being very fast, the approximation of the cross bilateral filter can result in visually disturbing ringing artifacts. 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 gradientdomain image reconstruction and gradient transformation with affinity-based. They also propose and evaluation method depends upon sharpness enhancement, sharpness distribution analysis techniques with respect and contrast of characteristics of sharpness. They develop a new pipeline with three committed steps: saliency representation of sharpness, gradient transformation based on affinity and image reconstruction with gradient domain. [5.]. Kaiming He, Jain Sun, Xiaoou Tang (2013) propose a image filter called guided filter that computes output with factorization techniques using consider the substance of a guidance image, it may be used and considered as an operator of edge-preserving smoothing as the bilateral filter, it has been also shown that its behavior is good near edges and By using it guidance image structure can be transferred or converted to filtering output by activating new application of filtering like dehazing and guided eathering [2.].

II. Filtering Techniques

Spatial Mask

Lots of methods for enhancing images depends upon the spatial operations made on the pixels of neighborhood for the pixels of input image. In spatial filtering we use spatial mask for input digital picture or image. [17.]. let us assume an image),(yxf with 2N size and neighborhood are defined for each and every pixel. Consider an example window of size 33'.Here every pixel is replaced by average weight of neighbourhood pixels then we get the reply from the mask for pixels 5z is a=91iiizw. and this process is repeated for complete image.

wi	w_2	w ₃	
W4	W ₅	<i>w</i> ₆	
W7	Wg	W9	

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

Low Pass and High Pass Spatial Filtering

A 33' 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.

(a) This mask may generate a new and better image's version with low frequecies.

Consider a mask in given below form

a	b	С	
d	1	e	
f	g	h	

Figure: Spatial Masks 2 (Taken from *Digital Filters: Analysis and Design[41]*

To measure the affects of afore mentioned mask with coefficients *hgfedcba*,,,,,,,, let us assume one dimensional mask

d 1	e
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Consider that we apply mask for a signal) (*nx*. Then this operation output can be) (*ny* as :[17.] $y(n)=dx(n-1)+x(n)+ex(n+1)\Rightarrow Y(z)=dz^{-1}X(z)+X(z)+ezX(z)\Rightarrow$ $Y(z) = (dz^{-1}+1+ez)X(z) \Rightarrow$ $\frac{Y(z)}{X(z)} = H(z) = dz^{-1}+1+ez$. 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

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

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

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

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



Figure: 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.

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

Figure: 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) and (y) [A7.] median $\{x(n) + y(n)\} \neq median \{x(n)\} + median \{y(n)\}$

Below is the example.



Figure: 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.]

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

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

For high pass filter low pass part of image is subtracted from the original image as given by below formula:[28.] (High pass part of image)=(Original)-(Low pass part of image) and high boost filter works as per following formula: (Highboost-image)=() (Original)-

(Lowpass) = (A - 1) (Original) + (Original) - (Lowpass)

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

below is the example.

	-1	-1	-1
$\frac{1}{9} \times$	-1	9 <i>A</i> –1	-1
	-1	-1	-1

Figure: 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). If we focus on its gradient it wil be vector as follows

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

where ∇f is given by following

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

For the gradient's approximation:

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



Figure: 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.]

 $\nabla f \cong |z_5 - z_8| + |z_5 - z_6|$ (2) now as per cross differences

 $\nabla f \cong |z_5 - z_9| + |z_6 - z_8|$ (3) The implementation of Equations (2), (3) is given by following.



Roberts operator Figure: Robert Filter (Taken from Digital Filters: Analysis and Design[47.])

Prewitt Operator

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

$$\nabla f \cong |(z_7 + z_8 + z_9) - (z_1 + z_2 + z_3)| + |(z_3 + z_6 + z_9) - (z_1 + z_4 + z_7)|$$

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

1	-1	-1
	-	
	0	0
	1	1
		1

Figure: 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:

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

-1	0	1	-1	-2	-1
-2	0	2	0	0	0
-1	0	1	1	2	1

Figure: 1 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:

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

k

5.2.1 Bilateral Filter

Using average weighted of neighborhood pixels filter output is computed by bilaterel filter. It preserve edges when smoothes edges.[16]. Because of this great characteristic we use it in abstraction of images, HDR compression, and decomposition using multi scale and obviously in noise reduction.

7 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]:

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 $\sum_{j} W_{ij}^{u_i} = 1$ K_i is the normalizing parameter. For adjusting the range and spatial similarity the parameters $\sigma_s = \sigma_r$ are used. If we assume p and I are same or identical then the The joint bilateral filter degrades to the original bilateral filter.

So we are going to define the guided kernel and its 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. Her $\nabla q = a \nabla I$. 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:

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

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

$$a_k = \frac{\frac{1}{|\omega|\sum i \in w_k} I_i \varphi_i - \mu_k \varphi_k}{a_k^2 + \varepsilon}.$$
(9)

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

Here $\mathbb{G}_{l_{*}}^{\mathbb{Z}}$ and μk 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:

$$\bar{a}_{i} = \frac{1}{|\omega|} \sum_{k \in W_{i}} a_{k} \text{ and } \bar{b}_{i} = \frac{1}{|\omega|} \sum_{k \in W_{i}} b_{k}$$

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

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:

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.]:



$$\begin{split} I(x,y) &= Image \ before \ filtering, \\ I'(x,y) &= Image \ after \ filtering \\ M, N &= dimensions \ of \ the \ image \\ D &= 255 \ (for \ unit8 \ data \ type) \ or \ 1 \ (for \ double \ data \ type) \\ Lower \ the \ value \ of \ the \ mean \ square \ error \ better. \end{split}$$

$$MSE = \frac{1}{MN} \sum_{Y=1}^{M} \sum_{X=1}^{N} \left[\frac{I(X,Y) - I^{T}(X,Y)}{2} \right].....(14)$$

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.]:

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



BOAT IMAGE

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

Image filter	Gaussian filter	Averag e filter	Sobel filter	Median filter	Guided image
MSE	0.0027	0.0208	6.0369	0.0128	0.0015
PSNR	2110	16.82	-7.80	18.91	28.32

Table : Comparison of MSE and PSNR for the Boat Image

I. 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.

Further study, other advanced models/features might be applied to guided filter to obtain new filters. Research may be undertaken to devise better enhancement techniques.

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