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A Survey on Various Image Filtering Techniques for Image Sharpening

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Abstract: ***Filtering is a technique used for modifying or enhancing an image. This paper surveys the impact on various image filtering techniques such as bilateral filters, Gabor filter and Guided filter for image sharpening and denoising. For comparison various performance metrics are used such as complexity, SNR (Signal to Noise Ratio), accuracy are compared. The results shows that guided filters are best filter than that of other filters.***

Keywords: Metrics, SNR, Denoising, Gabor, Guided, Bilateral

1. Introduction

An image is a projection of three dimensional object to a two dimensional object [6]. Image processing techniques treats the image as two dimensional signal and applying standard signal processing techniques to it. A gray scale image in a two dimensional vector can be defined as X (i,j) where i and j are the spatial co-ordinates and the values of X (i,j) indicates the value of that pixel location, Whereas in case of color images we need to consider the multi-color channel with their specific value. For color images intensity value of pixel (,) will be represented as: Corresponding to red, green, blue channel respectively [7].

Image filtering plays a crucial role in image processing. Filtering is an important part of digital image processing because it has a variety of applications. These applications include the medical image processing, improvement of image quality on display devices such as digital television (DTV), closed circuit television (CCTV), reduce noise and/or extract useful image structures, image denoising, image enhancement etc. Various filtering techniques used for image sharpening are bilateral filters, gabor filters, recursive filters, median filters, guided filters etc. These filters are used as edge preserving filters in various applications.

Bilateral filter is basically a edge-preserving non-linear, and Gaussian noise reducing filter used for gray and color images [8]. It smoothens the image and then preserves edges of the image. We know that color images have three bands ie, RGB. If these color three bands are filtered separately, the smoothness of the image at the edges will be different. It will disturb the balance of colors and hence unexpected color combinations may appear. Therefore, bilateral filters can operate on three bands of color at once and tell which colors are similar so they can be averaged together.

Gabor filters, after Dennis Gabor is a linear filter used for edge detection. Frequency and orientation representations of the Gabor filter are similar to those of the human visual system. The Gabor transform is a classical method of time frequency analysis [5]. This method is computationally efficient and can reduce the noise while preserving the resolution of the original image.

Guided filter is non-iterative, fast, accurate edge preserving filtering [9]. The guided filter computes the filtering output by considering the content of a guidance image, which can be the input image or another different image. It uses the color images for implementation because color guidance image can better preserves the edges than that in gray-scale. It can perform better at the pixels near the edge when compared to bilateral filter.

In this work, we are trying to find which filtering technique is best for medical applications and primary goal is to study different filtering techniques used digital image processing.

2. Bilateral Filter

In this filter there is the combination of both range and domain filtering and hence denote the combined filter as bilateral filtering [10]. It computes the filter output at a pixel as a weighted average of neighboring pixels and also it smoothes the image while preserving edges. Due to this property, it has been widely used in noise reduction, HDR compression and multi-scale detail abstraction. Bilateral filtering makes a nonlinear combination of similar pixel values and it filters the image using range and domain filter. For domain filtering, values chosen show the desired amount of combination of pixels, while the range filtering chooses values based on the desired amount of low pass filtering [11]. Bilateral filter can eliminate the noise point and keep the characters of edges. Therefore this filter is a proper method to solve the halation problem [13]. The bilateral filter can be expressed as equation

$$y_i = \sum_{k=0}^{i} R_{k,i} * S_{k,i} * x_k \quad (1)$$

Where x is the input image and y is the output image, R(k,i)= R(xk, xi) is value range filter that measures the similar degree between the pixel i and k, Sk,i = S(k, i) is spatial filter that measures the distance of the two pixels. It takes both proximity distance and gray value between the pixels in mask into account, so the output of the filter concerns about not only the gray value between the pixels in mask but also their spatial distance [13]. This is the how bilateral filter has the ability to solve the halation problem.

The figure 1 shows an implementation of bilateral filtering for 3D images. This filter smoothes the image while preserving edges.

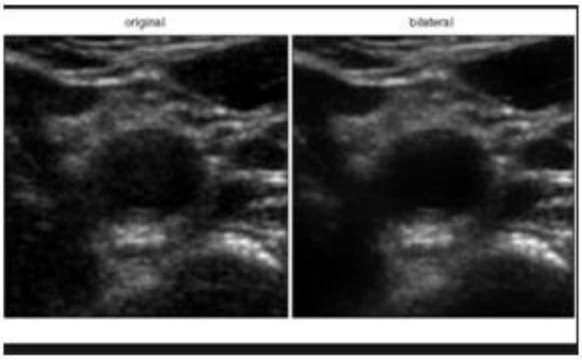


Figure 1: Implementation of bilateral filtering for 3D images

3. Gabor Filter

Important characteristics of an image are their spatial frequencies and their orientations. Frequency characteristics of an image can be determined by using spectral decomposition methods like Fourier analysis [4]. Gabor filter are the popular tool for extracting spatially localized spectral features which require in applications like tracking, object recognition etc.

Gabor transform is a classical method of time frequency analysis [5]. This filter is obtained by modulating a sinusoid with a gaussian. In case of one dimensional signal, a 1D sinusoid is modulated with a gaussian which will therefore respond to some frequency but only in the localized part of the signal. The gabor filter composition for one dimensional signals is illustrated in figure 2 [4].

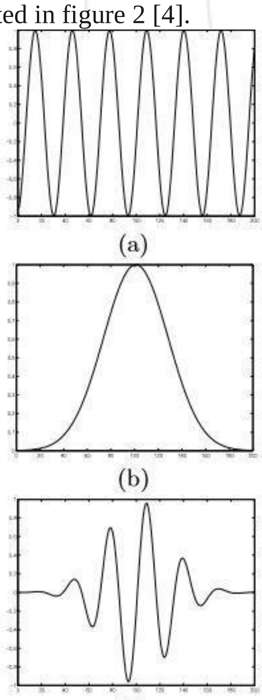


Figure 2: Gabor filter composition for 1D signals: (a) sinusoid, (b) a Gaussian kernel, (c) the corresponding Gabor filter.

For an image such as two dimensional signals, consider the sinusoid shown in figure 3.

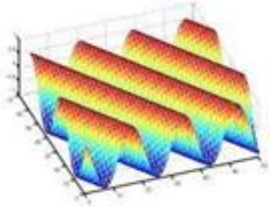


Figure 3: 2D sinusoid oriented at 30◦ with the x-axis.

Let g θ) be the function defining gabor filter which is centered at origin where θ is the spatial frequency and $\emptyset$ is the orientation

$$g(x,y,\emptyset,\theta) = \exp\left(\frac{-x^2+y^2}{\sigma^2}\right)\exp\left(2\pi\theta i(x\cos\emptyset + y\sin\emptyset)\right) \quad (2)$$

Here, σ is standard deviation of gaussian kernel which depends upon the spatial frequency.

In gabor filter the response of an image is obtained by a two dimensional convolution operation. Let the image is denoted by I(x,y) and $\emptyset,\theta$) denotes the response of gabor filter with θ and orientation $\emptyset$ to an image. G(.$\emptyset,\theta$) is obtained as

$$G(x,y,\emptyset,\theta) = \iint I(p,q)\, g(x-p, y-q, \emptyset, \theta)\, dp\, dq \quad (3)$$

Figure 4 shows the implementation of gabor filter in different wavelength and orientation.

$$G(x,y,\emptyset,\theta) = \iint I(p,q)\, g(x-p, y-q, \emptyset, \theta)\, dp\, dq \quad (3)$$

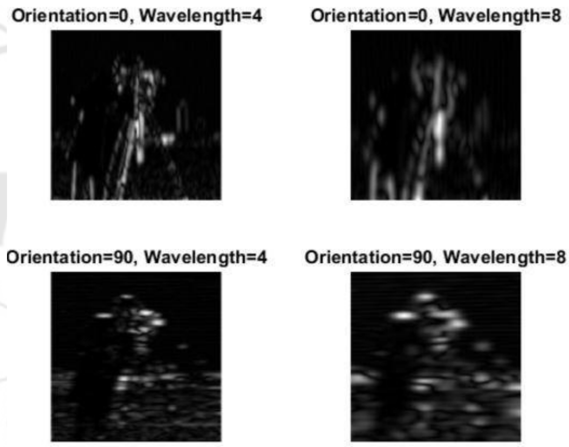


Figure 4: Gabor filter to an input image

Gabor features have shown beneficial properties in feature extraction for many computer vision tasks, but their computational complexity has prevented their use in practice [14].

4. Guided Filter

Guided filter is derived from a local linear model such that guided filter generates the filtering output by considering the content of a guidance image, which can be the filtering image itself or another different image. The guided filter can be perform as an edge preserving smoothing operator like the bilateral filter but has better performance near the edges [1]. Guided filter will enhance the sharpness and reduce the noise of blurred, noisy images in relatively less computational time. The computational complexity is independent of its kernel size [1]. This filter has an edge preserving smoothing property and has an O(N) time (in number of pixels N) algorithm for both gray scale and color images.

Guided filter is a linear translation variant filter[2] such that the output pixel of the image I is computed as the linear transform of the guidance image G, where G can be the input image itself or another image in a local window w_k centered at pixel k[2][3].

$$q_i = a_k I_i + b_k \forall \in w_k \quad (4)$$

Where a_k, b_k) are linear coefficients to be constant in w_k. This model ensures that the output image q has an edge if and only if input image I has an edge, because $\Delta q = a\nabla i$[3]. The linear coefficient a_k *and* b_k are estimated by solving the following optimization problem as,

$$E(a_k, b_k) = \sum_{i\in w_k}((a_k I_i + b_k - b_i) + \epsilon\, a_k{}^2) \quad (5)$$

Where $\in$ is regularization or smoothing parameter which is given by the user. The coefficients a_k *and* b_k can be estimated by using linear regression.

$$a_k = \frac{\frac{1}{|w|}\sum_{i\in w_k} I_i P_i - \mu_k p_k}{\delta_k + \varepsilon} \quad (6)$$

$$b_k = p_k - a_k \mu_k \quad (7)$$

Where μ_k *and* δ_k are mean and variance of input image I. $|w|$ is the number of pixels in w_k *and* p_k is the mean of p in. It is assumed that all local windows centered at pixel k in the window w_i will contain pixel I, then the value q_i will change when it is computed in different windows. To solve this variation all the possible values of coefficient a_k *and* b_k are averaged and then filtering output is estimated. The output image can be calculated according as follows

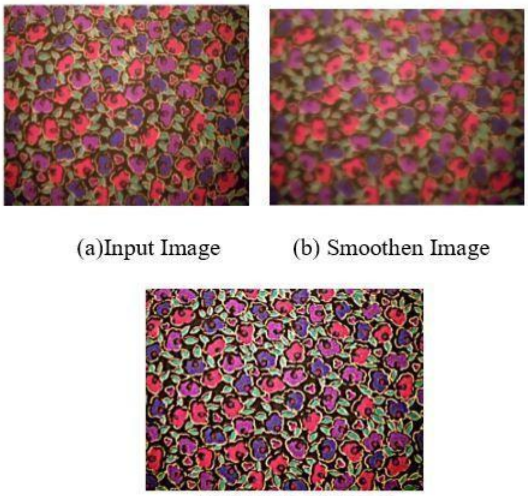
$$q_i = a_i I_i + b_i \quad (8)$$

Where $a_i \frac{1}{|w|}\sum_k \in w_i a_k$ (9)

And, $b_i = \frac{1}{|w|}\sum_k \in w_i b_k$ (10)

When guidance image does not vary in w_k then a_k=0 and b_k=p_k . Whereas when guidance image changes a lot within w_k ie, high variance area a_k become close to 1 and b_k= 0. When a_k *and* b_k are averaged to get a_i *and* b_i the output obtained is , if the pixel is the middle of high variance then the output pixel value will be unchanged.

In case of HD filtering, guided filter adopts fast and non-approximation characteristics of linear time algorithm. Hence, it is used as one of the fastest edge preserving filters.



(a)Input Image (b) Smoothen Image

(c) Enhanced Image

Figure 5: Output of guided filter algorithm

The computation time of guided filter has an O(N) time (in the number of pixels N) algorithm for both gray scale and color images, regardless of the kernel size and the range of intensity. O(N) time indicates the time complexity which is independent of the window radius(r) and hence arbitrary kernel sizes can be used in the applications[1].

5. Discussion

This survey is mainly used for the comparing performance. The parameters used for comparison are

- Accuracy
- Complexity
- Signal to noise ratio(SNR)

The table below shows the accuracy, complexity and SNR of these three filters.

Table 1: Performance Comparison Table

Filters	*Complexity*	*Accuracy*	*SNR*
Bilateral	O (ND^2)	High	Low
Gabor	O (M^2)	Medium	Medium
Guided	O (N)	High	High

Each filter has its own advantages, and disadvantages. Some methods may be good for less noise density images and other methods might be highly computationally efficient. Some filters are better for applications such as medical applications whereas others may be good for other various applications.

Table 1: Advantages and Disadvantages

Methods	*Advantages*	*Disadvantages*
Bilateral filter	Eliminate noise points Preserve edges	Introduction of false edges
Gabor filter	High visual quality Edge preservation	Time consuming
Guided filter	Fast and linear time algorithm Computed efficiently and exactly	Needs a guidance image

6. Conclusion

By comparing various filtering techniques it can be concluded that guided filter is better than other filters ie, bilateral filter and gabor filter in medical applications. It will make a better output by smoothening and sharpening the image in an efficient manner and also it diminishes noises.

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