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An Efficient Image Denoising Technique for Various Noisy Images

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Abstract: ***During transmission the different types of noise that are either in the image during captured or injected in to the image. When captured images usually have Gaussian noise, Speckle noise, and Salt and pepper noise. To remove these types of noise applied image filtering methods on images. In this paper, four different image filtering methods are compared using the Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) for the three different noise types. The median filter gives desirable results in terms of the above parameters for three different noises.***

Keywords: Median filter, Ideal filter, bilateral filter, Mean Square Error.

1. Introduction

Generally images are collected by image sensors which are contaminated by the different type of noise. To analyze various filters such as median filter, ideal filter, butterworth filter and bilateral filter used for suppressing or denoising Gaussian noise, Salt and Pepper noise, Speckle noise.

1.1 Digital images and noise

An image may be contaminated by noise in its transmission or acquisition. Noise is any unwanted information that corrupts an image. From different resources noise comes into an image. There are many different types of noise which can be classified into Gaussian noise, speckle noise and salt & pepper noise. Add these noises in various noiseless images in order to investigate the performance of edge detection algorithms. The main challenge is a search for efficient image denoising methods.

2. Filtering Methods

2.1 Median Filtering

The median filter is a non linear filtering method which attempts to returns the median value of the pixels in its k-neighborhood. It is similar to a uniform blurring filter which returns the mean value of the pixels in a neighborhood of a pixel. Unlike a mean value filter the median tends to preserve sharp edges. It is a simple and ideal for removing salt and pepper noise in the image processing, where neighboring pixels are very similar spatial components.

$$g[k, l] = median\{x[i, j]. (i, j) \in w\} \tag{1}$$

The neighborhood w can be represented on location (k, l) in the image. When applying a median filter can eliminate edge regions from the texture map. Median is an order filter, it uses order statistics. The median filter selects the middle value of pixel (x,y).For an NxN window W(x,y) with pixel (x,y) and the midpoint of W, the intensity values of pixels in W are ordered from smallest to the largest, as follow:

$$I_1 \leq I_2 \leq I_3 \leq \ldots \leq I_N^2 \tag{2}$$

2.2 Bilateral filtering

The bilateral filter is a non linear filter and it provides an effective image denoising. By combining two Gaussian filters which one filter applies in spatial domain and the other one works in intensity domain that achieves spatial weighted averaging without smoothing edges. After segmentation, the image quality can be improved by using the bilateral filter. The bilateral filter calculate a weighted sum of the pixels in a local neighborhood that weights depends on both spatial and intensity distance. The output of a bilateral filter can be computed at a pixel location x as follows,

$$\tilde{I}(x) = \frac{1}{C}\sum_{y\in N(x)} e^{\frac{-\|y-x\|^2}{2\sigma_d^2}}\, e^{\frac{-|I(y)-I(x)|^2}{2\sigma_r^2}}\, I(y) \qquad (3)$$

Where σ_d and σ_r are controlling the fall-off of weights in spatial and intensity domains parameters respectively. N(x) is a spatial neighborhood of pixel I(x), with the normalization constant C.

2.3 Ideal Filtering

Ideal filter is a linear filter with the filter function H(u,v) having the set of frequencies $\omega = (u, v)$. When the set of frequencies |H(u,v)| > 0 is called the pass-band of the filter or |H(u,v)| = 0 is called the stop-band of the filter. Besides, depending on the location of stop-band is divided into four filters such as low-pass, high-pass, band-pass and band-stop filters. The low-pass filter is used as noise filter. The term ideal as it is used of an ideal low pass filter should not be taken to mean that this filter is optimal for low pass filtering. It simply cut off all high frequency components that are from the origin of the transform. In order to change the distance which results changes the behavior of the filter. In Ideal low pass filter, the transfer function can be defined as,

$$H(u,v) = \begin{cases} 1 & \sqrt{(u-u_0)^2 + (v-v_0)^2} < f_c \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

2.4 Butterworth Filtering

Butterworth filter is characterized by the property and its magnitude response is flat in both pass-band and stop-band. The magnitude squared response of an N-order low-pass filter. It does not have sharp discontinuity and no clear cut-off between passed & filtered frequencies.

$$|H_a(j\Omega)|^2 = \frac{1}{1+\left(\frac{\Omega}{\Omega_c}\right)^{2N}} \qquad (5)$$

Where Ω_c is the cutoff frequency in rad/sec.

Properties

- The Magnitude response is,
  - $H_a(0)|^2 = 1$, $|H_a(j\Omega_c)|^2 = 0.5$, for all N at Ω_c 3dB attenuation.
  - $|H_a(j\Omega)|^2$ monotonically decrease for Ω
  - Approaches to ideal filter when $N\to\infty$
- To determine the system function $H_a(s)$

$$H_a(s)H_a(-s) = \frac{1}{1+\left(\frac{s}{j\Omega_c}\right)^{2N}} = \frac{(j\Omega_c)^{2N}}{s^{2N}+(j\Omega_c)^{2N}} = \frac{(j\Omega_c)^{2N}}{\prod_{k=1}^{2N}(s-p_k)} \qquad (6)$$

$$p_k = (-1)^{\frac{1}{2N}}(j\Omega_c) = \Omega_c e^{j\frac{\pi}{2N}(2k+N+1)},\ k = 0,1,\cdots,2N-1 \qquad (7)$$

- A circle of radius Ωc equally distributed with pi/N radians angular spacing.
  - For N odd, $p_k = \Omega c e^{j2pik/N}$
  - For N even, $p_k = \Omega c e^{j(pi/2N+kpi/N)}$
- Symmetry respect to the imaginary axis.
- Only if N is odd, a pole falls on the real axis and on the imaginary axis it never falls.
- By selecting poles in the left half-plane a stable and causal filter $H_a(s)$ can be specified as,

$$H_a(s) = \frac{\Omega_c^{\ N}}{\prod_{LHP\ poles}^{N}(s-p_k)} \qquad (8)$$

3. Experimental Results and Discussion

All four filtering methods were tested on several images with added Gaussian white noise, salt & pepper noise and speckle noise. Bilateral, butterworth and ideal filtering methods were compared to the median filtering method using three different criteria such as visual quality, mean square error (MSE) and peak signal to noise ratio (PSNR) comparison. When compared visually, the denoised images obtained using the median filtering method were clear and did not seem to contain any noise. The smaller MSE value and the larger PSNR value determine which filter is the best performance on image denoising.

Table 1: PSNR and MSE values for Gaussian noise

	PSNR value	MSE value
Noisy Image	51.5536	0.4547
Bilateral filter	73.0494	0.0032
Butterworth filter	71.3608	0.0047
Ideal filter	70.7528	0.0054
Median filter	71.7145	0.0043

Table 2: PSNR and MSE values for Salt & pepper noise

	PSNR value	MSE value
Noisy Image	51.5536	0.4547
Bilateral filter	66.3365	0.0151
Butterworth filter	69.6229	0.0081
Ideal filter	69.0105	0.0093
Median filter	79.2482	0.0014

Table 3: PSNR and MSE values for Speckle noise

	PSNR value	MSE value
Noisy Image	51.5536	0.4547
Bilateral filter	66.955	0.0131
Butterworth filter	71.852	0.0042
Ideal filter	71.222	0.0049
Median filter	72.5422	0.0036

3.1 Visual Quality

Visual Quality Comparison between various noises which used to preserve the edge detection. For example, Gaussian noise added to the image and bilateral filtering image give an assure to visual quality when compare to other image denoising technique as shown in figure 1.

Gaussian noise image Bilateral filtering image

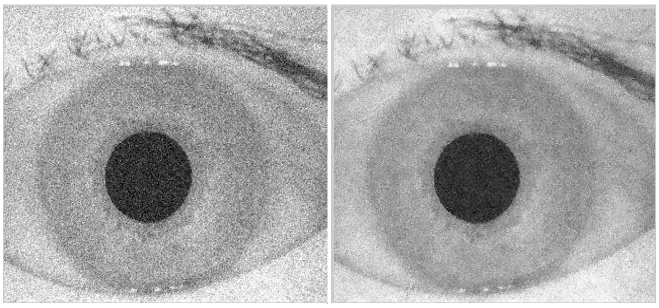
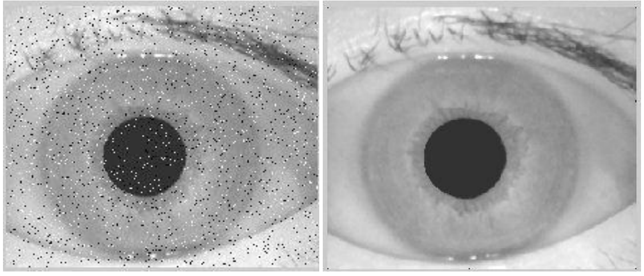


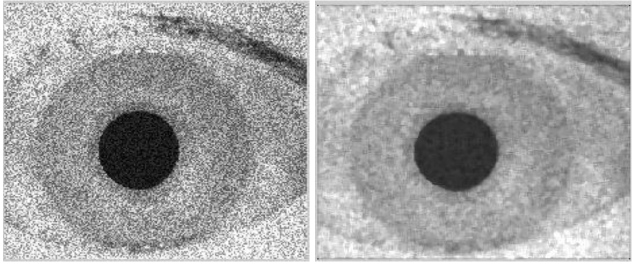
Figure 1: An example for efficient bilateral image denoising technique for Gaussian noise image.

When salt& pepper noise and speckle added to same image using median filtering which provides the efficient and clear image as shown in figure 2 & 3.



Salt & pepper noise image Median filtering image

Figure 2: An example for efficient median filtering for salt & pepper noise



Speckle noise image Median filtering image

Figure 3: An example for efficient median filtering for speckle noise.

4. Conclusion

After the analysis of the test results the median filter proved to be better method for image denoising. The Butterworth and ideal filtering method performed poorly on all the test cases. However, the denoised images still appeared significant amount of noise. The Bilateral filter managed to perform a little better than other filters in Gaussian white noise. But the denoised images still contained to be blurry. For preserving edges in pattern recognition, the median filter provides images clear and visually better quality. The median filter method had the best performance out of other three methods based on smaller MSE values. It was able to recover much more detail of the original image and lightly successful way of approaching image denoising.

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