Comparison Of Different Techniques Of Digital Image Denoising

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Abstract

Digital images play very important role in daily life applications as well as in the areas of research and technology .But main disadvantage of digital images is that noise is added during their transmission. Noise in the digital images can be removed by several techniques. Selecting appropriate techniques for de-noising plays an important role. Several techniques are proposed for image de-noising and each technique has its advantages and disadvantages. Mainly two types of denoising techniques are there .One is spatial domain filtering and other is transform domain filtering. Choice of denoising technique is dependent upon the type of noise which is present in the digital image. In this paper after a brief introduction, overview of different denoising techniques and their analysis is given.

1. Introduction

In digital imaging, the acquisition techniques and systems introduce various types of noises and artifacts. Image denoising is more significant than any other tasks in image processing, analysis and applications. Besides the noisy image produces undesirable visual quality, it also lowers the visibility of low contrast objects. Hence noise removal is essential in digital imaging applications in order to enhance and recover fine details that are hidden in the data. In many occasions, noise in digital images is found to be additive in nature with uniform power in the whole bandwidth and with Gaussian probability distribution. Such a noise is referred to as Additive White Gaussian Noise (AWGN). It is difficult to Suppress AWGN since it corrupts almost all pixels in an image [1]-[2]. In denoising there is always a trade-off between noise suppression and preserving actual image discontinuities. To remove noise without excessive smoothing of important details, a denoising technique needs to be spatially adaptive. Different techniques are used depending on the noise model. Due to sparsity, an edge detection and multiresolution property the wavelet representation naturally facilitates such spatially adaptive noise filtering [3].

2. Noise models

Different type of noise is present in digital images .Noise may be present in additive or multiplicative form [4].

2.1. Additive Noise Model

Noise signal that is additive in nature gets added to the original signal to produce a corrupted noisy signal and follows the following model:

$$w(x, y) = s(x,y) + n(x,y) \qquad (1)$$

2.2. Multiplicative Noise Model

In this model, noise signal gets multiplied to the original signal. The multiplicative noise model follows the following rule:

$$w(x, y) = s(x,y) \times n(x,y) \qquad (2)$$

where, $s(x,y)$ is the original image intensity and $n(x,y)$ denotes the noise introduced to produce the corrupted signal $w(x,y)$ at (x,y) pixel location[4].

3. Various type of noise

There are different types of noise is present and each type of noise has different characteristics.

3.1. Gaussian noise

Gaussian noise is evenly distributed over the signal. Each pixel in noisy image is the sum of true pixel value and a random gaussian distributed noise value [4].

3.2. Salt and Pepper Noise

Salt and Pepper is an impulse type of noise and is also referred to as intensity spikes. It is generally caused due to errors in transmission. It has only two possible values, a high value and a low value. The probability of each is typically less than 0.1. The corrupted pixels are set alternatively to minimum or to maximum values giving the image Salt and Pepper‖ like appearance. The unaffected pixels remain unchanged [4].

3.3. Speckle Noise

Speckle noise [14]-[15] is multiplicative noise. This type of noise occurs in almost all coherent systems such as SAR images, Ultrasound images etc. The source of this noise is random interference between the coherent returns [4].

4. Different denoising techniques

There are basically two approaches for image denoising.One is spatial filtering method and other is transform domain filtering method.

4.1. Spatial domain filtering

This is traditional way to remove noise from digital images. Spatial domain filtering is further classified into linear filters and non-linear filters [5].

a. Smoothing (linear) spatial filter

Smoothing filters are used for blurring and noise reduction. Blurring may be implemented in preprocessing tasks to remove small details from an image prior to large object extraction. The output of a smoothing (averaging or lowpass) linear spatial filter is the average of the pixels contained in the neighborhood of the filter mask. By replacing the value of every pixel in an image by the average of the intensity levels in the neighborhood defined by a filter mask, the resulting image will have reduced "sharp" transitions in intensities. However, edges (characterized by sharp intensity transitions) will be blurred [6].

b. Order-statistic(nonlinear) filters

Order-statistic filter are nonlinear spatial filters whose response is based on ordering (Ranking) the pixels in the neighborhood and then replacing the value of the center pixel by the value determined by the ranking result. The median filters are quite effective against the impulse noise (salt-and-pepper noise). The median of a set of values is such that half the values in the set are greater than the median and half is lesser than it[6].

c. Bilateral Filter (BF)

Recently most popular denoising method is the bilateral filter [7]. The bilateral filter is a nonlinear weighted averaging filter and also the weights depend on both the spatial distance and the intensity distance with respect to the center pixel. The main feature of the bilateral filter is its ability to preserve edges while doing spatial smoothing. The bilateral filter is a robust filter because of its range weight, pixels with different intensities. It averages local small details and ignores outliers[1].

The main drawback in bilateral filter is its incapacity in eliminating salt-and-pepper noise. The second drawback of the bilateral filter is that it produces staircase effect and it is also single resolution in nature[8].

d. Trilateral filter(TF)

Trilateral filtering is one of the most efficient technique for denoisation of the multi-dimensional signals in computer graphics. By means of non-linear combination of information of adjacent pixel it can smoothen the edges and keeps the details of the images. Moreover the process is less iterative and is applicable for N dimensional images as well. Trilateral filtering apart from cumulating geometric and photometric similarities also implements a new concept of local structural similarities specially in the inhomogeneous portions. Homogeneous portions are however low-pass-filtered out directly without any significant change in composition. Trilateral filtering shows high performance in high contrast image display and edge smoothening. It can extract the original information from a noisy image and can predict gradient discontinuities in spacial domain. It is very useful in image processing where noise is maximum and retrieval of the original image is a must for proper utilization of information like in medical image processing or in real-time video-streaming where the image quality is not high and little noise may create large problem[9].

4.2. Transform domain filtering

The transform domain filtering can be further divided into data adaptive and non-adaptive filters. Main type of transform domain filtering is wavelet based filtering.

a.Data-Adaptive Transforms

Recently a new method called Independent Component Analysis (ICA) has gained wide spread attention.One exceptional merit of using ICA is it's assumption of signal to be Non-Gaussian which helps to denoise images with Non-Gaussian as well as Gaussian distribution[11][12].

b. Non-Adaptive Transform

Wavelet transform: The term "wavelets" is used to refer to a set of orthonormal basis functions generated by dilation and translation of scaling function φ and a mother wavelet ψ. The finite scale multiresolution representation of a discrete function can be called as a discrete wavelet transforms The modeling of the wavelet coefficients can either be deterministic or statistical[16]. Wavelet approach for noise removal has been successfully exploited by several in the past few decades. It has been proved that the use of wavelets successfully removes noise while preserving the signal characteristics, regardless of its frequency content[12]-[13].

Wavelet transform is a mathematical function that analyzes the data according to scale or resolution. Noise reduction using wavelets is performed by first decomposing the noisy image into wavelet coefficients i.e. approximation and detail coefficients. Then, by selecting a proper thresholding value the detail coefficients are modified based on the thresholding function. Finally, the reconstructed image is obtained by applying the inverse wavelet transform on modified coefficients[4].

Basic procedure for all thresholding method is

1. Calculate DWT if the Image.
2. Threshold the wavelet components.
3. Compute IDWT to obtain denoised estimate.

There are two thresholding functions frequently used i.e. Hard Threshold [10], Soft threshold. Hard-Thresholding function keeps the input if it is larger than the threshold; otherwise, it is set to zero. Soft-thresholding function takes the argument and shrinks it toward zero by the threshold. Soft-thresholding rule is chosen over hard-thresholding, for the soft-thresholding method yields more visually pleasant images over hard thresholding. A result may still be noisy. Large threshold alternatively, produces signal with large number of zero coefficients. This leads to a smooth signal. So much attention must be paid to select optimal threshold[4].

5. Conclusion

In this paper different denoising techniques are discussed. The study of various denoising techniques for digital images shows that wavelet filters's performance is better than spatial domain filters. Spatial domain filters operate by smoothing over a fixed window and sometimes causes over smoothing and it blurred the digital image. Wavelet Transform is better denoising technique than spatial filtering because of its properties like multiresolution and multiscale nature. Main advantage of wavelet transform is that it is easy to implement.

6.References

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