International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 9, September - 2013

Image Denoising Using Joint Fuzzyfication

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Abstract

Digital images are degraded by various types of noises. The search for efficient image denoising methods is still a valid challenge at the crossing of functional analysis and statistics. A new hybrid image denoising method using Bilateral filter (BF),Trilateral Filter (TF), and fuzzy logic is used for image denoising. The bilateral filter is a nonlinear filter that does spatial averaging without smoothing edges. The bilateral filter takes a weighted sum of the pixels in a local neighbourhood; the weight depends on both the spatial distance and the intensity distance. With the help of nonlinear combination of information of adjacent pixel, trilateral filter smoothen the edges and preserve the edge details of the images. In the first stage, the noisy image is passed through Bilateral Filter but only some amount of noise get reduced but the image gives a blurred appearance and it is has a problem with extreme outliers. Hence to preserve the edge details and reduce the blur effect,image is passed through Fuzzy Logic. In the second stage,image is passed through Trilateral Filter and then fuzzy logic is applied for image denoising.At last,comparison of values of PSNR of both stages is done.

1. Introduction

Image denoising is the process in which the original image is estimated from an image that has been degraded by different types of noise. Noise reduction and elimination is the technique of removal of noise from a noisy image while keeping its features unaffectedThe task is to decompose a noisy image into a clean image and a noise component.

Image denoising is most important than other methods in digital image processing image processing. The main aim of denoising is to find noises in the image which are both semantically and visually relevant to users based on image descriptors. Most of the time noise in digital images is found to be additive in nature with uniform power in the whole bandwidth and with Gaussian probability distribution. This type of noise is called as Additive White Gaussian Noise (AWGN). It is very difficult to remove AWGN because it corrupts almost all of the pixels in a digital image [1]-[2].

Image denoising plays an important role in a wide variety of applications such as object recognition, image segmentation, photo enhancement etc. 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].

Different Type of Noise

Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon

ISSN: 2278-0181
Vol. 2 Issue 9, September - 2013

detector .Image noise is generally considered as an undesirable product of image capture [4].

The magnitude of noise present in the image can range from almost imperceptible specks on a digital photograph taken in good light, to optical and radio astronomical images that are almost entirely noise, from which a small amount of information can be derived by sophisticated processing [4]. Typical images are corrupted with noise modeled with either Gaussian,uniform,or salt and pepper distribution. Another typical noise is a speckle noise, which is multiplicative in nature. Noise is present in an image either in an additive or multiplicative form.

Different types of noise present in image are:

1. Gaussian noise
2. Salt-and-pepper noise
3. Shot noise (Poisson noise)
4. Speckle noise

1. Gaussian Noise

Gaussian noise is equally distributed over the signal. Each pixel in noisy image is the sum of true pixel value and a random gaussian distributed noise value. The standard model of gaussian noise is additive, Gaussian, independent at each pixel and independent of the signal intensity.

This type of noise has a Gaussian distribution, which has a bell shaped probability distribution function given by,

$$F(g) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(g-m)^2/2\sigma^2}$$

In color cameras where more amplification is used in the blue color channel than in the green or red channel, there can be more noise in the blue channel. Gaussian noise is a main part of the "read noise" of an image sensor, that is, of the constant noise level in dark areas of the image [4]-[5].

2. Salt-and-Pepper Noise

An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. The value of the noisy pixels is therefore completely uncorrelated with the value of the same pixels in the clean image, which is different from AWG or Poisson noise. Salt-and-pepper noise can arise due to errors during transmission of an image.

This type of noise can be eliminated in large part by using dark frame subtraction and by interpolating around dark or bright pixel [4]-[5].

3. Possion Noise

Poisson noise or shot noise is a type of electronic noise which occures when the finite number of particles that carry energy, such as electrons in an electronic circuit or photons in an optical device, is small enough to give rise to detectable statistical fluctuations in a measurement. Poison noise is induced by the nonlinear response of the image detectors and recorders. Possion noise is image data dependent. This term arises because detection and recording processes involve random electron emission having a Poisson distribution with a mean response value [5].

4. Speckle noise

Speckle noise is multiplicative type of noise. This type of noise present in almost all type of coherent systems such as SARSAR (Synthetic Aperture Radar) images, Ultrasound images etc.

The main source of this type of noise is random interference between the coherent returns. Fully developed speckle noise has the characteristic of multiplicative noise[5]. Speckle noise follows a gamma distribution and is given as

$$F(g) = \frac{g^{\alpha-1}}{(\alpha-1)!\,a^{\alpha}} e^{-\frac{g}{a}}$$

2.Different Techniques of Image Denoising

In case of image denoising technique , the characteristics of the degrading system and the noise is assumed to be known .

There are mainly two types of denoising techniques

2.1. Spatial Domain filtering

2.2. Wavelet Domain filtering

2.1. Spatial Domain Filtering

A traditional way to remove the noise from image data is spatial filtering. Filters play very important role in the image denoising process. The basic concept behind image denoising using linear filters is digital convolution and moving window principle. Let w(x) be the input signal to the filtering, and z(x) be the filtered output. If the filter satisfies certain conditions such as linearity and shift invariance, then the output filter can be expressed mathematically in simple form as

$$Z(x) = \int w(t)\, h(x-t)\, dt$$

2.1.1. Linear filtering

Linear filters tend to blur sharp edges, destroy lines and other fine details of image. It includes Mean filter and wiener filter. The wiener filtering method requires the information about the spectra of the noise and the original signal and it works well only if the underlying signal is smooth. Wiener method implements spatial smoothing and its model complexity control correspond to choosing the window size [6].

2.1.2 Non linear filtering

With the non-linear filter, noise is removed without any attempts to explicitly identify it. Spatial filters employ a low pass filtering on the group of pixels with the assumption that noise occupies the higher region of frequency spectrum. Generally spatial filters remove the noise to reasonable extent but at the cost of blurring the images which in turn makes the edges in the picture invisible [5].

2.2. Wavelet Transforms

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[7].

2.2.2. Wavelet Thresholding

From their properties and behavior, wavelets play a major role in image compression and image denoising. Wavelet coefficients calculated by a wavelet transform represent change in the time series at a particular resolution. By considering the time series at various resolutions, it is then possible to filter out noise. The term wavelet thresholding is explained as decomposition of the data or the image into wavelet coefficients, comparing the detail coefficients with a given threshold value, and shrinking these coefficients close to zero to take away the effect of noise in the data. The image is reconstructed from the modified coefficients. This process is also known as the inverse discrete wavelet transform[7].

Proposed Method

4.1 Bilateral filter

The bilateral filter is a nonlinear filter that does spatial averaging without smoothing edges. An important issue with the application of the bilateral filter is the selection of the filter parameters, which affect the results significantly. The bilateral filter takes a weighted sum of the pixels in a local neighborhood; the weight depends on both the spatial distance and the intensity distance. In this way, edges are preserved well while noise is averaged out. A bilateral filter is an edge-preserving and noise reducing smoothing filter. The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight is based on a Gaussian distribution. Crucially the weights depend not only on Euclidean distance but also on the radiometric differences (differences in the range, e.g. color intensity or Z distance) [8].

The bilateral filter takes a weighted sum of the pixels in a local neighbourhood, the weights depend on both the spatial distance and the intensity distance. Let N(x) be a spatial neighborhood of x , The weight of each pixel $y \in N(x)$ is the product of two components, one spatial weight component and one intensity weight component

$$w(x, y) = w_S(x, y) w_R(x, y)$$

where

$$w_S(x, y) = \exp(- |x - y|^2 / 2\sigma^2)$$

$$w_R(x, y) = \exp(- |u(x) - u(y)|^2 / 2\sigma^2)$$

Finally, the restored pixel u(x) is calculated as follows :

$$u(x) = \frac{\sum_{y \in N(x)} w(x,y) u(y)}{\sum_{y \in N(x)} w(x,y)}$$

The w_s weighting function gives higher weight to pixel y that are spatially close to the central pixel x and the w_R weighting function is used to penalize the difference of intensities between x and y . In weighting functions, the parameter σ_S and σ_R control the behaviour of the bilateral filter. σ_S and σ_R characterizes the spatial and intensity domain behaviours. In case of image denoising applications, the selection of optimal parameter values has not a universal rule.

4.2 Trilateral filter

Trilateral filter is single-pass nonlinear filter for edge-preserving smoothing and visual detail removal for N dimensional signals in computer graphics, image processing and computer vision applications.Built from two modified forms of Tomasi and Manduchi's bilateral filter, the new "trilateral" filter smoothes signals towards a sharply-bounded, piecewise-linear approximation. Unlike bilateral filters or anisotropic diffusion methods that smooth towards piecewise constant solutions, the trilateral filter provides stronger noise reduction and better outlier rejection in high-gradient regions, and it mimics the edge-limited smoothing behavior of shock-forming PDEs by region finding with a fast min-max stack. Yet the trilateral filter requires only one user-set parameter, filters an input signal in a single pass, and does not use an iterative solver as required by most PDE methods. Like the bilateral filter, the trilateral filter easily extends to *N*-dimensional signals, yet it also offers better performance for many visual applications including appearance-preserving contrast reduction problems for digital photography and denoising polygonal meshes [9].

The trilateral filter combines two modified bilateral filters with a novel image-stack scheme for fast region- finding to avoid these problems. Its novel contributions are:

1.Tilting: Its filter window is skewed or tilted by the bilaterally-smoothed image gradient vector to track high-gradient regions .

2.Adaptive Region-Growing: The local neighborhood or domain automatically adapts to local image features to smooth the largest possible region with similar smoothed gradient values.

4.3 FUZZY LOGIC

We use from fuzzy logic and fuzzy reasoning for noise correct detection. Fuzzy logic can be decrease uncertainty in noise detection, thus we introduce fuzzy effective value with assistance of neighborhood for each pixel and decision for noisy pixel that is really noise or not. All membership functions are types of triangular encountering but the number they are variables in the different nature of the natural parameters such as body temperature is originated [10].

Fuzzy Logic is one of the finest filteration algorithm which supports both manual threshold and automated threshold. The fuzzy logic is performed in the following manner:

TABLE 1. Denoising result

Level of Noise	σ = 10	σ = 20	σ = 40	σ = 60
Noisy PSNR	27.8959	22.8442	20.3884	18.7749
Bilateral filter + fuzzyfication	32.4102	24.3610	22.6731	19.5439
Trilateral filter + fuzzyfication	40.0647	32.6675	29.2371	25.9362

1. First of all, we define the boundary values of the image so that further steps can be considered. Boundary values help out in defining the threshold. This is called preprocessing.
2. Now for contrast adjustment we define the region based on the boundaries.The threshold would be different for every region.
3.This is the final step here based on threshold, the membership function are called and then filteration gets started.

Conclusion

With all the experimental work which we have done , we can conclude that both the bilateral filter and trilateral filter are efficient enough to de noise a particular noisy image if they are combined with fuzzy logic system . Still if we need to find best out of best then the trilateral filter has definitely a better edge. It sharpens the image quite efficiently and as a result we get a better PSNR value.We can also conclude that Fuzzy logic is a effective method and it can be combined with any algorithm to produce better results.

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