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Survey of De-noising Methods Using Filters and Fast Wavelet Transform

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Abstract: There are many noise reduction techniques have been developed for removing noise and retaining edge details in images. Choice of de-noising algorithm is application dependent and depends upon the type of noise present in the image. Each technique has its own assumptions, advantages and limitations. The idea behind these techniques is to acquiesce better results in terms of quality and in removal of different noises. This paper covers almost all the de-noising techniques.

Keywords: Image de-noising, Gaussian noise, Salt and pepper noise, Poisson noise, Impulse noise, Speckle noise, Spatial filters, Wavelet transform.

I. INTRODUCTION

With recent advances in image technology, image denoising has found renwed interest for researchers. Image denoising is one of the fundamental challenges in the field of image processing and computer vision, where the underlying goal is to estimate the original image by suppressing noise from a noise-contaminated version of the image. Image noise may be caused by different intrinsic (i.e., sensor) and extrinsic (i.e., environment) conditions which are often not possible to avoid in practical situations. Therefore, image denoising plays an important role in a wide range of applications such as image restoration, visual, tracking, image registration, image segmentation, and image classification, where obtaining the original image content is crucial for strong performance. The goal of de-noising is to remove the noise while retaining as much as possible the important signal features of an image. Different types of images inherit different types of noise and different noise models are used to present different noise types. Denoising method tends to be problem specific and depends upon the type of image and noise model.

II. NOISE MODELS

Noise is present in image either in additive or multiplicative form [6].

A)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:

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

The Gaussian noise is a type of additive noise it evenly distributes itself over the signal. This type of noise has a Gaussian distribution [12].

B) Multiplicative Noise Model

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

$w(x, y) = s(x,y) \times n(x,y)$ …………………(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.

III. TYPES OF NOISES

The noise is characterized by its pattern and by its probabilistic characteristics. There is a wide variety of noise types while we focus on the most important types, they are; Gaussian noise, salt and pepper noise , poison noise, impulse noise, speckle noise.

A) Gaussian Noise

Gaussian noise is statistical noise that has its probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed. A special case is white Gaussian noise, in which the values at any pair of times are identically distributed and statistically independent (and hence uncorrelated). In applications, Gaussian noise is most commonly used as additive white noise to yield additive white Gaussian noise.

B) Salt And Pepper Noise

Salt and pepper noise is a form of noise typically seen on images. It represents itself as randomly occurring white and black pixels. An effective noise reduction method for this type of noise involves the usage of a median filter, morphological filter or a contra harmonic mean filter. Salt and pepper noise creeps into images in situations where quick transients, such as faulty switching, take place.

C) Poison Noise

Poisson noise is induced by the nonlinear response of the image detectors and recorders. This type of 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. Since the mean and variance of a Poisson distribution are equal, the image dependent term has a standard deviation if it is assumed that the noise has a unity variance.

D) Impulse Noise

Impulse noise is a category of (acoustic) noise which includes unwanted, almost instantaneous (thus impulse-like) sharp sounds (like clicks and pops). Noises of the kind are usually caused byelectromagnetic interference, scratches on the recording disks, and ill synchronization in digital recording and communication. High levels of such a noise (200 + Decibels) may damage internal organs, while 180 Decibels are enough to destroy or damage human ears.

E) Speckle Noise

Speckle is a complex phenomenon, which degrades image quality with a backscattered wave appearance which originates from many microscopic diffused reflections that passing through internal organs and makes it more difficult for the observer to discriminate fine detail of the images in diagnostic examinations. 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. The speckle noise follows a gamma distribution [5]. Thus, denoising or reducing the noise from a noisy image has become the predominant step in medical image processing. For the quality and edge preservation of images we have taken different denoising techniques into consideration.

IV. DENOISING TECHNIQUES

There are basic two approaches of the image denoising: spatial domain filtering and transform domain filtering.

A) *Spatial Domain Filtering*

Spatial filters are direct and high speed processing tools of images. This is the traditional way to remove the noise from the digital images to employ the spatial filters. Spatial domain filtering is further classified into linear filters and non-linear filters.

1)** Linear filters**:

Mean filter: Mean filtering is a simple, intuitive and easy to implement method of smoothing images, *i.e.* reducing the amount of intensity variation between one pixel and the next. It is often used to reduce noise in images. The idea of mean filtering is simply to replace each pixel value in an image with the mean (`average') value of its neighbors, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. The two main problems with mean filtering, which are:

- A single pixel with a very unrepresentative value can significantly affect the mean value of all the pixels in its neighborhood.
- When the filter neighborhood straddles an edge, the filter will interpolate new values for pixels on the edge and so will blur that edge. This may be a problem if sharp edges are required in the output.

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[7]. Wiener filtering is able to achieve significant noise removal when the variance of noise is low, they cause blurring and smoothening of the sharp edges of the image[8].

2) *Non-linear filter:*

i*) Median filter:*Median filtering is a common step in image processing. Median filter is a well-used nonlinear filter that replaces the original gray level of a pixel by the median of the gray values of pixels in a specific neighborhood. The median filter is also called the order specific filter because it is based on statistics derived from ordering the elements of a set rather than taking the means. This filter is popular for reducing noise without blurring edges of the image[9]. It is particularly useful to reduce salt and pepper noise and speckle noise as well . Its edgepreserving nature makes it useful in cases where edge blurring is undesirable.

B) *Transform Domain Filtering*

The transform domain filtering can be subdivided into data adaptive and non-adaptive filters. Transform domain mainly includes wavelet based filtering techniques [6]. Data adaptive transform includes Independent component analysis(ICA).

1) *Data-Adaptive Transforms*

Recently a new method called Independent Component Analysis (ICA) has gained wide spread attention. The ICA method was successfully implemented in [38, 39] in denoising Non-Gaussian data. 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[7].

2) Non-Adaptive Transform

Wavelet transform: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[11].

Wavelet transformation is a multiresolution representation of signal and image in two dependant domains, which decompose the signal and image into multiscale resolution. The localization of the wavelet basis functions in both time and frequency domain leads to multiresolution analysis and effective filter designs for specific applications. Wavelet decomposition preserved and depicted the sharp transition in images, which results in very accurate edge detection in images. These properties of the wavelet transform make it very effective for denoising. Wavelet gaining popularity in the area of biomedical image denoising due to its sparsity and multiresolution properties. In recent years, the multiresolution wavelet denoising techniques have employed in biomedical image. Several wavelets such as haar, daubechies, symlet, discrete meyer coiflets and biorthogonal have been implemented for denoising.

The Daubechies wavelet transforms are defined in the same way as the Haar wavelet transform by computing the running averages and differences via scalar products with scaling signals and wavelets the only difference between them consists in how these scaling signals and wavelets are defined[14]. This wavelet type has balanced frequency responses but non-linear phase responses. Daubechies wavelets use overlapping windows, so the high frequency coefficient spectrum reflects all high frequency changes. Therefore Daubechies wavelets are useful in noise removal of image processing [15].

The Fast Wavelet Transform is a mathematical algorithm designed to turn a waveform or signal in the time domain into a sequence of coefficients based on an orthogonal basis of small finite waves, or wavelets. The transform can be easily extended to multidimensional signals, such as images, where the time domain is replaced with the space domain. It has as theoretical foundation the device of a finitely generated, orthogonal multiresolution analysis (MRA). Transform coding is a widely used method of compressing image information. In a transform-based compression system two-dimensional (2-D) images are transformed from the spatial domain to the frequency domain. An effective transform will concentrate useful information into a few of the low-frequency transform coefficients.

Wavelet-based image processing systems are typically implemented by memory-intensive algorithms with higher execution time than other transforms. In the usual DWT implementation [16], the image decomposition is computed by means of a convolution filtering process and so its complexity rises as the filter length increases. Moreover, in the regular DWT computation, the image is transformed at every decomposition level first row by row and then column by column, and hence it must be kept entirely in memory. Fast wavelet transform algorithms have been proposed in order to reduce both memory requirements and complexity. This approach increases flexibility when applying wavelet transform and significantly reduce the memory requirements.

In 1988, Mallat produced a fast wavelet decomposition and reconstruction algorithm [Mal89]. The Mallat algorithm for discrete wavelet transform (DWT) is, in fact, a classical scheme in the signal processing community, known as a two-channel subband coder using conjugate quadrature filters or quadrature mirror filters (QMFs).

- The decomposition algorithm starts with signal s, next calculates the coordinates of $A1$ and $D1$, and then those of $A2$ and $D2$, and so on.
- The reconstruction algorithm called the inverse discrete wavelet transform (IDWT) starts from the coordinates of AJ and DJ, next calculates the coordinates of AJ–1, and then using the coordinates of AJ–1 and DJ–1 calculates those of AJ–2, and so on.

Non linear Thresholding Filtering

Thresholding approach is sensitive to noise components. In the recent years there has been a fair amount of research on wavelet thresholding and threshold selection for signal de-noising because wavelet provides an appropriate basis for separating noisy signal from the image signal. The motivation is that as the wavelet transform is good at energy compaction, the small coefficient are more likely due to noise and large coefficient due to important signal features. These small coefficients can be thresholded without affecting the significant features of the image.

Thresholding is a simple non-linear technique, which operates on one wavelet coefficient at a time. In its most basic form, each coefficient is thresholded by comparing against threshold, if the coefficient is smaller than threshold, set to zero; otherwise it is kept or modified. Replacing the small noisy coefficients by zero and inverse wavelet transform on the result may lead to reconstruction with the essential signal characteristics and with less noise. It is important to know about the two catagories of thresholding. They are hard thresholding and soft thresholding.

In hard thresholding all coefficients whose magnitude is greater than the selected threshold value λ remains same and the others whose magnitude is smaller than λ are set to zero. It creates a region around zero where the coefficients are considered negligible. In soft thresholding, the coefficients whose magnitude is greater than the selected threshold value are shrunk towards zero by an amount of threshold λ and others set to zero. The choice of a threshold is an important point of interest. It plays a major role in the removal of noise in images because denoising most frequently produces smoothed images, reducing the sharpness of the image. Care should be taken so as to preserve the edges of the denoised image.

V. CONCLUSION

Denoising or noise reduction has been a permanent research topic for engineers and scientists and one reason for it is the lack of a single technique, which is able to achieve denoising for a wide class of images. Though, traditional linear noise removal techniques like Wiener filtering, has been existing for a long time for their simplicity and are able to achieve significant noise removal when the variance of noise is low, they cause blurring and smoothening of the sharp edges of the image. Hence, in recent years there has been a fair amount of research on non-linear noise removal techniques and prominent among them are the wavelet based denoising techniques. Wavelet transform is best suited for performance because of its properties like sparsity, multiresolution and multiscale nature,which wavelet is applied depends upon the nature of the application. DWT has a disadvantage of Shift in varience whereas daubechies wavelet transform is effiecient to remove noise and a new technique fast wavelet transform represents with less memory requirement and complexity.

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