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A Survey on Image Noises and Denoise Techniques

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Abstract— **Digital images are noisy due to environmental disturbances. To ensure image quality, image processing of noise reduction is a very important step before analysis or using images. Data sets collected by image sensors are generally contaminated by noise. Imperfect instruments, problems with the data acquisition process, and interfering natural phenomena can all degrade the data of interest. The importance of the image denoising could be a serious task for medical imaging, satellite and areal image processing, robot vision, industrial vision systems, micro vision systems, space exploring etc. 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 of noises and de noise filters been developed to reduce noise from corrupted images to enhance image quality.**

Index Terms— **Image noise, Denoising, Median filter, Wiener Filter.**

I.INTRODUCTION

Digital image processing is the use of computer algorithms to perform image processing on digital images. Image noise is random variation of brightness or color information in images, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera or in the image transmission period [1]. The original meaning of "noise" was and remains "unwanted sound"; unwanted electrical fluctuations in signals received by AM radios caused audible acoustic noise ("static"). By analogy unwanted electrical fluctuations themselves came to be known as "noise" Image noise is, of course, inaudible. In video and television , noise refers to the random dot pattern that is superimposed on the picture as a result of electronic noise, the 'snow' that is seen with poor (analog) television reception or on VHS tapes. Interference and static are other forms of noise, in the sense that they are unwanted, though not random, which can affect radio and television signals.

A. Noise Model

Imaging sensors can be affected by ambient conditions. Interference can be added to an image during transmission . We can consider a noisy image to be modelled as follows:

$$g(x,y) = f(x,y) + \eta(x,y) \tag{1}$$

where $f(x, y)$ is the original image pixel, $\eta(x, y)$ is the noise term and $g(x, y)$ is the resulting noisy pixel. If we can estimate the model the noise in an image is based on this will help us to figure out how to restore the image. Although these unwanted fluctuations became known as "noise" by analogy with unwanted sound they are inaudible and actually beneficial in some applications, such as dithering [2].

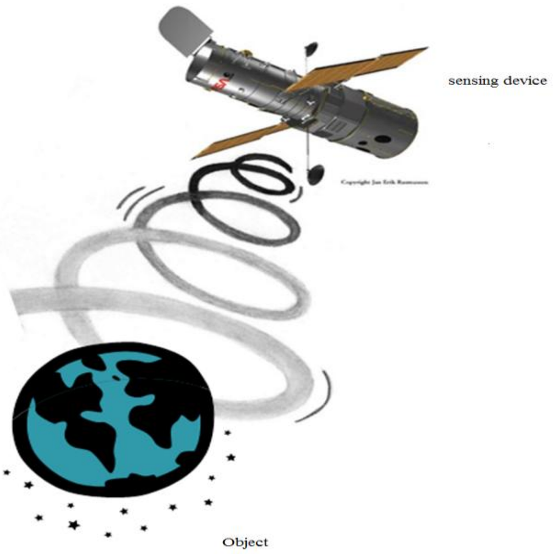

Fig.1: Noise Model

B. Image Noise Types

1. Gaussian noise- The standard model of amplifier noise is additive, Gaussian, independent at each pixel and independent of the signal intensity, caused primarily by Johnson–Nyquist noise (thermal noise), including that which comes from the reset noise of capacitors ("kTC noise"). 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. Amplifier noise is a major part of the "read noise" of an image sensor, that is, of the constant noise level in dark areas of the image [3].

2. Salt-and-pepper noise - Fat-tail distributed or "impulsive" noise is sometimes called salt-and-pepper noise or spike noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. This type of noise can be caused by analog-to-digital converter errors, bit errors in transmission, etc. Dead pixels in an LCD monitor produce a similar, but non-random, display. This can be eliminated in large part by using dark/bright pixels.

3. Film grain- The grain of photographic film is a signal-dependent noise, with similar statistical distribution to shot noise. If film grains are uniformly distributed (equal number per area), and if each grain has an equal and independent probability of developing to a dark silver grain after absorbing photons, then the number of such dark grains in an area will be random with a binomial distribution; in areas where the probability is low; this distribution will be close to the classic Poisson distribution of shot noise. A simple Gaussian distribution is often used as an adequately accurate model. Film grain is usually regarded as a nearly isotropic (non-oriented) noise source; its effect is made worse by the distribution of silver halide grains in the film also being random.

4. Shot noise- The dominant noise in the lighter parts of an image from an image sensor is typically that caused by statistical quantum fluctuations, that is, variation in the number of photons sensed at a given exposure level; this noise is known as photon shot noise. Shot noise has a root-mean-square value proportional to the square root of the image intensity, and the noises at different pixels are independent of one another. Shot noise follows a Poisson distribution, which is usually not very different from Gaussian. In addition to photon shot noise, there can be additional shot noise from the dark leakage current in the image sensor; this noise is sometimes known as "dark shot noise" or "dark-current shot noise".

5. Quantization noise -The noise caused by quantizing the pixels of a sensed image to a number of discrete levels is known as quantization noise; it has an approximately uniform distribution, and can be signal dependent, though it will be signal independent if other noise sources are big enough to cause dithering, or if dithering is explicitly applied. This error is either due to rounding or truncation. The error signal is sometimes considered as an additional random signal called quantization noise because of its stochastic behaviour.

6. Anisotropic noise- Some noise sources show up with a significant orientation in images. For example, image sensors are sometimes subject to row noise or column noise. Anisotropic noise textures are interesting for many visualization and graphics applications. The spot samples can be used as input for texture generation, e.g., Line Integral Convolution (LIC), but can also be used directly for visualization by itself. They are especially suitable for the visualization of tensor fields that can be used to define a metric for the anisotropic density field. We present a novel method for generating stochastic samples to create anisotropic noise textures consisting of non-overlapping ellipses, whose size and density match a given metric. Our method supports an automatic packing of the elliptical samples resulting in textures similar to those generated by anisotropic reaction-diffusion.

7. Speckle Noise- Speckle noise is a multiplicative noise. This type of noise occurs in almost all coherent imaging systems such as laser, acoustics and SAR(Synthetic Aperture Radar) imagery[4]. The source of this noise is attributed to random interference between the coherent returns. Fully developed speckle noise has the characteristic of multiplicative noise. Speckle noise follows a gamma distribution and is given as

$$F(g)=\{ g^{\alpha-1}/(\alpha-1)!\,\alpha^{\alpha} \}\, e^{-g/\alpha} \qquad (2)$$

where variance is $a2\alpha$ and g is the gray level.

C. Use of Noise

High levels of noise are almost always undesirable, but there are cases when a certain amount of noise is useful, for example to prevent discretization artifacts (color banding or posterization). Some noise also increases acutance (apparent sharpness). Noise purposely added for such purposes is called dither; it improves the image perceptually, though it degrades the signal-to-noise ratio.

II. EDGE DETECTION TECHNIQUES AND EDGE PRESERVING

Edge detection is a terminology in image processing and computer vision particularly in the areas of feature detection and extraction to refer to the algorithms which aims at identifying points in a digital image at which the image brightness changes sharply or more formally has discontinuities. The need of edge detection is to find the discontinuities in depth, discontinuities in surface orientation, changes in material properties and variations in scene illumination [5].

Edge-preserving smoothing is an image processing technique that smooth's away textures at the same time it retains sharp edges[6]. When we need to:-

- preserve edge information
- preserve the edges

III. IMAGE DENOISING

Image denoising refers to the recovery of a digital image that has been impure by the noise. In case of image denoising methods, the characteristics of the degrading system and the noises are assumed to be known beforehand.

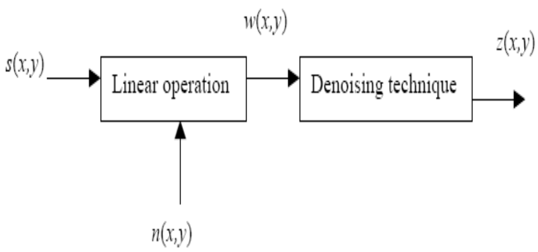

Fig. 2: Denoising concept

The image s(x,y) is blurred by a linear operation and noise n(x,y) is added to form the degraded image w(x,y). This is convolved with the restoration procedure g(x,y) to produce the restored image z(x,y). The "Linear operation" shown in Fig .2 is the addition or multiplication of the noise n(x,y) to the signal s(x,y).Once the corrupted image w(x,y) is obtained, it is subjected to the denoising technique to get the denoised image z(x,y).The point of focus in this thesis is comparing and contrasting several "denoising techniques" (Fig. 2) [7].

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IV. CLASSIFICATION OF DENOISING ALGORITHMS

There are two basic approaches to image denoising, spatial filtering methods and transform domain filtering methods [8].

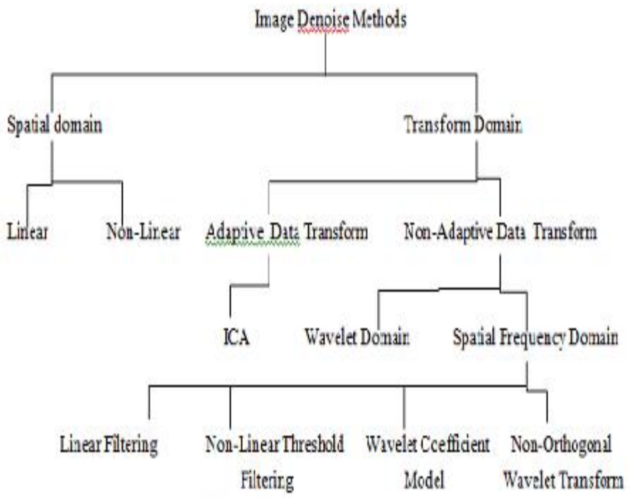

Fig. 3: Classification of Image denoising Methods

A. Spatial Filtering

A traditional way to remove noise from image data is to employ spatial filters. Spatial filters can be further classified into non-linear and linear filters.

1. Non-Linear Filters

The Median Filter is performed by taking the magnitude of all of the vectors within a mask and sorted according to the magnitudes. The pixel with the median magnitude is then used to replace the pixel studied. The Simple Median Filter has an advantage over the Mean filter since median of the data is taken instead of the mean of an image. The pixel with the median magnitude is then used to replace the pixel studied. The median of a set is more robust with respect to the presence of noise [9]. The median filter is given by

Median filter(x1…xN) = Median(||x1||2……||xN||2). (3)

2. Linear Filters

The goal of the Wiener filter is to filter out noise that has corrupted a signal. It is based on a statistical approach. Typical filters are designed for a desired frequency response. The Wiener filter approaches filtering from a different angle. One is assumed to have knowledge of the spectral properties of the original signal and the noise, and one seeks the LTI filter whose output would come as close to the original signal as possible [10]. Wiener filters are characterized by the following:

a. Assumption: signal and (additive) noise are stationary linear random processes with known spectral characteristics.

b. Requirement: the filter must be physically realizable, i.e. causal (this requirement can be dropped, resulting in a non-causal solution).

c. Performance criteria: minimum mean-square error.

The Wiener filter is:

$$G(u, v) = H^*(u, v)\, P_s(u, v) / \{ |H(u, v)|^2 P_s(u, v) + P_n(u, v) \} \quad (3)$$

Dividing through by P_s makes its behavior easier to explain

$$G(u, v) = H^*(u, v) / \{ |H(u, v)|^2 + P_n(u, v) / P_s(u, v) \} \quad (4)$$

Where,

H(u, v) = Degradation function

H*(u, v) = Complex conjugate of degradation function

Pn (u, v) = Power Spectral Density of Noise

Ps (u, v) = Power Spectral Density of un-degraded image The term P_n/P_s can be interpreted as the reciprocal of the signal-to-noise ratio.

B. Transform Domain Filtering

The transform domain filtering methods can be subdivided according to the choice of the basis functions . The basis functions can be further classified as data adaptive and non-adaptive. Non-adaptive transforms are discussed first since they are more popular.

1. Non-adaptive transforms

1.1. Spatial-Frequency Filtering

Spatial-frequency filtering refers use of low pass filters using Fast Fourier Transform (FFT) [11]. In frequency smoothing methods the removal of the noise is achieved by designing a frequency domain filter and adapting a cut-off frequency when the noise components are decorrelated from the useful signal in the frequency domain. These methods are time consuming and depend on the cut-off frequency and the filter function behaviour. Furthermore, they may produce artificial frequencies in the processed image.

We want to solve the problem of finding the intensity $u(x,t)$ of every row in an image. At both sides of the interval $0 \leq x \leq n$, the intensity values are set to be zero. By adding the inhomogeneous terms into the diffusion equation with the derivative of Delta functions, the proposed denoising method is called the Edge Preserved Inhomogeneous Diffusion Equation (EPIDE) method [12].The EPIDE method is used to smooth the noisy image (N) or the previously denoised image (P) with the modified edge map (I). Both in x-direction and y-direction, two images X and Y are generated by the EPIDE method. Finally a denoised image (D) can be obtained by an average combination of the image X and Y.

1.2. Wavelet domain -Filtering operations in the wavelet domain can be subdivided into linear and nonlinear methods.

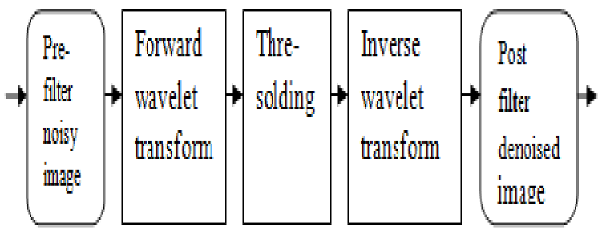

Fig.4: Diagram of wavelet based image De-noising

**. Linear Filters*

Linear filters such as Wiener filter in the wavelet domain yield optimal results when the signal corruption can be modelled as a Gaussian process and the accuracy criterion is the mean square error (MSE) [13, 14]. However, designing a filter based on this assumption frequently results in a filtered image that is more visually displeasing than the original noisy signal, even though the filtering operation successfully reduces the MSE. In [a wavelet-domain spatially adaptive FIR Wiener filtering for image denoising is proposed where wiener filtering is performed only within each scale and intrascale filtering is not allowed [15].

**. Non-Linear Threshold Filtering*

The most investigated domain in denoising using Wavelet Transform is the non-linear coefficient thresholding based methods. The procedure exploits sparsity property of the wavelet transform and the fact that the Wavelet Transform maps white noise in the signal domain to white noise in the transform domain. Thus, while signal energy becomes more concentrated into fewer coefficients in the transform domain, noise energy does not. It is this important principle that enables the separation of signal from noise.

**. Non-orthogonal Wavelet Transforms*

Undecimated Wavelet Transform (UDWT) has also been used for decomposing the signal to provide visually better solution. Since UDWT is shift invariant it avoids visual artefacts such as pseudo-Gibbs phenomenon. Though the improvement in results is much higher, use of UDWT adds a large overhead of computations thus making it less feasible. In normal hard/soft thresholding was extended to Shift Invariant Discrete Wavelet Transform [16].

**. Wavelet Coefficient Model*

This approach focuses on exploiting the mult-resolution properties of Wavelet Transform. This technique identifies close correlation of signal at different resolutions by observing the signal across multiple resolutions. This method produces excellent output but is computationally much more complex and expensive .The modelling of the wavelet coefficients can either be deterministic or statistical.

2. Data-Adaptive Transforms

The behaviour of adaptive filters changes depending on the characteristics of the image inside the filter region. Recently a new method called Independent Component Analysis (ICA) has gained wide spread attention. The ICA method was successfully implemented in in denoising Non-Gaussian data [17,18]. 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. Drawbacks of ICA based methods as compared to wavelet based methods are the computational cost because it uses a sliding window and it requires sample of noise free data or at least two image frames of the same scene.

V. THE PEAK SIGNAL-TO-NOISE RATIO

The performance measure by using the peak signal-to-noise ratio is defined as follows:

$$\mathrm{PSNR} = 20 \cdot \log_{10} \frac{255}{\mathrm{RMSE}}, \tag{6}$$

where RMSE is Root Mean Square Error, and it is defined as follows:

$$\mathrm{RMSE} = \sqrt{\frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} (f(i,j) - g(i,j))^2}\ . \tag{7}$$

The functions $f(i,j)$ and $g(i,j)$ are original and denoised image, respectively. The numbers m and $n$are the size of an image.

VI. DIFFERENT DENOISE TECHNIQUES ON DIFFERENT AREA

De-noised all noisy images by all filters and conclude from the results that: (a) The performance of the Wiener Filter after de-noising for Speckle and Gaussian noisy image is better than Median filter. (b) The performance of the Median filter after de-noising for Salt & Pepper noisy image is better than Wiener filter.

Median Filter**,** Excellent at noise removal, without the smoothing effects that can occur with other smoothing filters .Particularly good when salt and pepper noise is present .

The key to understanding the algorithm is to remember that the adaptive median filter has three purposes: (a) Remove impulse noise,(b) Provide smoothing of other noise, ©Reduce distortion .

It have been concluded that amongst all type of spatial filters and wavelet based homomorphic techniques, wavelet based techniques gives better results as compared to spatial filtering techniques. In case of wavelet based denoising methods, noise is removed while preserving the edges with less loss of detail. The main idea is the use of realistic distributions of the wavelet coefficients [19].

The EPIDE denoising method with edge preservation capability has the best OCR result in the experiment compared to the results from the wavelet denoising method and anisotropic diffusion filters. , it is suitable to use the character recognition software JOCR to obtain the words in noised and denoised images.

An image denoising technique based on Neutrosophic Set approach of wiener filtering [20]. A Neutrosophic Set (NS), a part of Neutrosophy theory, studies the origin, nature, and scope of neutralities, as well as their interactions with different ideational spectra. The properties of Neutrosophic image will achieve more applications in processing and computer vision. Now, we apply the Neutrosophic set into image domain and define some concepts and operators for image denoising We have conducted experiments on a variety of noisy images using different types of noises with different levels. The performance of the proposed filter is compared with Median and Wiener filter based on Peak Signal to Noise Ratio (PSNR) and Root Mean Square Error (RMSE). The experimental results demonstrate that the proposed filter can remove noise automatically and effectively.

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Based on a simple piecewise-smooth image prior,a segmentation-based approach to automatically estimate and remove noise from color images. The NLF is obtained by estimating the lower envelope of the standard deviations of image variance per segment. Experiments were conducted to test both the noise estimation and removal algorithms [21].

We verified that the estimated noise level is a tight upper bound of the true noise level in three ways: 1) by showing good agreement with experimentally measured noise from repeated exposures of the same image, 2) by repeatedly measuring the same NLF with the same camera for different image content, and 3) by accurately estimating known synthetic noise functions. Our noise estimation algorithm can be applied to not only denoising algorithms but other computer vision applications to make them independent of noise level [22].

De-noising and edge detection are so essential for the processing of cold trap radiographic images. From the analysis of de-noising techniques median filter works better than the mean filters [23].

VII. CONCLUSION

Images are very sensitive to environmental effect .Causes of these effect are thermal variation, fluctuation of quantum, orientation of image, image conversion etc. they produces noises and decrease quality of image. Denoising of images using the linear and nonlinear filtering techniques where linear filtering is done using the mean filter and the LMS adaptive filter while the nonlinear filtering is performed using a median filter. These filters are good for removing noise that is impulsive in nature. The mean filters find applications where a small region in the image is concentrated. Besides, implementation of such filters is easy, fast, and cost effective. The median filter provides a solution to this, where the sharpness of the image is retained after denoising. Our denoising algorithm outperforms the state-of-the art wavelet denoising algorithms on both synthetic and real noise-contaminated images by generating shaper edges, producing smoother flat regions and preserving subtle texture details. Wavelets play a very important role in the removal of the noise, especially when it is of the Gaussian type. The contribution of the paper is procedure to smooth the noisy or denoised image with any kind of denoising algorithm for desired edge preservation.

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