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Taxonomy on Mathematical Image Noise Reduction Techniques: A Review

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Abstract: Image processing is the main area for research these days. When the image is captured by some sensor or camera it contains some noise. Some processing is required for noise reduction in digital image. To reduce noise or to improve quality of an image, many mathematical algorithms or functions are developed. This paper discusses some popular image noise reduction techniques like Gaussian Blur, Box blur, Geometric Mean filter, Dark frame subtraction, Shrinkage Fields, Average with limited data validity, Median Filter, Anisotropic diffusion, Local pixel Grouping, Block-matching and 3D filtering.
Keywords: Image Processing, Gaussian Blur, Box Blur, Median Filter, Shrinkage Fields.

I. Introduction

All the digital images are stored in mathematical form. In case of continuous function, digital image is scanned as a planer image by a 2D function of $(x,y) \rightarrow f(x,y)$ where x,y are the spatial positive coordinate and the function $f$must be finite. After scanning of the image, sampling of image and quantization is done. Sampling means digitization of coordinate value and quantization means calculate amplitude of an image as a result the image is stored in the form of 2D matrix.
These days digital image is widely used in computer vision [1-3]. And to improve the performance of any image specific application like biometric system, facial expression [4], image categorization etc. , quality of image should be very high. But when the image is stored digitally, some noise is also stored which reduces the quality of the image. So to improve the quality of an image or smoothing the image, this noise must be removed.

II. Techniques of Noise Reduction

Gaussian Blur

This technique is named after scientist and mathematician Carl Friendrich Gauss. Gaussian function is used to blur or smoothing the image as Gaussian blur [5-7]. Mathematically, Gaussian blur means the image is convolving with the Gaussian function i.e. normal distribution is applied on each pixel of the image to transform the image. This is also called as 2D Weierstrass transform. Gaussian function in two dimension is as follows:

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Here x represents the horizontal distance from origin, y denotes the vertical axis distance from origin and $\sigma$is the standard deviation.
Another Gaussian blur technique uses the Fourier transform, which reduces image component of high frequency. Bokhe effect is reproduced by convolve with a circular box blur. Gaussian blur applying successively is same as a large, single Gaussian blur applied as rooted of sum of squares of the radii.

To reduce the noise of an image, Log filtering also known as Laplacian of Gaussian [8] is also used for Gaussian blur before the edge detection of the image.

(a) (b)

Figure 1: (a) Shows the original image capture using sensor and (b) shows the smoothing of an image using Gaussian Blur

Box Blur

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The Box Blur is also called as linear filter. First the pixel of entire image is calculated and then for each pixel, average of the entire neighbor is taken is considered as new pixel. Box blur is 2 by 2 matrix of equal weight i.e.

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}$$

In central limit theorem, Box blur is repeatedly used to calculate Gaussian Blur. The component of zero or negative value is used in frequency domain.

(a) (b)

Figure 2: (a) shows the original image and (b) shows the box blur effect

Geometric Mean Filter

This technique is used for smoothing the image and reduction of the noise of an image [9]. This technique uses the geometric mean of mathematics. For filtering process in Gaussian noise, geometric mean filter is used.

Dark-frame subtraction

When the shutter is off of the sensor and the image is captured then it is known as dark frame. Dark-frame subtraction is used in digital photography by minimizing image noise of the image capture with long exposure times and on high temperature. When the image is captured some defective pixels are included in the image and highlighted more than other pixels. Then the average of the entire dark frame is taken and subtracted from the image. It corrects the fixed pattern noise. Digital photogrammatery, satellite contrast, photogram are some applications where dark frame subtraction is used [10].

Median filter

It is a non linear filtering technique used to remove noise from an image. It is used as a preprocessing step of the image. Median filter removes noise but preserves edge. It is widely used in signal processing. Firstly entry by entry signal is taken, and then median of neighbor entry is replaced each entry. Window of neighbor pattern is slide over each entry of the entire signal. Let it be discussed with example of window size of three and each entry is replaced by median filter following by 1D signal.

p= (3, 4, 60, 8).

So, q (the median filtered signal) will be:

q_1 = med(3, 4, 60) = 4,
q_2 = med(4, 60, 8) = med(4, 8, 60) = 8,
q_3 = med(60, 8, 3) = med(3, 8, 60) = 8,
q_4 = med(8, 3, 4) = med(3, 4, 8) = 4,

i.e. q = (4, 8, 8, 4).

Median filter is also used as smoothing technique and is better than Gaussian filtering with fixed window size [11].

Shrinkage Fields (Image Restoration)

Image restoration is also referred as deblurring or denoising. Shrinkage field is a technique of machine learning. A linear combination of kernels based on radial basis is a shrinkage field function [12]. If there are *P* number of pixels of an image then *P(log P)* time is needed for running and gives promising results compared to other state of art.

Average with limited data validity

This is also used for filtering the image by preserving features during noise removal. As it preserves some noise feature so these are used for detecting some invalid pixel of an image and smooth only valid pixel using these invalid pixels [13]. This is used for different criteria like image intensity, brightness, strengthen of edges [14]. In intensity criteria, it defines an interval of data that is invalid by filtering only modifying pixels and average data of neighborhood valid data. In the brightness criteria it defines an interval of brightness changes that is invalid by removing background brightness that continuously changes.

Local pixel grouping

In 2010, Local pixel grouping given by Lei et. al. [15] PCA (principal component analysis) is used for noise reduction from an image and improves the quality of the image. PCA is a technique given by Karl Pearson [16]. PCA preserve the principal component of high variance and discard the low variance component. Let image is denoted by X and noise is denoted by Y thenthe image with noise is calculated as $I=X+Y$. After the image is stored, data set is trained by using local pixel and then PCA is applied for noise reduction.

Anisotropic diffusion

It is a noise reduction technique which does not blur the edges, lines and other important part of an image [17]. It is also known as Perona Malik diffusion because in 1987, it is given by Perona ans Malik [18]. It is a type of non linear transformation in homogeneous. This technique is generally used in edge detection algorithm because it does not blur the edge while removing noise.

Block-matching and 3D filtering

This is a technique primarily used for noise reduction [19]. In this technique, first the similar fragments of the image are grouped together based on some threshold value, then the collaborative filtering is done on every fragment. For collaborative filtering, wiener filtering is used. In last, aggregation is applied to get back the 2D image.

III. Conclusion

This paper contributes the most popular noise reduction technique for digital image. From the study it is concluded that all the digital images are scanned, processed and restored by mathematical functions or algorithms.

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