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Image Denoising- A Novel Approach

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Abstract: Images play an important in research and technology such as geographical information systems. Information is transmitted in the form of digital images and becoming a major method of communication in the modern age, but the image obtained is often corrupted with noise. Image processing plays a very important role in image denoising. Most of the applications make use of images in various fields such as medical, space exploring, aerial images, satellites images and many more. Images are received in defective conditions due to poor scanning and transmitting devices. Consequently, it creates problems for the process to read and understand such images. Before it can be used in applications the image that is received needs processing. To produce a visually high quality image, Image denoising is used which involves the manipulation of the image data. Selection of the denoising algorithm is dependent on application. Hence, the necessity to have detail information about the noise present in the image, to select the appropriate denoising algorithm is required. Image denoising issues can be addressed as an inverse problem. The paper presents an efficient denoising scheme by using LPG with PCA for better preservation of image local structure. LPG-PCA is compared by fast non- local means algorithm and the proposed method. In LPG-PCA, the pixel and its nearest neighbors are modeled as a vector variable. Trading samples are selected from the local search window by using block matching based on LPG. Such an LPG procedure guarantees that only the sample looks with similar content are used in the local statistics calculation. This calculations are for PCA transform estimation, so that the image local features can be well reserved. In order to accelerate the algorithm a Fast non- local means algorithm was developed to accelerate the calculation. Using proposed method the denoising performance is improved. Furthermore, results obtained by simulation using Matlab. We finally demonstrate the potential of the algorithms through comparisons. This paper specifies the description of noise, types of noise and LPG-PCA, Fast NLM and proposed algorithm that has been used for denoising the image.

Keywords: noise; types of noise; LPG-PCA algorithm; Fast NLM.

I. INTRODUCTION

Images play an important part in research and technology such as geographical information systems as well as it is the most important part in the field of medical science such as X-ray imaging, Computer tomography, ultrasound imaging and MRI. A very large portion of image processing includes image restoration. During the image capturing images get degraded. Image restoration is a method of removal or reduction of degradation that are incurred during capturing. Degradation occurs due to noise as well as blurring comes from electronic and photometric sources. Blurring is form due to bandwidth reduction of images caused by an optical system that is out of focus or by imperfect image formation process such as motion between camera and original scene [9]. Noise degrades the visual quality of digital image and is unwanted signal that interferes with the original image. The main sources of noise in digital images are imperfect instruments, interference natural phenomena, problem with data acquisition process, transmission and compression. Image denoising is the pre-processing step in the field of photography, research, technology and medical science, where image has been degraded and needs to be restored before further processing. As image denoising causes blurring and introduces artifacts. Image denoising is still a challenging problem for researchers [8]. Different types of images inherit different noises and different noise models which are used to present different noise types.

There are different methods to restore an image from noisy degradation. Selecting the proper method plays a major role in getting the desired image. For example, a method that is used to denoise medical images may not be suitable for denoising satellite images. In order to verify the performance of the various denoising algorithms, an image is taken and some known noise is added to it. Then it would be given as input to the denoising algorithm, the algorithm produces an image close to the original high quality image. The characteristics of the degrading system and the noises are assumed to be known beforehand, in case of image denoising methods. The input image s(x, y) is degraded by a linear operation and noise n(x, y) is added to form the distorted image d(x, y). This is convolved with the restoration procedure g(x, y) to produce the restored image r(x, y).

II. NOISES

Noise is the random fluctuations in brightness or color information in images. Noise occurs due to unwanted information hence distorting the image quality. Noise is not a part of the original image information, but it is

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defined as a procedure that affects the image quality. In Digital image noise may occur due to various sources. Noise are optical signals that are converted into electrical and then digital signal and mostly introduced in digital images during acquisition process. Due to natural phenomena at every stage of conversion process, each stage experiences a fluctuation that adds a random value to the pixel in a resulting image. Noise is considered as an undesirable by-product of image that is captured.

A. Addictive and multiplicative noise

Information about the type of noise present in the image denoising process plays an important role. As the detail information about the noise helps to decide the denoising technique, which will be better to remove the noise as well as help in preserving the image content. Images are corrupted with noise modelled with either a Gaussian, salt or pepper or uniform, distribution. Speckle noise is multiplicative in nature.

Noise is present in an image is either a multiplicative or an additive noise.

An additive noise satisfies the rule

$A = B + C$,

And the multiplicative noise satisfies

$A = B \times C$,

Where B is the original signal, C denotes the noise introduced into the signal to produce the distorted image A.

B. Types of Noise

1. Gaussian noise

Nature of Gaussian noise is statistical. Noise whose probability density function is equal to that of normal distribution, is called as Gaussian distribution. Values of the noise are being distributed in a Gaussian manner in Gaussian noise. One type of Gaussian noise is white Gaussian noise, in which the image values are statistically independent. Gaussian noise is also used as additive white noise for various applications, to produce additive white Gaussian noise in image. Gaussian noise is said as the noise with a Gaussian amplitude distribution. Gaussian noise is white noise that describes the correlation of various noises. Gaussian noise is said to be as white Gaussian noise sometimes, but it may not always the case.

2. Salt And Pepper Noise

There is only two possible values x and y in salt & pepper noise model. The probability of getting each of them is less than 0.1. The salt & pepper noise would greatly dominate the image. The intensity value for pepper noise and for salt noise typically found nearer to 0 and 255 respectively for 8 bit/pixel image. The salt & pepper noise is typically seen in images. In image the salt & pepper noise represents as randomly occurring black and white pixels. It occurs in images due to quick transients, such as faulty switching. This type of noise can be seen due to malfunctioning of analog-to-digital converter, bit errors in transmission, etc. This noise can be reduced using the algorithm that involves the usage of median filter [2], [6].

3. Poisson Noise

Poisson noise is a type of electronic noise. It is also known as shot noise. Poisson noise occurs where there is statistical transients in the measurement caused either due to finite number of particles like electron that carry energy in a circuit, or in an optical device due to the photons [2].

4. Speckle Noise

In [2],[7],[5], Speckle noise causes deterioration in the image quality. It is a type of granular noise. Speckle noise degrades the image that is being received from the synthetic aperture radar (SAR) as well as active radar images. Speckle noise occurs due to unwanted changes in the receiving signal from an object in radar and that is not big as single image-processing element. In local area of an image the mean grey level increases due to speckle noise. Speckle noise causes difficulties for image clarification and to extract detailed information in SAR images and are more serious issue. It is occurred from various distributed targets, due to coherent processing of back scattered signals.

III. IMAGE DENOISING

Image denoising refers to the restoration of an image that has been degraded by the noise. Various denoising algorithms have been studied so far and their application depends upon the type of image and characteristics of noise present in the image.

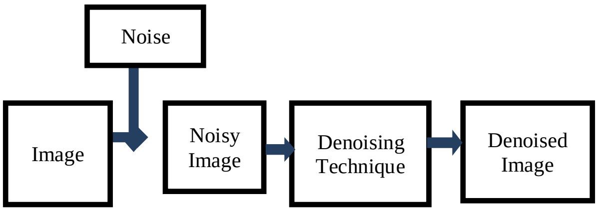

Fig 1: Denoising Concept.

Objective Of Image Denoising:

- To suppress the noise in uniform regions.
- To preserve edges
- To preserve image characteristics.
- To provide a visually natural appearance [4].

1. LPG-PCA Technique:

The LPG PCA helps in grouping every pixel and its neighboring elements, so the process involves each and every object in the test images, which helps to improve the efficiency and learn the technique of the process. In general, energy of the noise will evenly spread over the whole dataset, while the signal energy will concentrate on a small subset of the PCA transformed [2]. Therefore, by preserving only the most important subset of the transformed dataset. By conducting the inverse PCA transform the noise could be significantly reduced while the signal being well recovered. The visual artifacts are occurred due to noise residuals in the image, since the PCA [2] is applied to the noisy image directly without any

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data selection. So this is avoided by modeling a pixel and its nearest neighbor.

The training samples of vector variable are selected by grouping the pixel underlying in the local window to the pixels with similar local spatial structures. With such an LPG procedure [2], the image edge structures can be well preserved after shrinkage in the PCA domain so the local statistics of the variables can be accurately computed. LPG PCA is a spatially adaptive image representation technique which helps in better characterizing the images.

a. Flowchart

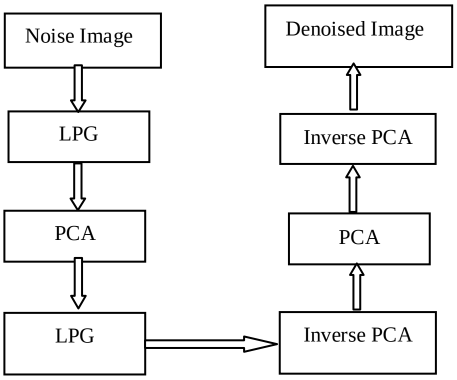

Fig 2. Stage LPG-PCA Denoising Technique

b. LPG-PCA Algorithm
Following are steps.

[1] Consider a noisy image.
[2] Apply LPG (local pixel grouping).
[3] Then apply PCA transform and de-noising.
[4]Inverse PCA transforms.
[5] Next update noise level & LPG.
[6] PCA transform and de-noising.
[7]Inverse PCA transform.
[8]Calculate PSNR, and Computational Time.
[9] To obtain de-noised image.

2. Fast NLM Technique:
Fast non-local means algorithm is based on Summed Squared Image (SSI) [10] and fast Fourier transform (FFT), together with an approach for estimating the standard deviation of noise. An improvement in efficiency of image quality towards the original algorithm is by ignoring the contributions from dissimilar windows. Even though the weights of pixel are very small, the new estimated pixel value can be severely biased due to the many small contributions. Weights for the most meaningful pixels are computed, using a pre-classification technique. This pre-classification is a quick way to exclude dissimilar windows, which results in better overall denoising quality and even in a smaller computation time. Fast non-local means algorithm is optimized by taking advantage of the symmetry in the weights and also used a lookup table to speed up the weight computations.

For the fast acceleration, fast non-local means algorithm adopted the Euclidean distance [10] to compare two neighbourhoods,

$$S(i, j) = \| N_i - N_j \|^2 = \sum_{l=0}^{M-1} \sum_{m=0}^{M-1} [l_i(l,m) - l_j(l,m)] \quad \ldots\ldots 1$$

Where $l_i(l,m)$ and $l_j(l,m)$ represent the corresponding pixels in N_i and N_j respectively. In fact, $l_j(l,m)$ in equation (6.7) can be represented in the global coordinates on the mirrored image as:

$$l_j(l - x_j, m - y_j) \text{ with } x_j = \frac{3M}{2} + x_j, y_j = \frac{3M}{2} + y_j \ldots\ldots 2$$

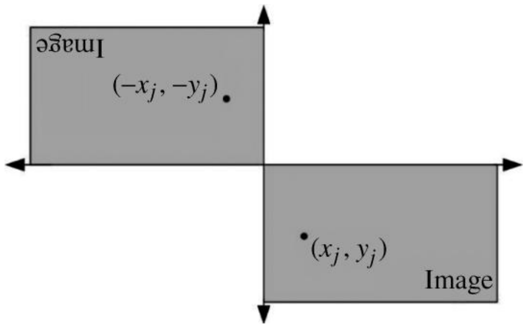

Fig 3. Mirrored image

$$S(i, j) = \sum_{l=0}^{M-1} \sum_{m=0}^{M-1} [l_i(l,m) - l_j(l - x_j, m - y_j)]^2 = N_i^2 + N_j^2 - N_i * N_j \ldots\ldots 3$$

Where

$$N_i^2 = \sum_{l=0}^{M-1} \sum_{m=0}^{M-1} [l_i(l,m) - l_j(l,m)]^2 \ldots\ldots 4$$

$$N_j^2 = \sum_{l=0}^{M-1} \sum_{m=0}^{M-1} [l_i(l,m) - l_j(l - x_j, m - y_j)]^2 \text{ and} \ldots\ldots 5$$

$$\mathbf{N_i * N_j} = 2\sum_{l=0}^{M-1} \sum_{m=0}^{M-1} [l_i(l,m) \cdot l_j(l - x_j, m - y_j)]^2 \ldots\ldots 6$$

denotes the convolution between $\mathbf{N_i}$ **and** $\mathbf{N_j}$. In above formula, $\mathbf{N_i * N_j}$ can be figured out easily with multiplications under the fast Fourier transform, while $\mathbf{N_i^2}$ and $\mathbf{N_j^2}$ can be fast calculated by using the Summed Squared Image (SSI). If the compare window size is $M * M$, computing the similarity of the two compare window requires M^2 pixel operations, while, in algorithm, it is figured out once which is achieved by means of FFT.

a. Fast NLM algorithm:
Following are the steps:

[1]Random Array helps in adding noise to the image.
[2]Add pad to array
[3]Create Kernel and apply windowing.
[4]Find weight for each pixel and estimate the value.
[5]Create new denoised image.

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3. Proposed Technique

Different grouping techniques such as block matching, k-means clustering can be employed. In LPG-PCA algorithm we use block matching method for LPG. Then grouping the training samples similar to the central GxG block in the HxH training window. Then we apply the PCA. After getting data from PCA we perform mean calculation and mean subtraction from each pixel. Then calculating the covariance matrix and then eigenvectors and eigenvalues of same covariance matrix.

Deriving the new data set and getting the old data back. Updating the noise level and apply the NLM for the same. Fast non-local means algorithm is based on Summed Squared Image (SSI) [10] and fast Fourier transform (FFT), together with an approach for estimating the standard deviation of noise. This pre-classification is a quick way to exclude dissimilar windows, which results in better overall denoising quality and even in a smaller computation time.

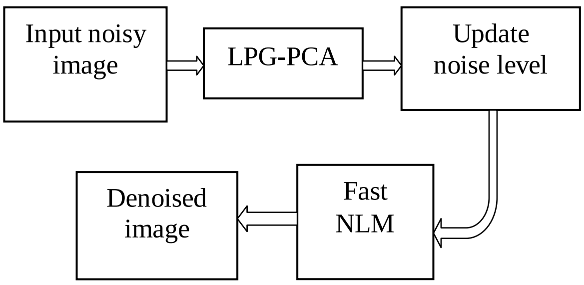


Fig 4. Proposed Technique

a. Proposed Technique algorithm:

Following are the steps:

[1] Consider a noisy image.
[2] Apply LPG (local pixel grouping).
[3] Then apply PCA transform and de-noising.
[4] Inverse PCA transforms.
[5] Next update noise level
[6] Add pad to array
[7]Create Kernel and apply windowing.
[8]Find weight for each pixel and estimate the value.
[9]Create new denoised image.
[10]Calculate PSNR, and Computational Time.

IV. EXPERIMENTAL RESULTS

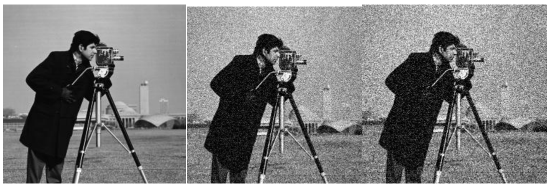
The algorithm that has been proposed the LPG-PCA as well as Fast NLM and Proposed algorithm are denoising based algorithm. The Peak Signal to Noise Ratio use to measure the pixel intensity difference between two images. Generally quality of image can be measured by Peak Signal to Noise Ratio. [7]. To evaluate the performance of our approach for image denoising (with Gaussian noise), we collect and conduct experiments on several images. We manually add Gaussian noise with σ = 25, 35, 45 to the input noise-free images.

Table 1: Performance Evaluation (In Terms Of PSNR) in dB of Image Denoising

	Cameraman	
Noise Variance	σ = 25	σ = 35
LPG-PCA	28.68	27.08
Fast NLM	28.22	26.40
Proposed Method	31.15	31.26

Table 2: Performance Evaluation (In Terms Of Computational time) in sec of Image Denoising

	Cameraman	
Noise Variance	σ = 25	σ = 35
LPG-PCA	56.98	54.56
Fast NLM	4.57	4.14
Proposed Method	48.04	54.83



(a) Original Image (b) Noisy image σ = 25 (c) Noisy image σ = 35

(d) Denoised Image by LPG-PCA for σ = 25

(e) Denoised Image by LPG-PCA for σ = 35

(f) Denoised Image by Fast NLM for σ = 25

(g) Denoised Image by Fast NLM for σ = 35

(h) Denoised Image by Proposed method for σ = 25

(i)Denoised Image by proposed method for σ = 25

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V. CONCLUSION

The LPGPCA technique used for all types of images like jpg, gif, tiff, bmp etc., it also works with any size of image. As expected the LPG-PCA framework first groups the local pixel from the input image for image representation. Image components associated with different context information will be undergo PCA transform, which does not need the prior knowledge on the type of images nor the collection of training image data. There is a noticeable improvement in LPG PCA based deblurring process, which results in the improvement of the image quality without degradation of local structures. The Fast non-local means method performed marginally better. As expected, the fast non-local means did a better job of preserving edges. It performed best on periodic textures. The fast non-local means algorithm accomplished its goals of removing noise and preserving detail. The Proposed method performed exceptionally well. As expected, the proposed method did a better job of preserving edges. More noise was removed by this method. . Experiments using LPG-PCA and Fast NLM confirmed the use of our proposed method, which was shown to quantitatively and qualitatively outperform existing denoising approaches.

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