Combined Method of Two Stage LPG-PCA Denoising with Impact on Preprocessing Step for Noisy Images

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ABSTRACT
Image denoising plays a vital role in many image processing application to reduce the noise level without affecting the original image features. In this paper a powerful image denoising algorithm LPG-PGA with preprocessing step like Diffusion is introduced to improve the quality of the image. Per-processing step like diffusion is a necessary one in-case of noise is an important consideration, where the diffusion filter has strong smoothing characteristics [4-5]. PCA is statistical techniques which can be used to reduce the dataset from higher dimension to lower dimension without huge loss of image features [1]. The proposed system performance is evaluated by using various types of objective metrics like PSNR, SSIM, MSE, LMSE and NAE. The result shows that the proposed method has good promising performance compare to existing method.

Keywords
LPG-PCA denoising, Edge enhancing diffusion.

1. INTRODUCTION
Image processing is an active research area in many applications like Remote Sensing, Medical Imaging, Non-destructive Evaluation, Forensic Studies, Textiles, Material Science, Military, Film industry, Document processing, Graphic arts, Printing Industry, etc. Several image processing techniques are introduced to enhance the image quality by suppress the noise level [1-4]. Each method has its own merits and demerits. In this paper we combine two stage LPG-PCA method with preprocessing step (Diffusion) which is shown in Fig 1.

Image smoothing is a technique of improving the quality of an image by removing the noise in that image [7]. Among the several image processing technique we introduce LPG-PCA De-noising with preprocessing step to improve the quality of an image compare to existing methods. PCA is a de-correlation technique in statistical signal processing which can be used in several applications like pattern recognition, Dimensionality reduction, etc. In PCA the local statistics are calculated from the local PCA transformation matrix by using the moving window. In LPG-PCA the local statistics are computed in such a way that it preserves the edge structures of the image after the shrinkage in the PCA domain [1]. The diffusion process can be seen as an evolution process with an artificial time variable t denoting the diffusion time where the input image is smoothed at a constant rate in all directions [6]. Linear Diffusion is a conventional way to smooth an image in a controlled way to convolve with a Gaussian kernel. The main drawback of linear diffusion method is, the smoothing process does not consider the information about important image features such as edges. It follows that same amount of smoothing to be applied at every image location. As a result, the diffusion process does smooth not only noise, but also image edges [6]. Hence we apply one of the Nonlinear diffusion method called edge enhancing diffusion which is discussed in section 3.

2. LPG-PGA BASED DE-NOISING
Principle Component Analysis (PCA) is a method of identifying patterns in the data, and expressing the data in a way of highlight their similarities and differences. Since patterns in the data can be hard to find in the data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analyzing data. The other main benefit of PCA is that once the patterns can be found it is easy to compress the data (i.e. by reducing the number of dimensions), without much loss of information [1-3].

Statistically, PCA is a de-correlation technique which is mainly used in pattern recognition, dimensionality reduction, etc. By transforming the original dataset into PCA domain and preserving only the several most significant principal components, the noise and trivial information can be removed. A PCA-based scheme was proposed for image de-noising by using a moving window to calculate the local statistics, from which the local PCA transformation matrix was estimated. PCA can be used to remove noise from images. PCA is a powerful statistical technique that is designed for determining lower dimensional representations of sampled data, which at first glance in its original representation may seem unstructured and random.

3. DIFFUSION
Recently several techniques are introduced to enhance the quality of an image. Among all these methods diffusion is one of the method used to enhance the quality of an image. In this method smoothing can be done by preserving the features of the original image. Among linear and non-linear diffusion here we propose a non-linear diffusion called edge enhancing diffusion which involves, constructing the diffusion tensor so that it mirrors the edge structure, thus preserving the edges by smoothing parallel to the edges. This allows smoothing near the edge, while preserving the edges themselves [4].

Edge enhancing diffusion constructs the diffusion tensor D as,

$$D = R^T \begin{pmatrix} C_1 & 0 \\ 0 & C_2 \end{pmatrix} R \tag{1}$$

R is a rotation matrix which is calculated as,

$$R = \frac{1}{\sqrt{\left(L_x^u\right)^2 + \left(L_y^u\right)^2}} \begin{pmatrix} L_x^u & -L_y^u \\ L_y^u & L_x^u \end{pmatrix} \quad (2)$$

Hence the D is calculated as,

$$D = \frac{1}{\left(L_x^u\right)^2 + \left(L_y^u\right)^2} \begin{pmatrix} C_1\left(L_x^u\right)^2 + C_1\left(L_y^u\right)^2 & \left(c_2 - c_1\right) L_x^u L_y^u \\ \left(c_2 - c_1\right) L_x^u L_y^u & C_1\left(L_y^u\right)^2 + C_1\left(L_x^u\right)^2 \end{pmatrix} \quad (3)$$

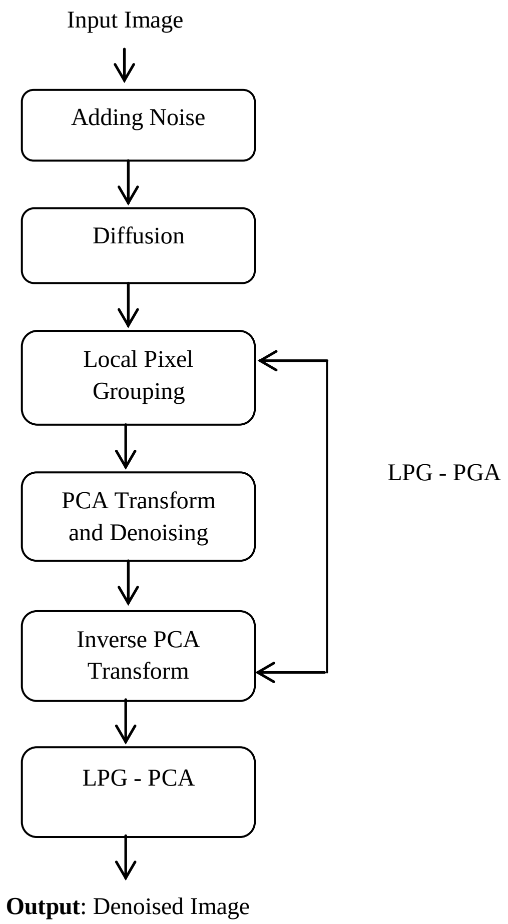


Fig 1: Two stage LPC-PGA Denoising with Diffusion

4. IMAGE QUALITY MEASUREMENTS

The various image quality metrics are used to discover the quality of the output image which are discussed below.

4.1 Peak Signal to Noise Ratio (PSNR)

$$PSNR = 10 \log_{10}\left(\frac{Peak^2}{MSE}\right) \quad (4)$$

$$PSNR = 10 \log_{10}\left(\frac{255^2}{MSE}\right) \quad (5)$$

PSNR is commonly expressed in terms of the logarithmic decibel scale. Higher PSNR value offers a good image quality.

4.2 Structural Similarity Index Metrics (SSIM)

$$SSIM = \frac{\left(2\sigma_{xy} + C_2\right)\left(2 \times \bar{x} \times \bar{y} + C_1\right)}{\left(\sigma_x^2 + \sigma_y^2 + C_2\right)\left(\left(\bar{x}\right)^2 + \left(\bar{y}\right)^2 + C_1\right)} \quad (6)$$

Where C_1 and C_2 are constants.

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$$

The SSIM index is in the range between [0, 1]. A value 0 indicates no correlation between the images. A value is close to one indicates that the denoised image is as close as to original image.

4.3 Mean Squared Error

$$MSE = \frac{1}{MN}\sum_{ij}\left(A_{ij} - B_{ij}\right)^2 .$$

(7)

Where A_{ij} is the original image, B_{ij} is the denoised image. Larger the MSE value, image quality is poor.

4.4 Laplacian Mean Squared Error (LMSE)

$$LMSE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\nabla^2 A - \nabla^2 B\right)^2}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\nabla^2 A\right)^2} \quad (8)$$

Smaller value of laplacian mean squared error provides good denoised image

4.5 Normalized Absolute Error (NAE)

$$NAE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left|\nabla^2 A - \nabla^2 B\right|}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left|\nabla^2 A\right|} \quad (9)$$

Smaller value of Normalized Absolute Error (NAE) provides good denoised image.

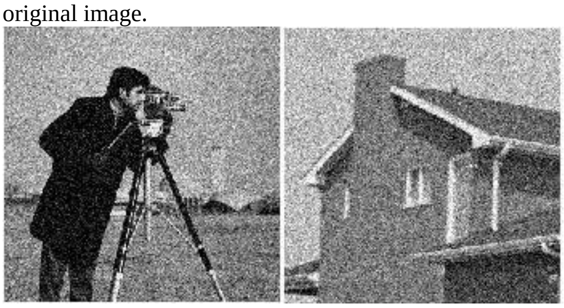
5 EXPERIMENTS AND DISCUSSION OF RESULTS

The diffusion method discussed in section 3 were used to experimenting with a data base consists of various images. LPG-PCA and LPG-PCA along with diffusion method were applied to all images and their performance is compared.

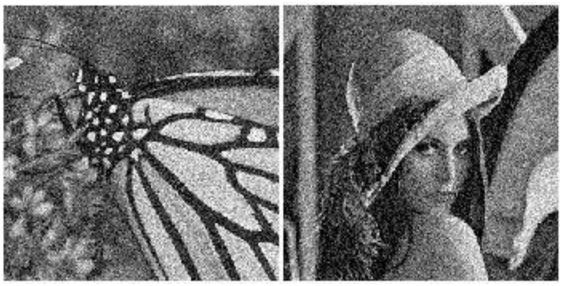
5.1 Experiment with preprocessing step

Preprocessing step so called diffusion is a method used for smoothing the image. The two anisotropic diffusion edge enhancing diffusion technique is proposed and the result is shown in Fig 2. Most of the PDE based methods are very crucial for Denoising and edge protective applications in images. While Perona and Malik types of nonlinear diffusion are isotropic, it preserves image features in the diffusion process by reducing dissipation in regions along image edges [11].

An advanced diffusion scheme was introduced by Weickert, called anisotropic diffusion. Among the two anisotropic diffusion edge enhancing diffusion is a Direction dependent diffusion method were strong diffusion is occurred along image edges, and weak diffusion is occurred across image edges. Edge Enhancing Diffusion Technique smooth's the original image.



(a) (b)



(c) (d)

Fig 2: Illustrate the impact after pre-processing

5.2 LPG-PCA with Diffusion Method

The experiment is done by adding noise to the original image with various sigma values like 20, 30, and 40. After that Preprocessing step like edge enhancing diffusion is applied to that noisy image and the result is shown in Fig 2. Then the two stage LPG-PCA denoising method is applied to that diffused image and the result is shown below. In Figure 3(d), 4(d), 5(d), 6(d), displays LPG-PCA denoising first stage result and Figure 3(e), 4(e), 5(e), 6(e), displays LPG-PCA denoising second stage result. In LPG-PCA De-noising, first stage removes most of the noise in the diffused image and second stage further improves the result of the first stage.

(a) (b)

(c)

(d) (e)

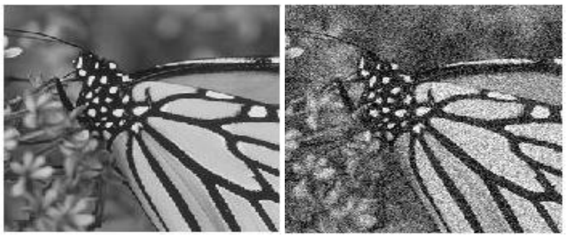
Fig 3: Illustrate the performance of proposed method with sigma=30. (a) Original image (b) Noisy image with sigma=30. (c) Diffused image (d) Denoised image after the first stage. (e) Denoised image after the second stage.

(a) (b)

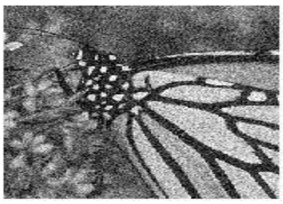
(c)

(d) (e)

Fig 4: Illustrate the performance of proposed method with sigma=30. (a) Original image (b) Noisy image with sigma=30. (c) Diffused image (d) Denoised image after the first stage. (e) Denoised image after the second stage.



(a) (b)



(c)

(d) (e)

Fig 5: Illustrate the performance of proposed method with sigma=30. (a) Original image (b) Noisy image with sigma=30. (c) Diffused image (d) Denoised image after the first stage. (e) Denoised image after the second stage.

(a) (b)

(c)

(d) (e)

Fig 6: Illustrate the performance of proposed method with sigma=30. (a) Original image (b) Noisy image with sigma=30. (c) Diffused image (d) Denoised image after the first stage. (e) Denoised image after the second stage.

A total of two tables are illustrated to specify the performance of LPG-PCA and LPG-PCA with Diffusion method. Table 1 shows the precision obtained by the two stage LPG-PCA denoising method. Various image quality metrics like PSNR, SSIM, MSE, LMSE, NAE, are used for finding the quality of the image. The experiment is done with different sigma values. For each sigma value the image quality metrics are calculated for both stages. The result shows that PSNR and SSIM values are increased in stage 2 compare to stage 1 and MSE, LMSE, NAE values are decreased in stage 2 compare to stage 1.Most of the noises are removed in stage1 and stage 1 result is further improved in stage 2.

Table 1: Two stage LPG-PCA denoising method

IMAGES	σ	PSNR1	PSNR2	SSIM1	SSIM2	MSE1	MSE2	LMSE1	LMSE2	NAE1	NAE2
1) 	20	32.2241	33.0828	0.8098	0.8677	38.9647	31.9743	0.9311	0.5092	0.0339	0.0281
	30	29.7824	31.2095	0.7082	0.8393	68.3666	49.2187	1.6650	0.6364	0.0453	0.0341
	40	27.8644	29.7322	0.6100	0.8124	106.3271	69.1613	2.6603	0.7464	0.0571	0.0400
2) 	20	29.6746	30.0384	0.8779	0.9145	70.0847	64.4525	0.4963	0.3882	0.0539	0.0493
	30	27.2477	27.7209	0.7989	0.8735	122.5483	109.8977	0.7636	0.5218	0.0720	0.0643
	40	25.4704	26.0610	0.7185	0.8345	184.5184	161.0562	1.0694	0.6277	0.0894	0.0783
3) 	20	30.2040	30.5415	0.8448	0.8765	62.0411	57.4018	0.5795	0.4770	0.0585	0.0540
	30	27.8594	28.3595	0.7574	0.8292	106.4477	94.8703	0.8778	0.6250	0.0773	0.0691
	40	26.1654	26.8566	0.6714	0.7882	157.2327	134.0965	1.2286	0.7289	0.0952	0.0825
4) 	20	29.5114	29.7184	0.7980	0.8575	72.7683	69.3805	0.4088	0.3605	0.0502	0.0444
	30	27.3693	27.8174	0.6927	0.8151	119.1662	107.4829	0.6189	0.4742	0.0653	0.0543
	40	25.7708	26.4954	0.5978	0.7826	172.1858	145.7285	0.8609	0.5648	0.0795	0.0626

Table 2: Two stage LPG-PCA denoising with Diffusion

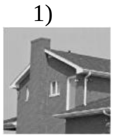
IMAGES	σ	PSNR1	PSNR2	SSIM1	SSIM2	MSE1	MSE2	LMSE1	LMSE2	NAE1	NAE2
1) 	20	32.4854	33.0838	0.8258	0.8669	36.6890	31.9667	0.7701	0.5025	0.0325	0.0280
	30	29.9675	31.2390	0.7223	0.8407	65.5137	48.8855	1.4711	0.6200	0.0441	0.0339
	40	27.9917	29.7592	0.6202	0.8144	103.2539	68.7323	2.4523	0.7274	0.0561	0.0397
2) 	20	29.8240	30.0707	0.8884	0.9164	67.7138	63.9750	0.4489	0.3796	0.0524	0.0488
	30	27.3481	27.7481	0.8085	0.8758	119.7484	109.2123	0.7102	0.5124	0.0707	0.0638
	40	25.5436	26.0869	0.7260	0.8368	181.4341	160.1008	1.0158	0.6192	0.0883	0.0778
3) 	20	30.3561	30.5660	0.8557	0.8778	59.9059	57.0794	0.5328	0.4751	0.0569	0.0535
	30	27.9566	28.3772	0.7669	0.8312	104.0934	94.4852	0.8232	0.6201	0.0760	0.0686
	40	26.2365	26.8750	0.6788	0.7903	154.6791	133.5290	1.1706	0.7227	0.0941	0.0821
4) 	20	29.6252	29.7841	0.8146	0.8572	70.8863	69.9316	0.3843	0.3667	0.0486	0.0442
	30	27.4570	27.8182	0.7063	0.8167	116.7832	107.6368	0.5873	0.4757	0.0639	0.0540
	40	25.8403	26.5001	0.6071	0.7849	169.4535	145.5693	0.8258	0.5642	0.0784	0.0624

Table 2 shows the precision obtained by the two stage LPG-PCA Denoising method with preprocessing step. In table 2 PSNR1, PSNR2, SSIM1, SSIM2 values are increased and MSE1, MSE2, LMSE1, LMSE2, NAE1, NAE2 values are decreased compare to table1. After preprocessing Two stage LPG-PCA denoising technique is applied and the result shows that the performance is improved compare to existing Two stage LPG-PCA denoising method.

6. CONCLUSIONS

LPG-PCA method along with Pre-processing step like Diffusion is used and the performance is validated through various performance metrics like PSNR, SSIM, MAE, LMSE, NAE and the result shows that our proposed method Two-stage image denoising by principal component analysis, local pixel grouping with Diffusion method has higher accuracy compare to Existing method Two-stage image de-noising by principal component analysis with local pixel grouping.

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