PCA based image denoising

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ABSTRACT: *Principal component analysis (PCA) is an orthogonal transformation that seeks the directions of maximum variance in the data and is commonly used to reduce the dimensionality of the data. In image denoising, a compromise has to be found between noise reduction and preserving significant image details. PCA is a statistical technique for simplifying a dataset by reducing datasets to lower dimensions. It is a standard technique commonly used for data reduction in statistical pattern recognition and signal processing. This paper proposes a denoising technique by using a new statistical approach, principal component analysis with local pixel grouping (LPG). This procedure is iterated second time to further improve the denoising performance, and the noise level is adaptively adjusted in the second stage.*

KEYWORDS: *Principal component analysis, local pixel grouping, denoising, filter and discrete wavelet transform.*

I. Introduction: PCA is a statistical procedure that uses an orthogonal property to transform to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables. The denoising phenomenon goal is to remove the noise while retaining the maximum possible the important signal or image features. At the time of acquisition and transmission the images are often corrupted by additive noise. The main aim of a denoising algorithm is to reduce the noise level, while preserving the image features. To achieve a good performance in this respect, a denoising algorithm has to adapt to image discontinuities. Generally the quality of image can be measured by the peak signal-to-noise ratio (PSNR). However, sometimes a denoised image with a high PSNR value does not have satisfactory visual quality [12].

PCA is a pre-processing transformation technique that creates new images from the uncorrelated values of different images [13]. This is accomplished by a linear transformation of variables that corresponds to a rotation and translation of the original coordinate system. PCA is used to find-out principal components in accordance with maximum variance of a data matrix. Based on the principle components a new technique, based on maximization of SNR was also proposed in [3]. The grouping procedure guarantees that only the sample blocks with similar contents are used in the local statistics calculation for PCA transform estimation, so that the image local features can be well preserved after coefficient shrinkage in the PCA domain to remove the noise. Experimental results shows this method gives better performance, especially in image fine structure preservation, compared with general denoising algorithms [4-9].

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II. Median Filter: A median filter belongs to the class of nonlinear filters unlike the mean filter. The median filter follows the moving window principle like the mean filter. A 3×3, 5×5, or 7×7 kernel of pixels is scanned over pixel matrix of the entire image. The median of the surrounding pixel values in the window is calculated, and the center pixel of the resultant is computed and replaced with the computed median. Median filtering is done by, first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value.

III. Lee Filter: This filter is an adaptive filter, which changes according to the local statistics of the current pixel. The Lee filter is based on the approach that if the variance over an area is low or constant, then the smoothing will be performed. Otherwise, if the variance is high, smoothing will not be performed.

IV. Gaussian filter: A gaussian filter is a filter whose impulse response is a gaussian function. Gaussian filters are designed to give no overshoot to a step function input while minimizing the rise and fall time. This behavior is closely connected to the fact that the Gaussian filter has the minimum possible group delay. Mathematically, a Gaussian filter alters the input signal by convolving with a Gaussian function.

V. Wiener filter: This approach often produces better results than linear filtering. This adaptive filter is more selective than a comparable linear filter, preserving edges and other high-frequency parts of an image. Wiener filters are a class of optimum linear filters which involve linear estimation of a desired signal sequence from another related sequence. The goal of the Wiener filter is to filter out noise that has corrupted a signal.

VI. Discrete Wavelet Transform: The Wavelet Transform provides a time-frequency representation of the signal. It was developed to overcome the previous method, Short Time Fourier Transform (STFT), which can also be used to analyze non-stationary signals. A time-frequency distribution of a signal provides information about how the spectral content of the signal evolves with time, thus providing an ideal tool to dissect, analyze and interpret non-stationary signals.

VII. Dual-tree complex wavelet transform: Dual tree complex wavelet transform (DT-CWT) has been developed to incorporate the good properties of the fourier transform in the wavelet transform. As the name implies 2 wavelet trees are used one generating the real part of the complex wavelet coefficients tree [10-11] and the other generating the imaginary part tree. The DTCWT comprises of 2 parallel wavelet filter banks trees that contain carefully designed filters of different delays that minimize the aliasing effects due to down sampling. The DTCWT of a signal is implemented using 2 critically sampled DWTs in parallel on the same data. Dual-tree complex wavelet transform has many attractive properties, for example, approximate shift invariance, good directional selectivity and limited redundancy.

VIII. LPG-PCA denoising algorithm: Principal component analysis was developed by famous personalities the Pearson and the Hotelling, whilst the best modern reference is Jolliffe [2]. PCA is a method of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. Since patterns in data can be hard to find in 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 you have found these patterns in the data, and you compress the data, ie. by reducing the number of dimensions, without much loss of information**.**

Statistically, PCA is a de-correlation technique and it is mainly used in pattern recognition and dimensionality reduction and 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 denoising 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.

As shown in figure1, the proposed algorithm has two stages, in the The first stage it gives an initial estimation of the image by removing most of the noise and the second stage will further refine the output of the first stage [1]. The second stage has the same type of procedure except for the parameter of noise level. Since the noise in the first stage is significantly reduced, the LPG accuracy will be much improved in the second stage so that the final denoising result is visually much better.

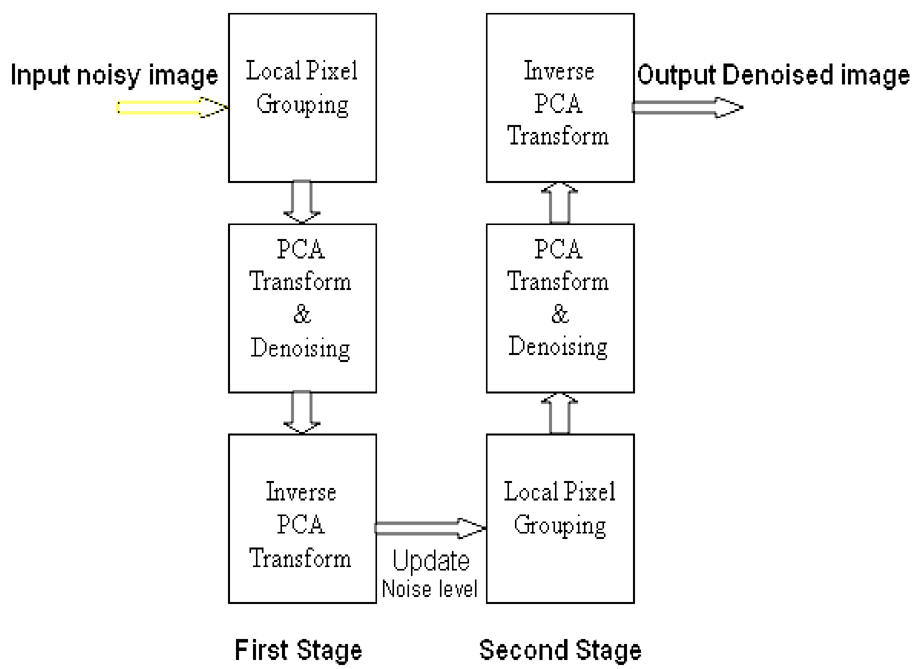


Figure 1:Two stage Principal component analysis

Thus we can implement the LPG-PCA denoising procedure for the second round to enhance the denoising results.

IX. Experimental results and discussions: Here we compared different denoising technologies like median filter, lee filter, weiner filter, gaussain filter, discrete wavelet transform, dual tree discrete wavelet transform and principle component analysis. Table1 shows the comparison of different denoising techniques for different test images. The two stage PSNR values have taken into consideration to compare.

It is clearly given that principle component analysis gives best PSNR value among all. The second stage got the better values compared to first stage. If the variance is high then second stage gives more signal-to-noise ratio values. For lower variance images first is sufficient to remove the noise.

Table.1: Comparison of PSNR values with different denoising techniques

	City	Lenna	Monarch	Cameraman	Village	River	Average
Median	23.7841	22.9481	20.6154	20.8301	28.5012	22.5348	**23.2022**
Lee	25.7401	25.7506	24.8241	25.6951	28.5655	24.6743	**25.8749**
Weiner	25.6134	26.0118	24.6756	25.6588	29.6443	23.9915	**25.9325**
Gaussian	26.7970	26.3957	25.2337	24.3735	29.3971	25.3792	**26.2627**
DWT	28.1815	28.9758	28.0575	28.3796	31.2737	26.2009	**28.5110**
DT-DWT	28.8201	30.1134	29.2085	29.0296	32.0129	26.5132	**29.2829**
PCA -1st Stage	28.7660	30.2040	29.6746	29.5114	31.2017	26.8473	**29.3675**
PCA -2nd Stage	28.7573	30.5415	30.0384	29.7184	31.5945	26.7205	**29.5617**

Table.2: Comparison of PSNR-1 & PSNR-2 values for different images

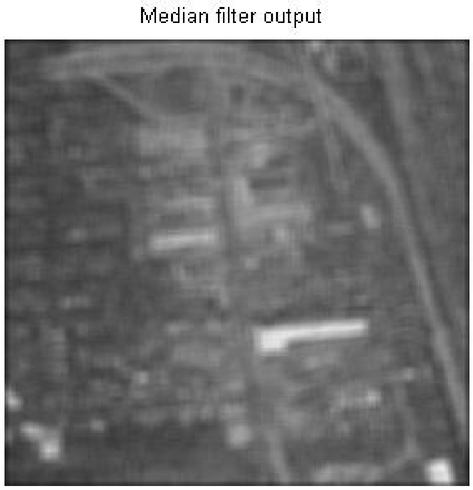
	City.tif		Village.png		Lenna.tif		River.png	
	PSNR-1	PSNR-2	PSNR-1	PSNR-2	PSNR-1	PSNR-2	PSNR-1	PSNR-2
$\sigma = 50$	24.1784	24.8051	26.2252	28.5672	24.8133	25.7227	23.2916	23.5307
$\sigma = 40$	25.2845	25.6322	27.5460	29.2136	26.1654	26.8566	24.1530	24.1649
$\sigma = 35$	25.9378	26.1675	28.2962	29.6198	26.9547	27.5468	24.6423	24.5817
$\sigma = 30$	26.6939	26.8223	29.1270	30.1129	27.8594	28.3595	25.2034	25.1005
$\sigma = 25$	27.6073	27.6555	30.0737	30.7416	28.9177	29.3343	25.8969	25.7758
$\sigma = 20$	28.7660	28.7573	31.2017	31.5945	30.2040	30.5415	26.8473	26.7205
$\sigma = 15$	30.3286	30.2897	32.6506	32.8287	31.8406	32.0964	28.3036	28.1741
$\sigma = 10$	32.6523	32.6112	34.7685	34.7989	34.1299	34.2963	30.7099	30.6055
$\sigma = 5$	36.9238	36.8965	38.6735	38.6163	38.0637	38.0966	35.4248	35.3854
$\sigma = 2$	43.2961	43.2829	44.3663	44.2776	43.6649	43.6157	42.4872	42.4830
$\sigma = 1$	48.6551	48.6536	49.2196	49.1426	48.6966	48.6810	48.2520	48.2520

Original image

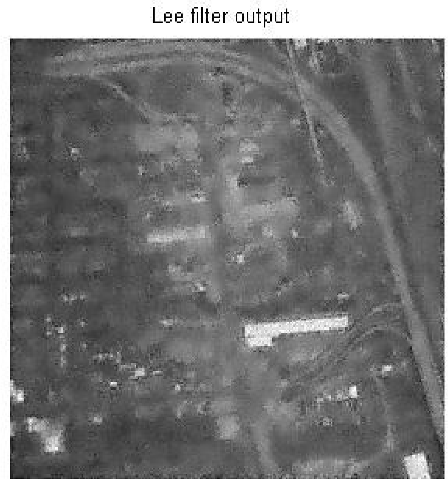
(I)

Noise image

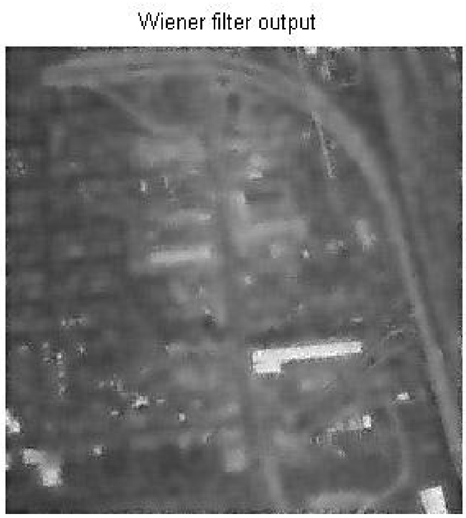
(II)


Median filter output

(III)


Lee filter output

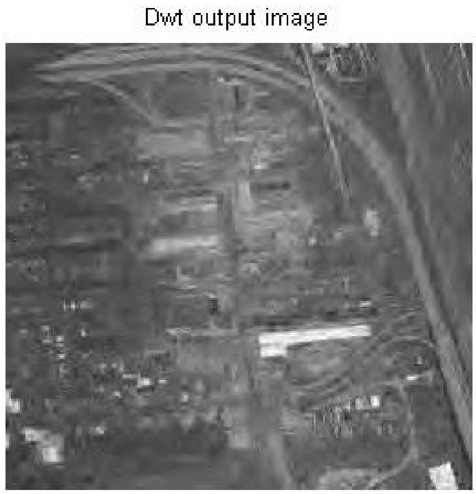
(IV)


Wiener filter output

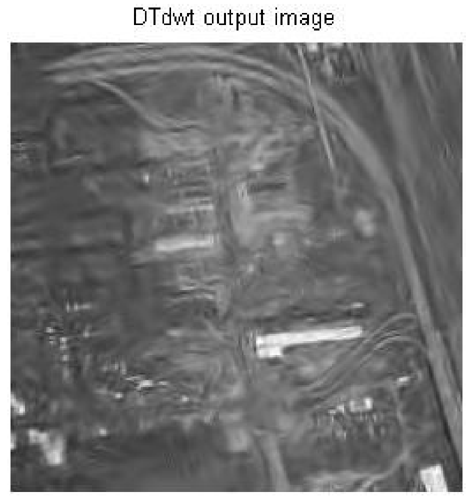
(V)


Gaussian filter output

(VI)



(VII)



(VIII)

(IX)

(X)

Figure2: (I) Original Image. **(II)**Noised Image. **(III)**Denoised image with median filter. **(IV)** Denoised image with lee filter. **(V)** Denoised image with weiner filter. **(VI)** Denoised image with gaussian filter. **(VII)** Denoised image with DWT. **(VIII)** Denoised image with DTDWT. **(IX)** Denoised image with 1st stage of PCA. and **(X)** Denoised image with 2nd stage of PCA.

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