IMAGE DENOISING USING ICA TECHNIQUE

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ABSTRACT
Denoising of natural images is the fundamental and challenging research problem of Image processing. Fourier transform method is localized in frequency domain where the Wavelet transform method is localized in both frequency and spatial domain but both the above methods are not data adaptive. Independent Component Analysis (ICA) is a higher order statistical tool for the analysis of multidimensional data with inherent data adaptiveness property. The noise is considered as Gaussian random variable and the image data is considered as non-Gaussian random variable. Specifically the Natural images are considered for research as they provide the basic knowledge for understanding and modeling of human vision system and development of computer vision systems.

Keywords (Image Denoising, Independent Component Analysis, wavelet transform)

1. INTRODUCTION
Aim of my paper is to remove the noise from the natural images and to calculate the various parameters for the images. Digital images play an important role both in daily life applications such as satellite television, magnetic resonance imaging, computer tomography as well as in areas of research and technology such as geographical information systems and astronomy. 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. Furthermore, noise can be introduced by transmission errors and compression. Thus, denoising is often a necessary and the first step to be taken before the images data is analyzed. It is necessary to apply an efficient denoising technique to compensate for such data corruption. Image denoising still remains a challenge for researchers because noise removal introduces artifacts and causes blurring of the images. This paper describes different methodologies for noise reduction (denoising) giving an insight as to which algorithm should be used to find the most reliable estimate of the original image data given its degraded version. Removing noise from the original signal is still a challenging problem for researchers. There have been several published algorithms and each approach has its assumptions, advantages, and limitations.

This paper presents a review of some significant work in the area of image denoising. After a brief introduction, some popular approaches are classified into different groups and an overview of various algorithms and analysis is provided.

2. PROBLEM FORMULATION
The basic idea behind this thesis is the estimation of the uncorrupted image from the distorted or noisy image, and is also referred to as image “denoising”. There are Various methods to help restore an image from noisy distortions. Selecting the Appropriate method plays a major role in getting the desired image. The denoising Methods tend to be problem specific. For example a method that is used to denoise satellite image may not be suitable for denoising medical images. In this thesis, a study is made on the various denoising algorithms and each is implemented in Matlab. Each method is compared and classified in terms of its efficiency. In order to quantify the performance of the various denoising algorithms, a high quality image is taken and some known noise is added to it. This would then be given as input to the Denoising algorithm, which produces an image close to the original high quality image. The performance of each algorithm is compared by computing Signal to Noise Ratio (SNR) besides the visual interpretation.

In case of image denoising methods, the characteristics of the degrading system and the noises are assumed to be known beforehand. 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 Figure 1.1 is the addition or multiplication of the Noise \( n(x,y) \) to the signal \( s(x,y) \) [101] (Refer to Chapter 2 for a detailed discussion). 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”.

Three popular techniques are studied in this thesis. Noise removal or noise reduction can be done on an image by principal component analysis (PCA), Adaptive principal component analysis, and Independent component analysis (ICA). Each technique has its advantages and disadvantages. Denoising by independent component analysis (ICA) has some of the recent approaches.

### 3. DENOISING ALGORITHM

Starting with a noisy image, the complete denoising algorithm is:

1. Estimate the noise variance, \( \sigma^2 \), using equation (2).
2. Partition the image into overlapping patches as shown on the left side of Fig. 1. Each patch, depicted on the right side of Fig. 1, contains a train region, a denoise region and an overlap region. The overlap region is included in the denoise region, which is included in the train region.
3. Fix the dimension, \( N^2 \), of the training vectors and generate S. The training vectors are \( N \times N \) patches, reordered in an \( N^2 \) long vector, and the training set S is the collection of all the possible \( N \times N \) patches included in the train region. To be consistent, the number of training vectors in S is M. The dimension of S, the matrix formed by ordering the vectors in S as column vectors, is \( M \).
4. The PC basis functions are the eigenvectors of \( Q = (ss^T)^{-1} \), which are also the principal components of S.
5. For \( l = 1 \ldots N^2 \) and \( i = 1 \ldots M \) find the PC coefficients \( y_l^i \) by taking projections of the training vectors in S onto the PC basis functions.
6. For \( l = 1 \ldots N^2 \) estimate the variance of the PC coefficients using equation (8).
7. Denoise the PC coefficients using equation (7) and reconstruct the denoised training vectors in S. Since the training vectors in S overlap, average out the results in regions of overlap after the denoised training vectors are put back into the train region. In the middle of the train region each pixel is estimated N2 times, while on the boundary, it may be estimated only once. Choose the denoise region such that each pixel is estimated N2 times. This step resembles the over-complete basis denoising algorithm of [3]. The training vectors are formed from a moving window, which is similar to shifting the signal. In this sense the denoising algorithm has a built-in shift invariant feature.
8. If the denoise region is too large, blocking artifacts in the denoised image can become a problem, even though the PSNR values are still good. To average out the blocking artifacts between different denoised regions, add an overlap region.

### 4. RESULTS

The Codes are written for PCA, Adaptive PCA, and ICA. These codes are simulated, synthesized and implemented in Matlab. The results of simulation are reported here. The images which are obtained are as follows:

Matlab figure window shows original image in jpg format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 6.816146 db, entropy 0.3334 , Variance 234.1728 , Correlation 0.882.
Fig. Original image + Noisy image
Matlab figure window shows original image in jpg format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 7.379763 db, entropy 0.0244, variance 254.7538, correlation 0.0486.

Fig. Noisy image + denoised image(JPG) by Adaptive PCA
Matlab figure window shows original image in jpg format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 6.936651 db, entropy 0.3216, variance 235.0867, correlation 0.0829.
Matlab figure window shows original image in jpg format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 13.704733 db, entropy 0.2117, variance 243.1234, correlation 0.0488.

Fig. Noisy image + denoised image(JPG) by ICA
Matlab figure window shows original image in GIF format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 6.962064 db, entropy 0.3217, Variance 235.1129, Correlation 0.0616.

Fig. Noisy image + denoised image(GIF) by PCA
Matlab figure window shows original image in GIF format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 8.099423 db, entropy 0.0237, Variance 254.7873 , Correlation0.0905 .

**Fig Noisy image + denoised image(GIF) by A daptive PCA**

Matlab figure window shows original image in GIF format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 13.751627 db, entropy 0.0415, Variance 243.1370, Correlation 0.2115.

**Fig Noisy image + denoised image(GIF) by ICA**

Matlab figure window shows original image in BMP format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 6.967201 db, entropy 0.3210 , Variance 235.1199, Correlation 0.0616 .

**Fig Noisy image + denoised image(BMP) by PCA**

Matlab figure window shows original image in BMP format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 7.809952 db, entropy 0.0238, Variance253.7528 , Correlation0.0906 .

**Fig Noisy image + denoised image(BMP) by Adaptive PCA**

Matlab figure window shows original image in BMP format of 256 X 256 pixels with noisy image having Gaussian noise with signal to noise ratio 13.699066 db, entropy 0.2115, Variance 243.1330, Correlation 0.0488.

5. CONCLUSION

The signal to noise ratio of an image under study is 8.5db. Principal component analysis will achieved an improve value of signal to noise ratio as 8.69db. Adaptive PCA has proven to show an enhanced value of signal to noise ratio upto 11.01db. Adaptive PCA has shown an improvement in noise reduction. Furthermore with independent component analysis with local maxima algorithm we could achieve an further enhancement value upto 15.18db of signal to noise ratio for the image under study. For various type of image format we get the different signal to noise ratio, and by
comparing the signal to noise ratio and parameter table we can conclude that ICA is the best tool for the image denoising. The improvement of signal to noise ratio proves that ICA is powerful tool for denoising of an image. Some preliminary studies have been made about the effectiveness of Independent Component Analysis. So we can conclude that ICA-based methods give, at least for their application, significantly better results than PCA. The superiority of ICA over PCA is also implicit in the use of PCA as a preprocessing step.

REFERENCES


[3] Xin Li and Michael T. Orchard,”Spatially adaptive image denoising under over complete expansion”, 0-7803-6297-7/100, 2008 IEEE.


