A method based on Wavelet Transform and Discrete K-L Transform for Color Image filtering

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***Abstract*—A new method of removing random noises in color images is described in this paper. It is based on wavelet transform combines with discrete K-L transform. The basic principle of the new method is that a color image is transformed from the RGB color space into a new space (JKL space) by discrete K-L transform in which the three components J，K and L are irrelevant; Then the color image is filtered in JKL space by wavelet transform; Finally, the color image after filtering is transformed into RGB space to display. Based on this method, the removing random noise from color image is simulated by Matlab. The experiment results show that the new method is better than the traditional transform method and can improve the effect of disposal.**

Keywords- color image filtering; discrete K-L transform; wavelet transform

I. INTRODUCTION

In the generation, transmission and transformation process of images, due to a variety of factors, images may be polluted by random noises in different degree. These noises can be divided into two main classes: Gaussian noise and impulse noise. Because of the image's distortion and degraded caused by these noises, in the follow-up steps, we need do de-noising processing for these images. Digital image filtering technique is developed up for this aim. Image filtering means to filter out the high-frequency noise to get closer to the true value of the signal In general, image filtering techniques can be divided into spatial domain, frequency domain and wavelet-domain filtering categories.

The traditional filtering method is that, by Fourier transform, noisy signals are transformed from time domain into frequency domain and then through a variety of filters to filter. Such solutions have limitations: When signal and noise's frequency bands are separated from each other, effective, however when overlap, less effective (For example, when the signal mixed with white noise) [1]; It can not express signals in the time domain partly in nature, also can not deal with non-stationary signals effectively; Most methods aiming for it are basically raised against the gray-scale images, but less for three-dimensional color image specifically. In practice of color image filtering, there are two ways: RGB and HIS model filtering method [2]. Therefore, it is necessary to research special technique of color image filtering.

Because it is a time-scale (time-frequency domain) analysis method, and has a low entropy, multi-resolution, décor-relation, flexible characteristics, wavelet transformation（WT） can flexibility extract the signal characteristics of the partial singular value. In recent years, people use a variety of wavelet ways to de-noise, but because of a high degree correlation among the three components of color RGB images, if the relevance is not considered, "color leaking" phenomenon can easily appear, that is, in some places there is an obvious stain. Discrete Karhunen-Loeve transformation (KLT) is based on statistical characteristics of the image. Its main characteristics are that it can eliminate the correlation of image data, separate information and highlight the role of different targets [3].

On the basis of reading the literature, this paper combines the WT and KLT，and proves that this method has a better effect than other methods in color image de-noising.

The following text describes KLT theory and WT method to remove random noise signals in color image, as well as the combination of WT and KLT.

II. DISCRETE KARHUNEN-LOEVE TRANSFORMATION

KLT is based on statistical characteristics of the image. Its main characteristics are that it can eliminate the correlation of image data, separate information and highlight the role of different targets. It is often used to extract coherent information from the seismic signal but remove random noise. Its basic process for RGB image is as follows [4]:

We could see the RGB image pixels as three-components of a three-dimensional random vector X, out vector $X_i = [R_i, G_i, B_i]^T$ (i=1, 2,…,m*n)

- Seeking sample mean vector

$$\overline{X} = [\overline{R_i}, \overline{G_i}, \overline{B_i}] = E\{X\} \quad (1)$$

- Seeking sample covariance matrix

$$C_x = E\{(X-\overline{X})(X-\overline{X})^T\} \quad (2)$$

- Seeking three mutually orthogonal eigenvalues e_i of the covariance matrix and the corresponding eigenvectors λ i(i=1,2,3),which meet the conditions λ1≤λ2≤λ3.
- Transform matrix $M = [e_1, e_2, e_3]^T$,the new random vector

$$Y = M(X-\overline{X}) = (J_i, K_i, L_i) \quad (3)$$

Based on the non-relevance of J, K and L components, we can flexibility use different methods separately or one method with different parameters to smooth.

Since T is an orthogonal matrix, combined with (3), we can get the inverse KL transform

$$X = M^T Y + \overline{X} \tag{4}$$

By (4), we can anti-calculate R, G and B components by the J, K and L components which have been filtered.

III. THE IMAGE DENOISING BASED ON WAVELET TRANSFORM

A. Intruduction

Based on discrete wavelet transform (DWT), two-dimensional wavelet analysis, in the frequency domain, decomposes the original image into different wavelet components in terms of size, orientation and position. By changing the coefficients of each frequency components (wavelet coefficients), we can improve the signal to noise ratio and achieve the purpose of eliminating noise. In practical engineering, the useful signal usually presents a low-frequency signal or a stable signal, noise signal is manifested as high-frequency signals, so we can approach to deal with the high-frequency coefficients to achieve the elimination the purpose of the noise.

B. Steps of Wavelet Transformation

The basic steps of de-noising (threshold method) by two-dimensional WT are as follows [5]:

- Choose suitable wavelet function and appropriate wavelet decomposition level N, do N-layer wavelet decomposition for two-dimensional image containing noise.
- In each layer, process the threshold of wavelet coefficients (may be soft or hard threshold methods or different thresholds form).
- With the Nth layer low-frequency coefficients and high-frequency coefficients after wavelet decomposition, make wavelet inverse transform and reconstruct the signal. Receive signal after de-noising.

C. Experiment Conclusion

In experiment, by adding Gaussian white noise N (0, 0.01) into a 512 × 512 × 3 original color image "Lena.jpg" (Fig.1 (a)) get the image signal with noise(Fig.1 (b)). Using traditional RGB model, during the wavelet de-noising process, we set a variety of parameters, a comparative analysis of different results help me get the following conclusions.

1. De-noising effected by decomposition layer

As the decomposition level increases, de-noising effect changed for the better, but increased to seven or more layers of decomposition level, de-noising effect becomes less obvious, the actual choice can be in the 3 ~ 5 layers. First, select a different decomposition layer, then de-noising. The peak signal to noise ratio (PSNR) of de-nosing image to the original image is showing in the Table 1.

2. Compare soft and hard threshold

Using soft-threshold approach, wavelet decomposition level, starting from the 3rd layer, visual effects of images after de-noising became blurred, signal to noise ratio also began to decline; using hard-threshold method, the visual effects are good, however, there are varying degrees of ringing effect, and with the decomposition level increasing, ringing effects become more evident.

3. The selection of wavelet decomposition functions

Matlab wavelet toolbox provided five wavelet functions aiming for the Gaussian white noise, which achieved a majority of wavelet classic de-noising algorithm.Sym5 wavelet has been selected in this article.

IV. THE COMBINATION OF WAVELET TRANSFORM AND DISCRETE KL TRANSFORM FOR DE-NOISING

A. Principle

The principle of this article is simply as follows.

- Do KLT for RGB color image, then with its features, transform the pixels R, G and B to J , K, and L components which are zero-mean, uncorrelated and the variance creasing by degress.
- As the J, K and L are not relevant, we do different DWT for each components, and so in different scales, their respective high and low frequency signals form wavelet plan surface with multiple bands;
- Reconstruct J, K and L by the wavelet coefficients after DWT.
- Apply of inverse KLT, anti-calculated R, G, B from the J, K, L components
- Last, reconstruct three-channel RGB color image to achieve the separation of signal and noise.

Tabel 1. THE EFFECTION OF DECOMPOSITION LAYER(PSNR/dB)

Method	Layers					
	2	*3*	*4*	*5*	*6*	*7*
Soft threshold	27.67	26.48	25.31	24.74	24.52	24.45
Hardthreshold	27.86	27.31	26.81	26.64	26.60	26.54

B. Test results and analysis

Since KLT is reversible orthogonal transformation, compared with the direct RGB filter model method, the approach using the same method on the J, K and L components would produce the same effect. So in experiment, when applying the method as mentioned before processing the image Fig.1 (b) with noisy signal, we should select different parameters or methods to achieve different de-noising effects. Practice as follows: for J, K and L, separately use the sym5 wavelet of 2, 3 and 4-layer to de-noise. For component of J, the threshold value is generated from the minimum punishment under the rules of style selection method (using wbmpen function), using the global threshold method; For K, threshold decided by Birge-Massart strategy of two-dimensional wavelet selection method (wdcbm2), from the horizontal, vertical and diagonal three directions, in the N-layer, process the wavelet coefficients with an appropriate threshold (soft or hard threshold);For L, the threshold determined by a function-oriented(ddencmp), using the global threshold method [6]. The results are Fig.2 (b) and Fig.2 (c) .

To compare the articles' smoothing results, based on the RGB model method, make airspace smoothing, the 5×5size of Gaussian-core and variance = 0.5, the result is Fig.2 (a).

At present, respectively take the subjective image effects and objective peak signal to noise ratio PSNR as benchmark to assess the effects of these de-noising algorithms [7].

From the simulation map and PSNR seen in Table 2 before and after de-noising, under the same conditions, compared to the usual filtering method, the Gaussian white noise in color image filtered by this article' method has been better suppression, signal to noise ratio has been improved to some extent.

Tabel 2. THE COMPARATION BETWEEN RGB AND THIS ARTICLE'METHOD

Filtering method	RGB method	This method	
		Soft threshold	***Hard threshold***
PSNR	23.94dB	27.80dB	28.43dB

V. CONCLUSION

From the experimental results, we can see that this paper presents a color image smoothing method, although apart from random noise up to a certain extent, but the results were not ideal: As mentioned in part 3, compared with the original image, vague appears in the image after de-nosing by soft threshold method; PSNR only increased the size of less than 5dB. But this is a new kind of method for color image de-noising processing and provides a new way worth considering for the future.

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Figure 1. Original and Nosise figure:(a) Original color image (b)Image with Gaussian Noise

Figure 2. Comparison of Images after de-nosing by diffirent methods:(a) Image after de-nosing by RGB

(b) Image after de-nosing by this method with soft threshold

(c) Image after de-nosing by this method with hard threshold