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Based on Wavelet Transform Plane Principal Component Inspection Application Research of Image Denoising Algorithm

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Abstract

As a kind of very effective methods of gathering data processing - principal component method, it can be used to determine the variables between the linear combination rule, reduce the dimension of feature space, select the optimal variables instead of the original. In recent years, as in the field of image processing, a wide range of application of principal component inspection technology, its shortcomings are also needless to say, the main components of investigation can only in the presence of one dimensional vector. Plane principal component, but can be on the premise of reducing data transformation between time, directly with two-dimensional vector matrix, which results in better image processing speed operation. On this basis, in the light of the characteristics of the remote sensing images, principal component and on the plane algorithm combining wavelet transform, put forward a kind of based on wavelet transform and principal component of the denoising algorithm. Experimental results show that the proposed method is better than first when some typical denoising method, this method can effectively remove gaussian noise of remote sensing images, made in the image edge details such as information can be more perfect.

Keywords: *image denoising；the wavelet transform；plane principal component；the simulation analysis*

1. Introduction

With the constant progress of science and technology, remote sensing technology in today's society has become the important way to gain the geographical image information in a timely manner. Traffic like by sensors detect the surface objects radiation energy, different sensors, is its imaging principle, with the spectral and spatial resolution will also each are not identical. Result of remote sensing image is different, these images as an important geographical analysis of data source, the remote sensing images of disk storage, photos, etc. Can be fixed by the image processing device for processing.

Contains all the important information of the earth's surface in the remote sensing image, the engineering construction and regional planning and so on has the important practical significance. Good the subsequent use of images of remote sensing image quality plays an important role. But in the process of gathering and transmission of remote sensing image will be affected by many external factors such as atmosphere, make the information acquisition image containing a certain amount of noise interference. The existence of interference, is bound to the subsequent image processing and transmission process of a series of inconvenience. Noise to a certain extent, make the image blur, affects the quality of the remote sensing image, and destroys the intrinsic attribute of the image. Therefore, in order to reduce the noise of the remote sensing image, improve the quality of the image to make people better and more convenient to analyze remote sensing images. To attain this goal, we must deal with the noise of image, thus ensuring the image obtain better visual effect when used. Denoising can effectively improve the quality of remote sensing image, optimize the edge details, lay a foundation for the further use of the image [1-3].

The traditional denoising method mainly based on Fourier transform, including median filter, adaptive filter and airspace median filtering, etc. Using the above methods to deal with the noise of image, the will to a certain extent, ruined the image details. This is because the original remote sensing image after transform, the high frequency images containing noise and image edge details, such as the traditional methods cannot effectively distinguish between, thus cause the loss in the process of removing noise more detail information, make the image blur. As after Fourier analysis, a new method of image processing in 1910 Haar wavelets constructed in the first place. Then scientists continuously analysis research, have created more new type of wavelet. Now wavelet theory has been gradually perfect, the theory has been widely applied to pattern recognition, image processing, and other fields. Because the wavelet transform has good time-frequency domain localization characteristic, can make the part each spectral remote sensing images with higher resolution. The image at the same time the structure of the performance in different resolution levels make it has the ability of edge detection. Therefore, according to the need to extract under different resolution remote sensing image information of different information handled separately. For remote sensing image denoising processing, can better distinguish between noise and edge information, so that separate processing can achieve better denoising effect. So in recent years, wavelet transform is widely applied to remote sensing image denoising field. Based on the above information, this paper compares the traditional wavelet threshold denoising methods, is put forward based on soft threshold and wavelet transform algorithm, by selecting the appropriate threshold value range, the remote sensing image denoising processing done in-depth research. Makes a deep exploration on the improved algorithm; Based on the planar principal component inspection and remote sensing image denoising algorithm of wavelet transform. This method can reduce the remote sensing image contains a lot of noise. On the premise of improve the computing speed, better to restore the original image, providing a solid foundation for the further processing of the image.

2. Related Works

The main components of investigation is a kind of statistical image characteristics for transform method. The method of covariance matrix is all elements are zero except the diagonal, thus eliminating the correlation between the various data. Thus in the process of compression information has played a vital role. Dimension reduction is in the image processing and pattern recognition is one of the main problems. In the process of pattern recognition of reality, we usually choose eigenvectors are related to each other. For its identification, most of the eigenvectors are useless, so if you can reduce the number of features that reduce the dimension of feature space. That would be less computational complexity and storage space for higher calculation accuracy. The number of principal component inspection algorithm is simplified arancio data collection at the same time, select the best feature variables to replace the original many variables. On the premise of reduce linearly dependent variables, to achieve the effect of simplified, dimension reduction. It can be used in many of the problems of image processing, such as classification, feature selection, compression, etc. The main idea of this method is to seek the orthogonal matrix, the transformation of information after the corresponding covariance matrix transpose for diagonal matrix, the concrete implementation process is as follows [4-5]:

1) The definition of covariance matrix

If f is a random vector $N \times 1$ collections, and $f = f(f_1, f_2, f_3, ..., f_n)$, f_i are random vector, the average of N sample vector estimation can be statistics, the average of μ May be defined as:

$$\mu = E(f) \approx \frac{1}{N}\sum_{i=1}^{N} f_i \tag{1}$$

Define the covariance matrix of the:

$$C_f = E\{(f-\mu)(f-\mu)^T\} = \frac{1}{N}\sum_{i=1}^{N}(f-\mu)(f-\mu)^T$$
$$\approx \frac{1}{N}[\sum_{i=1}^{N} f_i f_i^T] - \mu\mu^T \tag{2}$$

2) the eigenvalues of the covariance matrix of the solution:

$$C_f\Phi_i = \lambda_i\Phi_i, 0 \le i \le N-1 \tag{3}$$

Type λ_i is a characteristic value, the corresponding eigenvectors is Φ_i .

3) transformation matrix is defined and the realization of inverse transform

Transformation matrix is composed of feature vector: $\Phi . \Phi = \{\Phi_1\Phi_2\Phi_3...\Phi_n\}$ after the orthogonalization for Φ^{*T}, will be A

Therefore define one dimensional principal component inspection as follows:

$$F = \Phi^{*T}(f-\mu) = A(f-\mu) \tag{4}$$

Inverse transform is defined as:

$$(f-\mu) = \Phi^{*}F = A^T F \tag{5}$$

Summarize the process, main component can be obtained to investigate the characteristics of which were as follows:

(1) In the study of the main components, can choose not to exceed the maximum number of variables to be n principal component, to represent the initial m variables , and the change of the initial m variables can completely replace with n principal component;

(2) Diction, sorting feature vector from big to small, a few larger eigenvalues to the image in front of the main information;

(3) To select the best variables instead of initial, ensure each principal component between linear irrelevant;

(4) Set the initial value of each principal component are orthogonal to each other between 0 and each principal component;

Through a series of comparison, in view of the main components of the calculation process has the advantages and disadvantages of the following aspects:

1) Advantages: principal component inspection methods, the most important variable in the initial matrix combination are obtained, in just a few on behalf of the principal component to reflect the original image, effectively reduce the correlation between the variables, realized the purpose of dimension reduction of the image.

2) Disadvantages: principal component inspection need to convert the data sequence processing line, improve the computational complexity of time, increase the workload of calculation. In the main components of the selected not determine a threshold selection criteria, this makes when the main components, the choice is too small cannot fully expresses the characteristics of the original image.

By analyzing the disadvantage of principal component inspection algorithm, a kind of planar principal component inspection methods by derivation, the judge algorithm based on improved principal component. Main difference is that the structure of the covariance matrix method and the selection of the largest eigenvalue and eigenvector are bigger difference.

Through the above analysis can learn the main components of investigation is a kind of one-dimensional vector method based on objective observation. Reality and the main components of theory is essentially the same, is through linear transformation to extract high variance of main components to represent the original data. To convert data after examining image principal component analysis, this will make a lot of remote sensing image processing is more complicated. As the introduction of the plane of the principal component inspection methods, it can be spread to the conditions of observation for the two-dimensional matrix. We try to extract a few related variables, not let it replace the original multiple related variables. As a statistical analysis, hope the new variable can maximize the original information and make its maximum variance. Plane of the main components of inspecting is equivalent to the principal component of press line blocking, its dimension reduction principle is as follows [6-8]:

Set the size of the $M \times N$ image matrix to Y, principal component inspection divides the matrix Y $p \times q$ size image matrix, namely:

$$Y = \begin{bmatrix} Y_{11} & Y_{12} & \cdots & Y_{1q} \\ Y_{21} & Y_{22} & \cdots & Y_{1q} \\ \cdots & \cdots & \cdots & \cdots \\ Y_{p1} & Y_{p2} & \cdots & Y_{pq} \end{bmatrix} \quad (6)$$

Matrix Y_{ki} of them were $m_1 \times n_1$, $pm_1 = m, qn_1 = n$. If the original image is N, it carries on the chunking contains $p \times q \times N$ small images, can be obtained after them as a complete set of samples. Using principal component analysis of a number of projection direction, so it can be the small image converted to vector. Then will be displayed as small image decibels projection vectors are extracted, the final will be a number of small images, the characteristics of the integration of the reflect the characteristics of the original image.

Makes the image has been minus $\overline{Y}$, the centralized, Y_i according to the line of image block can be expressed as:

$$Y_i = \begin{bmatrix} (a_i)_1^T \\ (a_i)_2^T \\ \vdots \\ (a_i)_m^T \end{bmatrix} \quad (7)$$

Among them, $(a_i)_k^T = [(a_i)_{k1}(a_i)_{k2}...(a_i)_{kn}]$ for the first k lines image grey value, G_t calculation formula is:

$$G_t = \frac{1}{N}\sum_{i=1}^{N} Y_i^T Y_i = \frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{m}(a_i)_j (a_i)_j^T \quad (8)$$

Define the subscript $r = (i-1) \times m + j$, $\xi_r = (a_i)_j, r = 1,2,...mN$. By $\overline{Y}$ zero matrix, so the corresponding average of ξ_r also is zero vector. If the $\{\xi_r \mid r = 1,2,...mN\}$ principal component processing, its overall scattering matrix can be expressed as follows

$$S_t = \frac{1}{mN}\sum_{r=1}^{mN}\xi_r \xi_r^T \quad (9)$$

Ignoring the type coefficient, (9) for vector mode scattering matrix of principal component of the overall. The matrix multiplied by a factor of this eigenvalue and eigen vector does not have any effect. So pretty and partitioned according to row after investigation processing components of samples of the row vector of family.

Introduce below plane principal component inspection feature extraction methods, principal component inspection method is to use a 2 d plane data matrix to construct covariance matrix directly, solving get the eigenvalues of the covariance matrix, to order it.Construction coordinate system, use with the largest eigenvalues corresponding to the first n feature vector, and it will need to be trained data matrix projection on the coordinate system, thus it is concluded that the characteristics of the effective value.

With p pattern categories: $w_1, w_2, ...w_p$, the first class I have a training sample n_i: $A_{i1}, A_{i2}, ...A_{in}$, $N = \sum n_i$ as the total number of training samples, each sample is $M \times N$ matrix. Definition of the covariance matrix Y of S_X total divergence is: $J(x) = tr(S_x)$.The S_X can be expressed as:

$$S_X = E(Y - EY)(Y - EY)^T = E(AX - E(AX))(AX - E(AX))^T$$
$$= E[(A - EA)X][(A - EA)X]^T \quad (10)$$

$J(x)$ can be represented as:

$$tr(S_X) = X_T[E(A - EA)^T(A - EA)]X \quad (11)$$

By using the plane principal component inspection methods for image reconstruction, the remote sensing image denoising has obtained the good effect. Graphic analysis method of principal component inspection directly the two-dimensional image matrix, the information of the image compression transformation, can realize image on limited row or column dimension reduction. Dimension reduction to compress the number of variables, so that you can use less number of variables to said most of the variables in the original data, simplify the redundant information. So that it can eliminate the collinearity between the original variables, overcome the resulting operational problems such as instability, so also significantly improve the speed of operation, and is more suitable for image processing of large amount of data [9-11].

Plane of the main components of inspection is used for image denoising process is as follows:

Set $m \times n$ remote sensing image sets, $\{I_1, I_2, ..., I_p\}, p \in N$, p random variables on behalf of a remote sensing image of $m \times n \times p$.

(1) Calculation of remote sensing image sets A average of $\overline{A}$, and here called $\overline{A}$, the average image.

(2) Calculation of remote sensing image A covariance matrix

$$C_t = E[(A - EA)^T][(A - EA)] \quad (12)$$

And unbiased estimation

$$W_t = \frac{1}{p}\sum_{k=1}^{p}(I_k - \overline{A})^T(I_k - \overline{A}) \quad (13)$$

(3) To calculate the characteristic values, to calculate the maximum eigenvalue first S; Orthogonal vectors and the corresponding unit, which for the optimal projection axis matrix;

(4) A sample image of I_k image matrix for its projection to projection axis matrix

$$Y_k^{(w)} = A\xi_k, (w = 1, 2, ..., p; k = 1, 2, ..., s) \quad (14)$$

(5) P a sample image $\{I_1, I_2, ..., I_p\}$ after plane principal component inspected after transformation, principal component matrix can be calculated

$$P_w = [Y_1^{(w)}, Y_2^{(w)}, ..., Y_d^{(w)}], w = 1, 2, ..., p \quad (15)$$

$P = AQ$ is orthogonal, use the type can be rebuilt image:

$$A = PQ^T = \sum_{k=1}^{s} Y_k \xi_k^T, k = 1, 2, ..., s \quad (16)$$

The paper summarizes the process of the above, we can see the plane principal component inspection in remote sensing image denoising has the following advantages:

(1) The plane principal component of the overall discrimination rate is higher than principal component inspection;

(2) The plane principal component inspection on the overall amount of calculation is far less than principal component inspection and significantly increases the image feature extraction speed.

(3) Main components inspection based on image plane matrix, it is more simple and intuitive on image feature extraction;

3. Based on Wavelet Transform Plane Principal Component Inspection Denoising Methods

Two-dimensional principal component inspection method is through linear transformation, to find a set of orthogonal optimal vector base. With this group of a linear combination of the unit vector orthogonal basis to reconstruct the original sample, which makes the minimum error of old and new sample. In order to better analyze each parameter, the characteristics of the wavelet transform domain by wavelet transform is first after the high frequency part of original image is decomposed into size of $m \times n$ blocks for processing. In each sub-block of the wavelet transform coefficient of each dimension as a row vector X_i, has M matrix X, size of $M \times N$ row vector of the covariance matrix of the:

$$W_x = \frac{1}{M} \sum_{i=1}^{M} (x_i - m_x)^T (x_i - m_x) \quad (17)$$

Among them,

$$m_x = \frac{1}{M} \sum_{i=1}^{M} x_i \quad (18)$$

The covariance matrix of N eigenvalues in descending order; Their corresponding eigenvectors constitute a set of feature space. Select a threshold, remove the smaller feature vector, so that you can get effective the characteristic value of sorting, the top k base vector can describe the main features, is made up of the blue vector subspace is formed to describe x_i feature space before use the principal component model to estimate the reconstruction of the X :

$$Y = \sum_{i=1}^{k} X f_i \ f_i^T \quad (19)$$

Done according to the type of N row vector of refactoring, can realize the reconstruction of matrix X, dealt with after the high frequency coefficient matrix of the mountain in the sub-block is mostly caused by noise, after plane principal component to investigate treatment of reconstruction matrix widely reflect coefficient caused by noise amplitude characteristics. O out NSCT coefficients of the constitutive matrix in the absolute value of the mean T:

$$T = mean(|Y|) \quad (20)$$

The average r as caused by noise NSCT coefficients in the sub-block amplitude estimation as the initial threshold in this chapter.

In wavelet transform can detect the edge of the local mutation features. Plane of the main components of inspection technology can effectively for feature selection, reduce the vector dimensions. So that greatly reduce the amount of calculation and speed can be improved steadily. Therefore, put forward based on wavelet transform plane principal component inspection algorithm, experimental steps are as follows [12-13]:

(1) Contains noise of remote sensing images for 2-3 layers of wavelet decomposition, and the high frequency subband sub-block dividing along different directions;

(2) Each sub-block of high frequency subband respectively according to (17) and (20), get the estimates of the wavelet coefficient caused by noise, to get each sub-block are stated in the initial values ;

(3) Pairs of soft threshold wavelet coefficients, and its formula is as follows:

$$\overline{W_{jk}} = \begin{cases} \operatorname{sgn}(W_{jk})(|W_{jk}| - \lambda), & |W_{jk}| \geq \lambda \\ 0, & |W_{jk}| < \lambda \end{cases} \qquad (21)$$

Among them, $\overline{W_{jk}}$ threshold within sub-block before processing of wavelet coefficient, in W_{jk} for the soft value of new wavelet coefficients after processing.

(4) repeat step (2), (3), complete the processing of all blocks within each subband, using processed coefficient on the inverse transformation of wavelet, the reconstructed image is obtained after denoising of remote sensing images.

4. The Experimental Results and Analysis

Through a series of experiments to verify the authenticity of the algorithm, the gray level for 256 gray, size is 256 X 256, remote sensing image as the experimental samples. In the initial remote sensing images to add salt and pepper noise and gaussian white noise, its variance but different mean all set to 0.On this basis, the noise of image processing, wavelet threshold method respectively, based on wavelet change main components of denoising and algorithm in this paper. With the evaluation index of MSE and PSNR results analysis and evaluation is made on the final result [14-15].

In the image below, in which the initial image for the graph (a), add the images for noise figure (b), respectively, using the wavelet threshold method, principal component inspection denoising based on wavelet change, and the algorithm is shown in figure (c) - (e).By using difference image, which can be found that the difference of different algorithms in details, so you can better analyze the remote sensing image detection. Figure 1 is to add the standard variance of 25 white gaussian noise of remote sensing images the effect after denoising images with different method, the experimental results are shown below:

(a) The original image

(b) Add noise image

(c) Wavelet denoising image

(d) The main components of image denoising

(f) Plane of the main components of image denoising

Figure 1. Using Different Methods to Add Gaussian Noise of Remote Sensing Image Denoising and the Difference Image

Can be seen from the shown in the figure above, joined the images after gaussian white noise, in using the algorithm proposed in this paper it is concluded that the difference between original image and the new image of the smallest. The more close to the original image, denoising effect is the most significant. Table 1 is to add gaussian noise variance of remote sensing images using different numerical methods after denoising PSNR and MSE, the result is as follows:

Table 1. Adding Different Gaussian Noise Variance after Using Different Methods of Remote Sensing Image Denoising PSNR and MSE

σ	With noise image		Wavelet denoising		The main components of denoising		Algorithm of this paper	
	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE
10	53.41	0.24	53.46	0.22	53.67	0.23	53.97	0.21
20	52.32	0.36	52.34	0.33	52.34	0.35	52.76	0.33
30	51.37	0.47	51.31	0.45	51.78	0.47	51.30	0.46
40	50.18	0.53	50.23	0.57	50.25	0.51	50.37	0.58
50	49.63	0.64	49.45	0.68	49.80	0.63	49.23	0.61
60	48.74	0.79	48.47	0.73	48.35	0.74	48.75	0.72
70	47.24	0.85	47.12	0.84	47.89	0.85	47.08	0.83

Through the above form, you can see that the algorithm presented in this paper to add the gaussian noise of remote sensing image denoising, the result has a smaller mean square error (mse) value and higher peak signal to noise ratio. Compared with other methods, the simulation experiments, the method presented in this paper after denoising difference image difference is minimal. Keep the original image is clear texture and go in addition to the noise effectively, and the PSNR values are the most high and MSE values are relatively small. In addition, but also for comparing different algorithms of operation time, so you can draw a plane principal component algorithm reduces computational complexity, greatly improve computing speed. Table 2 is adding different intensity high, noise, using different methods of remote sensing image denoising of operation time, the experimental results as follows:

Table 2. Adding Different Intensity High, the Noise of Remote Sensing Image Denoising using Different Method of Computing Time

σ	Wavelet denoising	The main components of denoising	Algorithm of this paper
10	0.873	0.814	0.364
20	0.865	0.874	0.354
30	0.854	0.846	0.397
40	0.862	0.871	0.312

As can be seen from the table, the plane investigation denoising method of main component operation time is the shortest, obviously improve the computing speed. To add the standard strength of 30 gaussian noise of remote sensing image as an example, the speed of the algorithm in this paper a 63.6% increase over the wavelet threshold method, a 62.1% increase over the principal component inspection methods. So we directly use plane principal component inspection methods of matrix, the can achieve the purpose of reducing dimension, can greatly improve the running speed of the experiment. Above all, on the remote sensing image denoising, has certain advantages compared to other algorithms, this algorithm has good performance, the reason mainly has the following:

(1) Using the wavelet transform algorithm. Through the process of space and time frequency localization, applications scale translation operations for hierarchical classification of multi-scale refinement, to achieve the low frequency segment and high frequency time segment. To focus on any details of the image, it can achieve the ultimate goal of adaptive time-frequency information processing.

(2) To adopt two dimensional principal component to investigate this kind of statistical feature extraction method. By introducing noise based on wavelet transform coefficient vector distribution of feature extraction, directly on the coefficient of amplitude caused by noise to estimate, do not need to estimate noise

5. Conclusion

Based on the study of wavelet transform and two-dimensional principal component on the basis of investigation, will compare and merge. In remote sensing image processing, wavelet decomposition and reasonable level, adopt the method of principal component to investigate characteristics of high frequency coefficients are extracted, on the premise of reducing data transformation between time, directly with two-dimensional vector matrix, which results significantly improve image processing speed operation. Based on this estimation is introduced into the noise caused by the change of wavelet transform coefficient. To select the energy of noise as the initial threshold, then using the neighborhood information of high frequency coefficient and noise energy together, each layer of the threshold value is calculated, so that it can be remote sensing image denoising. Can be seen from the experimental results, the proposed method is better than first when some typical denoising method, this method can effectively remove gaussian noise of remote sensing images, made in the image edge details such as information can be more perfect.

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