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Research on Application of Image Penetration Technology in Image Denoising

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Abstract

Image denoising is a frequently encountered problem in image processing, this article through the analysis of the characteristics of denoising algorithm which based on wavelet transform and curvelet transform, focus on the artifacts phenomenon generated by curvelet transform denoising algorithm, and proposes a method based on fast discrete curvelet transform denoising algorithm and the non-sampling wavelet transform denoising algorithm and image penetration technology is applied to image denoising, the experimental results show that the method improves the speed of image processing, should have good practical value.

Key words: *Image denoising; wavelet transform; curvelet transform; image penetration technology*

1. Introduction

In real life, we all don't get most of the external information by visual activities. As one of the most important visual information, image information is an important source of knowledge of human understanding and cognition of the world. At the same time, due to human visual perception, we have complete in social life and the scientific research activities, therefore, we are basically through the image form to represent data, in order to facilitate our understanding, analysis, problem; And because the image in the medical, satellite remote sensing, industrial, military and video multimedia applications have extensive and irreplaceable, so the image signal processing has been a hot topic in the field of signal processing.

In many areas, we often want to obtain accurate images for analysis, and judgment. But by physical conditions and environmental factors, the image signal on sampling, quantization, coding, transmission, in the process of recovery, inevitably affected by the interference of noise. In image signal noise is an important factor of image quality to reduce, has a great influence on image analysis, image compression. So in the process of image processing, such as edge detection, image segmentation, feature extraction and pattern recognition and so on high level before processing, choose the appropriate method, as far as possible to remove noise is a very important preprocessing steps. Therefore, image denoising method study is the precondition of all image processing, is a hot issue in image processing field, has the vital significance.

Evolve from Fourier analysis and wavelet analysis, at the expense of some frequency performance for time-frequency analysis method of local performance. Wavelet transform can not only provide accurate time domain orientation ability, also can provide the precise positioning of frequency domain. Signals in the real world, show the more is the non-stationary characteristics of the wavelet transform of arbitrarily small compactly supported features, makes its rapid changes over time and non-stationary signal is a powerful tool. Due to local time and frequency analysis of the signal has a strong ability on a one-dimensional function of bounded variation class which has the optimal approximation performance, the wavelet transform theory has received the widespread attention. Image denoising is one of the important application of wavelet analysis theory,

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many scholars have made outstanding contributions in this field. In recent years, the denoising algorithm based on wavelet coefficient model has become the hot: the wavelet transform and hidden markov model, multi-scale stochastic process, context model and combine the bayesian model, in the process of image denoising has achieved fairly good results.

Because wavelet transform at the same time with local characteristics in time domain and frequency domain, so in many fields such as numerical calculation and signal processing has been more and more widely used. Said, however, the advantage of wavelet transform with isotropic (isotropic) the object of the singularity, which reflect the location of the singular point and characteristics, and the 2 d image edge information in such as curve or straight line shape features more higher dimensional singularity, with only limited information in the direction of the wavelet transform can't optimal said its characteristics. So the application of wavelet transform for image compression and denoising processing, inevitably lead to the image edge details and location of the fuzzy. In order to overcome a limitation that the wavelet Transform, on the basis of the theory of wavelet, Emmanuel Candes J said in 1998 first put forward the suitable for anisotropic multi-scale singularity method -- Ridgelet Transform (Ridgelet Transform). Ridgelet transform is essentially by the wavelet basis function characteristic parameters are introduced in the direction, so it is not only a local time-frequency analysis ability, but also has a strong direction selection and recognition, can effectively in said signal singularity characteristics of directional. And after that, Candes and David Donoho in 1999 put forward a new method of multiscale geometric analysis, Curvelet Transform (Curvelet Transform). Curvelet transform is essentially derived by ridgelet theory, is in the monoscale ridgelet or local ridgelet transform is used to describe a curve on the basis of the type of singularity boundary object. Curvelet transform multi-scale analysis of unique advantages, make full use of the combination of ridgelet at said linear features and the performance of the wavelet transform is suitable for dot, the advantages of the obtained good effect in the image denoising. But in 1999 the proposed curvelet transform structure is complex, prone to block in the process of implementation effect and has a high redundancy. Aiming at these shortcomings, 2005 Candes and Donoho and put forward the Fast Discrete Curvelet Transform (Fast Discrete 'Curvelet Transform, FDCT). Fast discrete curvelet transform is not only overcome the block effect of transformation, and simplifies the implementation process, greatly reduces the redundancy, to further promote the application of curvelet transform in image processing field.

Image is through a mathematical model for integrated many images from different sensors into a meet specific application requirements of image process, which can overcome the single image in the geometry of the limitation of spectral and spatial resolution and difference, improve the ability of analysis and extraction of image information. Image penetration technique is widely used in pattern recognition, computer vision, satellite remote sensing, robot, medical image processing, and other fields.

According to different, at the stage where infiltration processing image usually can be divided into pixel level, feature level and decision level. Different penetration levels, adopted by the algorithm and the applicable scope is not the same. At pixel level in the three levels of infiltration, infiltration as the basis of the penetration at all levels, can retain the scene of the original information as much as possible, provide other penetration level can provide rich, accurate and reliable information, is conducive to the further image analysis and processing and understanding, thus providing an optimal decision making and the recognition performance. In a lot of method, the pixel infiltration permeability algorithm based on wavelet transform has been widely studied. Along with the development of the Curvelet transform, Curvelet transform based image penetration algorithm has become a new hot spot, as Choi will Curvelet is first used in multispectral image and the penetration of panoramic image, melting and the result is more abundant spatial and spectral information and better visual effect.

2. Related Works

Fractional wavelet transform multi-resolution analysis of wavelet transform theory to promote the fractional Fourier domain, its associated with the evolution of the wavelet transform and the theory of fractional order, comprehensive characteristics of the two came into being at the same time, is a new kind of time and frequency domain analysis method. Compared with the wavelet transform, the biggest advantages of fractional wavelet transform added a variable p order of time, can be more flexible to adjust the wavelet coefficients. Good application prospects of fractional wavelet transform and the signal processing method based on fractional wavelet transform the potential applications of self-evident.

Secondary fractional order wavelet transform are defined as shown below [1]:

$$W(\mathrm{a}_{mn}, \mathrm{b}') = \iint\iint B_{\rho1,\rho2}(\mathrm{x},\mathrm{y},\mathrm{x}',\mathrm{y}')\,\mathrm{f}(\mathrm{x},\mathrm{y}) \times \mathrm{h}_{\mathrm{a}_{mn},\mathrm{b}'}(\mathrm{x}',\mathrm{y}')\,\mathrm{dxdydx'dy'} \tag{6}$$

Fractional domain is expressed as:

$$W(\mathrm{a}_{mn}, \mathrm{b}') = (\mathrm{a}_m \mathrm{a}_n)^{0.5} \iint H(\mathrm{a}_m \mu, \mathrm{a}_n \nu) \times \exp(\mathrm{j}2\pi\mu b_{\mathrm{x}'}, \mathrm{j}2\pi\nu\,\mathrm{b}_{\mathrm{y}'}) \times \mathrm{F}\left\{F^{\phi1,\phi2}[\mathrm{F}(\mathrm{x},\mathrm{y})](\mathrm{x}',\mathrm{y}')\right\}(\mu,\nu)\,\mathrm{d}\mu\,\mathrm{d}\nu \tag{7}$$

In it, $\mathrm{h}_{\mathrm{a}_{mn},\mathrm{b}'}(\mathrm{x}',\mathrm{y}')$ is the scale of the mother wavelet and translation function, as shown below:

$$\mathrm{h}_{\mathrm{a}_{mn},\mathrm{b}'}(\mathrm{x}',\mathrm{y}') = (\mathrm{a}_m \mathrm{a}_n)^{-0.5} h\left(\frac{\mathrm{x}' - b_{\mathrm{x}'}}{\mathrm{a}_m}, \frac{\mathrm{y}' - \mathrm{b}_{\mathrm{y}'}}{\mathrm{a}_n}\right) \tag{8}$$

$(\mathrm{a}_m \mathrm{a}_n) = (\mathrm{a}_m, \mathrm{a}_n)$ is discrete scale, $\mathrm{b}' = (b_{\mathrm{x}'}, \mathrm{b}_{\mathrm{y}'})$ is displacement scale. Secondary fractional order wavelet reconstruction formula [2] is:

$$\mathrm{f}(\mathrm{x},\mathrm{y}) = \frac{1}{C}\iint F\left\{\sum\sum\iint \frac{1}{\mathrm{a}_m \mathrm{a}_n} W(\mathrm{a}_{mn}, \mathrm{b}') \times H(\mathrm{a}_m \mu, \mathrm{a}_n \nu)\exp(-\mathrm{j}2\pi\mu b_{\mathrm{x}'}, -\mathrm{j}2\pi\nu\,\mathrm{b}_{\mathrm{y}'}) \times db_{\mathrm{x}'} d\,\mathrm{b}_{\mathrm{y}'}\right\}$$

$$(\mathrm{x}',\mathrm{y}') B_{-\rho1,-\rho2}(\mathrm{x},\mathrm{y},\mathrm{x}',\mathrm{y}')\,\mathrm{dx'dy'} \tag{9}$$

In image denoising, the pros and cons of various algorithms are ultimately comes down to the evaluation on the quality of the images, so you need a reasonable image quality assessment standards. Reference literature both at home and abroad, the evaluation standard is relatively uniform. After a lot of research and verification, the current widely used in scientific research personnel peak signal-to-noise ratio as evaluation indexes. Defined as: including noise image peak signal-to-noise ratio p0 and denoising image peak signal-to-noise ratio (p1, as shown below [3-5]:

$$p0 = -10\lg\left(\frac{\sum_{i=1}^{m}\sum_{j=1}^{n} N^2(\mathrm{i},\mathrm{j})}{m \times n \times 255^2}\right) \tag{10}$$

$$p1 = -10\lg\left(\frac{\sum_{i=1}^{m}\sum_{j=1}^{n} (\mathrm{X}(\mathrm{i},\mathrm{j}) - \mathrm{X}'(\mathrm{i},\mathrm{j}))^2}{m \times n \times 255^2}\right) \tag{11}$$

$\mathrm{X}(\mathrm{i},\mathrm{j})$ is primitive noise image, $X'(\mathrm{i},\mathrm{j})$ is for image denoising is estimated, $N(\mathrm{i},\mathrm{j})$ is the estimated noise. After denoising images of $p1$ value, the greater the denoising processing after the image more close to the original image, the image denoising effect is better.

Objective image quality index used peak signal[6-8] to noise ratio of p value, the optimal p values for images, need to accurately estimate the residual noise, here is mainly to have nothing to do with the image of the zero mean Gauss white noise estimation. The input image is often has been polluted by the noise of the image, contains xmn and noise of the image noise standard deviation a_{mn} is unknown, estimate of the image P values equivalent to the estimate of the standard deviation of a_{mn}.

Image noise estimation methods for the standard deviation of a_{mn} [9]: subtract with noise image denoising image difference to estimate the value of the noise signal, this method needs to use effectively filter out noise and well keep the edge details of both filter, will contain noise image into several parts, respectively estimates that each part a_{mn} , choose the more appropriate as a_{mn} actual estimated values; To estimate the noise of the image by image statistical features of the standard deviation a_{mn}.

Based on two-dimensional fractional wavelet transform[10] in image denoising, the optimal p value selection is a very important link. This paper puts forward a optimal p value selection method based on noise estimation, now define the input noise unknown root mean square error of the M and unknown input noise peak signal to noise ratio of Pu objective evaluation criteria for the new image denoising, such as formula (12) and (13) [11.12]:

$$M = \frac{1}{\mathrm{m} \times \mathrm{n}} \sum_{i=1}^{m} \sum_{j=1}^{n} (\mathrm{f}(\mathrm{i},\mathrm{j}) - N(\mathrm{i},\mathrm{j}) - X'(\mathrm{i},\mathrm{j}))^2 \tag{12}$$

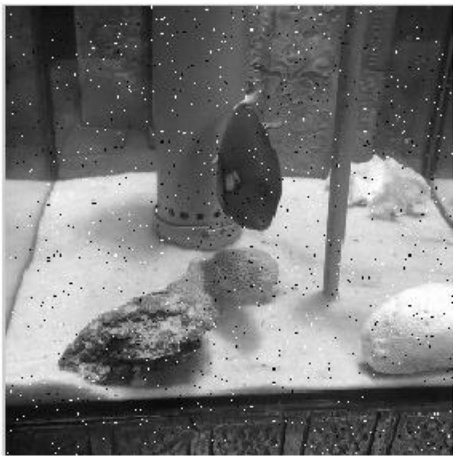
$$Pu = -10 \lg \frac{M}{255^2} \tag{13}$$

among them, $\mathrm{f}(\mathrm{i},\mathrm{j})$ is the original noise image， $X'(\mathrm{i},\mathrm{j})$ is estimated after denoising, image noise $N(\mathrm{i},\mathrm{j})$ is estimated.

$N(\mathrm{i},\mathrm{j})$ approximates to the real value of noise, f（i， j）-N（i， j）more close to the original image without noise, can be thought of as f（i， j）-N（i， j）on the estimate of $X'(\mathrm{i},\mathrm{j})$, and the fractional wavelet transform denoising after $X'(\mathrm{i},\mathrm{j})$ can also be considered for X(i,j) kind of estimate, by comparing two kinds of estimates have been the Pu can be used as $X'(\mathrm{i},\mathrm{j})$ standard to evaluate the gap between two estimates, Pu, the greater the degree of approximation, the higher of the two, this time can be thought of $X'(\mathrm{i},\mathrm{j})$, p value is the most optimal, when $X'(\mathrm{i},\mathrm{j}) = X(\mathrm{i},\mathrm{j})$, Pu is equal to p. And the P value by the same token, the M value is smaller, the Pu value, the greater the $X'(\mathrm{i},\mathrm{j})$ and $X(\mathrm{i},\mathrm{j})$ higher degree of approximation, show the better denoising effect. The optimal corresponding fractional time calculated Pu is the optimal estimates of the p values[13.14].

To illustrate the proposed by gaussian noise background, based on second order fractional wavelet transform denoising method is effective, here to unwater commonly used standard image as an example, the noise standard deviation of gaussian noise pollution for 30 cases, the wavelet transform and secondary fractional order wavelet transform denoising method to do a comparison, to verify the superiority of this method with high efficiency.

1. Noiseless image



2. Containing mixed noise image

3. Image after a wavelet filter

4. Image after the two-dimensional fractional wavelet filtering

Figure 1. Denoising of Unwater Image

By above knowable, the residual noise wavelet transform denoising is larger, and the secondary fractional order wavelet transform denoising based on better retain the useful detail information, in addition to the more noise, after denoising result in accordance with the original image better.

Early curvelet transform is derived by Ridgelet theory, the idea is that the curve is divided into small enough pieces, each piece of the curve is approximate to linear, local Ridgelet (Ridgelet) is then used to analyze its features. However, the implementation process of the curvelet transform is more complex, need to adopt contains seven parameters of complex structure, has been subband decomposition, smooth block, regularization and ridgelet (ridgelet) analysis steps. And in the transformation process prone to block effect, and due to the use of overlapping Windows, increased the curvelet transform redundancy of digital implementation. In order to overcome the above shortcomings, E.J. Candes and David Donoho et al., and puts forward a easy to realize and understand the Fast Discrete Curvelet Transform (Fast Discrete 'Curvelet Transform,] FDCT). A new fast curvelet transform algorithm has has nothing to do with ridgelet theory.

3. Image Penetration Denoising Model

Images based on wavelet transform is the basic principle of infiltration is: treat penetration image multi-layer wavelet decomposition, get the image of low frequency and high frequency components, then the low frequency component and high frequency component of the infiltration of the corresponding operator and penetration rules of infiltration processing, get infiltration images of low frequency and high frequency components, then wavelet inverse penetration after image. Of different sensors to get the same image, the low frequency components generally similar or identical, while high frequency component difference is larger. So the image of infiltration is the key to the penetration of high frequency components, so in osmotic treatment to cope with the high frequency component and low frequency components of image difference, the infiltration of different operator and the rule of infiltration.

The infiltration image technology to two or more images were taken from the same object, use the complementary information of the image will be the useful information from different images together. Image penetration technology was applied to image denoising process, can combine various denoising method, in order to get better effect.

In this paper, based on wavelet osmosis combined denoising method includes the following two steps:

1. The noise of images, respectively, using the sampling wavelet transform (UDWT) and fast discrete curvelet transform (FDCT) for noise reduction, I get after denoising image. A, B, I
2. The use of wavelet transform, the penetration of according to certain rules of IA, IB images penetrant, after denoising images of the IC.

When choosing infiltration rules, considering the regional characteristics of the image is often not to characterize by a pixel, but by a local area to represent multiple pixels, so, based on local energy at low and high frequency the infiltration of different permeability rules algorithm. Infiltration process is as follows:

(1) treatment of infiltration images I A, B I two-dimensional wavelet decomposition. Due to the infiltration process based on wavelet transform image, the image of the low frequency component of the focused image of the main energy, which reflect the image of the approximation and the average feature, so after the decomposition of low frequency part adopts weighted average operator. Considering the sampling wavelet transform denoising method in dealing with image even regional advantage, at the same time in order to be able to curb the fast discrete curvelet transform denoising algorithm of artifacts, when calculating the weighted coefficient, can be appropriately increased after the sampling wavelet transform denoising image proportion.

(2) the high frequency component reflects the brightness mutation characteristics of original image, the image edge information, regional characteristics, so the high frequency component of penetration results will affect the image details. Wavelet coefficients of high frequency component of the decomposed matrix are calculated respectively regional energy E kA, E M kAB kB and local matching degrees.

(3) according to the method of low frequency and high frequency wavelet coefficient matrix inverse transformation of wavelet eventually melts and results are obtained.

4. Experiment and Analysis

In order to verify the joint denoising method based on wavelet penetration effectiveness, we take the size of 512 x 512 Lena image and 256 x 256 woman image as a test image, adding noise sigma is 25,20,15 Gauss white noise. Based on the two images respectively, UDWT FDCT and wavelet osmosis combined denoising method of noise reduction processing, the simulation results are shown in figure 1, figure 2 and figure 3. Various denoising method of peak signal-to-noise ratio (PSNR) the results are shown in table 1 and table 2.

1. 25 Gauss noise

2. FDCT denoising

3. UDWT denoising

4. Penetration denoising

Figure 1. Image Denoising Effect Contrast Figure

1. 20 Gauss noise

2. FDCT denoising

3. UDWT denoising

4. Penetration denoising

Figure 2. Image Denoising Effect Contrast Figure

1. original image

2. 25 Gauss noise

3. UDWT denoising

4. FDCT denoising

5. Penetration denoising

Figure 3. Image Denoising Effect Contrast Figure

Table 1. Barbara Denoising Image PSNR Contrast

Noise standard deviation	25	20	15
Noise image	19.989	22.167	24.123
UDWT denoising	22.324	23.341	24.864
FDCT denoising	24.834	25.332	26.563
Penetration denoising	25.345	25.611	27.334

Table 2. Lena Denoising Image PSNR Contrast

Noise standard deviation	25	20	15
Noise image	19.345	22.167	24.342
UDWT denoising	29.452	31.178	32.542
FDCT denoising	30.728	32.256	33.254
Penetration denoising	31.836	33.276	34.325

From the simulation results showed that the sampling wavelet transform (UDWT) denoising algorithm can effectively remove the gaussian white noise in the image, and after denoising image smoothness is good, but after denoising loss of the details of the image information especially in the edge of the area to produce the fuzzy phenomenon; Fast discrete curvelet transform (FDCT) denoising algorithm is able to keep the details of image edge, but in the region of the image part of the uniform produced artifacts, and smoothness is a bit poor; In this paper, based on wavelet osmosis combined denoising method can remove noise in images, the denoising results on the basis of keep the details of the image and has good smoothness and visual effect, with the original noiseless image is more close to. From can also be seen in table 1 and table 2, the proposed joint denoising method based on wavelet permeability has higher peak signal to noise ratio.

5. Conclusion

Image denoising is frequently encountered problems in image processing, this article through the analysis based on wavelet transform and the characteristics of denoising algorithm based on curvelet transform, curvelet transform denoising algorithm artifacts generated by the phenomenon, with fast discrete curvelet transform denoising algorithm is proposed and the sampling denoising algorithm based on wavelet transform, the image in the process of osmosis technology is applied to image denoising methods, the experimental results show that the method improves the speed of image processing, should have good practical value.

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