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Sparse Matrix of Image Denoising Method based on SVD

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Abstract

In this paper, based on the K - SVD and residual error than the low SNR image sparse representation denoising algorithm. On the basis of the foregoing contents, this paper expounds on the build process and mechanism analysis of the algorithm, the paper on the basis of the subjective evaluation reference peak signal-to-noise ratio (PSNR) as the objective evaluation standard. Can be seen from the results of simulation experiments for different kinds of image denoising, image sparse decomposition based on a complete atom library has a better effect of denoising algorithm often, this is because after complete the atoms in the dictionary has redundancy, to show more abundant characteristic information, can more effectively extract the image features. In the proposed algorithm, the K - SVD algorithm for image sparse decomposition to optimize dictionary and residual error than the threshold for accurate division of image information and provide evidence for image noise effectively, a combination of both in image denoising, especially in low SNR image denoising experiment obtained good effect. The experimental results also from another side shows the sparse decomposition based on a complete atom library on image denoising application potential.

Keywords: *image denoising, K-SVD, OMP, sparse representation, SNR*

1. Introduction

Vision in human perception of the outside world plays a very important role in the process, in the information age, digital image has become an important object of human visual perception. Digital image processing is to use the computer for analysis and calculation to make it more in line with the process of people expect. With the development of computer and information technology, image processing, became a great achievements obtained in theory and practice subject. In the 1960 s, the use of image restoration technology to deal with satellites collect images of the moon's surface, obtain a great deal of valuable information [1]. In the 1970 s, the use of image enhancement and image recognition technology of satellite remote sensing images of the earth, for the country's agricultural planning, mineral exploration, hydrometeorological forecast provides extensive and reliable information. In the late 80 s and early 90 s, the rapid development of large scale integrated circuit technology for image processing provides a powerful computing platform, makes the image compression technology, such as text recognition technology has a rapid development. In the deepening development of Internet technology, cloud computing rise today, digital image has become more and more important information carrier, even become a new and important cultural forms. In People's Daily life, digital image has become people to enjoy the service, an important medium to create value, to the military, production, health care, education and so on various aspects of human activity had a profound impact. Demand based on this background, the fast development of the digital image processing technology, including image denoising is one of the hot spot of

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research. Image in the process of acquisition, transmission, tend to be affected by the equipment and the surrounding environment, such as sensitive to original uneven sensitivity in the photoelectric conversion process, in the process of digital image quantization error, in the process of image transmission channel noise, and so on, these will affect the quality of the image. How to filter the image noise, the natural shape of restored image is the ultimate goal of image denoising [2, 3]. Image denoising is itself an important theoretical and practical significance of the scientific research activity, is also the important link of image processing. General of image preprocessing, image processing and denoising is one of the important link, after denoising image will be late for image coding, image feature extraction, image segmentation, image compression, image transmission, etc. Therefore, image denoising effect is good or bad, directly affects the performance of other image processing link, the image denoising technology has important practical significance. Image denoising involves mathematical statistics, information theory, and many other fields. Based on image denoising research problem, using sparse decomposition based on a complete library of atomic theory as the method, to new understanding of image noise, obtained a new image denoising method, the result indicates that the algorithm has good image denoising features. The image in reality often contains noise, noise seriously affects the quality of the image, but also bring many difficulties to the subsequent processing of the image, so the image denoising is an important content of image processing. Image denoising is sometimes called the image smooth. In general, useful information mainly concentrated in the low frequency part of image, noise is usually randomly generated. The traditional image denoising methods, both space domain and transform domain, always will be regarded as the high frequency part of image noise. Useful information of the image, however, also has the high frequency components, such as image edges and details, etc., so the traditional denoising method in filter out noise and loss of high frequency components of the useful information, and the high-frequency useful information tend to reflect the important features of the image. Signal denoising based on sparse decomposition is a new thought to understand the signal and noise [4, 5]. Under the category of sparse decomposition research signal denoising is helpful to understand the relation between noise and signal, is helpful to use more simple and convenient way to separate the noise, to improve signal quality. Image denoising based on wavelet transform is the most common and most important class of algorithms. However, the one dimensional wavelet generated by tensor product of two dimensional wavelet base does not meet the relationship of the scale of the anisotropy, sparsely said can't contain line or face strange two-dimensional images. Therefore, Donoho *et al*. proposed the multi-scale geometric analysis (mga.to) method, this kind of method of image denoising is research a kind of more method in recent years, is widely applied. Relative wavelet transform, mga.to method can to more sparse representation of image, and achieve better denoising effect. However, a multi-scale geometric analysis method is often only some of the characteristics of image sparse representation, and are always contains various features in natural images, therefore, only use a certain kind of transformation is very difficult to treat all features effectively. In addition, the multi-scale image denoising algorithms, is still in a traditional perspective image noise: the noise as the high frequency part of the image. In image denoising and tend to be lower than a certain threshold of high frequency coefficients are set to zero, higher than the threshold coefficient remains constant. This in effectively remove noise but also lost the image some useful information. In recent years, due to the sparse representation of the image can depict the essential characteristics of image, and is widely used in image denoising, and become the research hot spot [6].

2. Related Works

In the field of image sparse representation, the design of the dictionary and generation is a complete one of the important research contents of sparse representation theory. Since the 1993 s. Mallat and z. Zhang, first put forward the concept of a complete library of atoms, atom library generation and structure design is a hotspot of scholars have been concerned, the multi-scale Gabor dictionaries, multiscale ridgelet dictionary and cascade dictionary and other research results. In addition, in recent years, scholars have looked through learning and training to get a complete atom library method, the method to generate variety and got great development. Over complete dictionary in deepening the research sparse decomposition theory and decomposition speed of the algorithm has a great role in promoting. In 2006, Michal Aharon et K - SVD algorithm is proposed, and used for adaptive update of the dictionary, this algorithm in image denoising, image compression, and other fields have achieved good effect. In the field of signal sparse representation, fast algorithm based on a complete dictionary sparse representation is a complete sparse representation of a hot research topic. In a period of time in the past, researchers have proposed many obtain approximation method of signal sparse representation. Among them, the matching pursuit algorithm is still one of the most effective sparse decomposition algorithm, and spawned many variant algorithm, and promote the development of the application of sparse decomposition. However, in the denoising algorithm based on image sparse representation, generally by setting a fixed threshold to residual signal energy as decomposition algorithm iterative termination conditions, and thus achieve the goal of denoising. While effectively filter out noise, this often caused the image part of the loss of useful information. Digital image in a computer often use a series of corresponding pixel point and each point of gray scale value or color coding. Digital image is to use (I, u (I)) of to form, the video is only on this to add a dimension of time. In gray image, I represent a two-dimensional space coordinates, which is composed of digital images, the smallest unit of pixels. U (I) represents the image of each pixel gray value. Digital image acquisition device is generally optical focusing system with CCD array, the value of each pixel in the image of u (I) is the sensitive point of light intensity on the CCD array induction results. A good feeling on the vision of gray image generally quantification for 256 level gray scale range, 0 (black and white 255 delegates. Scientists in the study of image denoising process, has achieved fruitful results. In a computer, usually with each pixel gray value of the collection to represent an image, and the influence of image noise is each pixel gray value. Grey value of noise itself can be regarded as a random variable, according to its influence on image, can be divided into the following three:

1) the additive noise. In this class under the influence of the noise image can be seen as the original image and the simple superposition of noise generation, noise intensity and the original image signal strength are independent of each other. Additive noise is commonly by the external environment disturbance, such as image noise is introduced in the process of transmission channel. Denoising method is relatively simple.

2) the multiplicative noise. This kind of noise intensity is related to the intensity of the original image signal and the noise intensity changes with the strength of the image signal. This kind of noise in processing can use mathematical means transformed into additive noise.

3) the quantization noise. This kind of noise is the main source of digital image noise, because the image must be carried out in the process of digital sampling, the hard to avoid in the process of sampling will introduce quantization error. Quantization error produced in acquiring images, the images and store the image. To treat this kind of noise, usually can be used in a way to increase the quantization digit to lower the noise close to the ideal state.

According to the gray statistical characteristic of noise noise in an image can be classified, common types are: gauss noise and salt and pepper noise, uniform noise, poisson noise, etc., such as snow point on the TV screen is salt and pepper noise, the thermal noise are gaussian noise. This article assumes that the image noise model for the gaussian white noise, energy spread in the whole frequency band. With the deepening of the understanding of image noise, de-noising algorithm emerge in endlessly, main algorithms can be classified into two types: spatial domain and transform domain.

1) the spatial domain image denoising algorithm. This kind of algorithm to deal with the noise in the image space domain directly. Algorithm is the basic train of thought first determine the template, and then through the analysis in the field of target pixels pixel gray level, to adjust the pixel gray value inside the template, and then move the template, repeat the adjustment process until they meet the requirements. This kind of algorithm can be divided into linear denoising algorithm and nonlinear denoising algorithm.

Linear denoising algorithm is the most representative of the mean denoising algorithms, the algorithm to grayscale average processing of all pixels, so denoising exists blindness and caused serious damage to the detail of image, the image blur. Scholars on the basis of the average algorithm is put forward a lot of improved algorithm, but denoising effect is always not satisfactory. Nonlinear denoising algorithm, namely median algorithm proposed raised a hot wave of image denoising algorithms, it turned out that the median algorithm can completely solve the problem of linear algorithm of fuzzy boundary, so in the history of image denoising algorithms have important significance. Sale: on February 19, 2013 idea is to gray to sort all pixels in the template, then use the sorted values in grey value instead of the target pixel gray value, this line of thinking clever suppress the pulse noise, and can better protect the edges of the image information. But also nots allow to ignore to the many shortcomings of median algorithm, such as its inhibition on gaussian and uniform noise is not strong, the denoising ability affected by noise density is big, destroy the image sharp edges and other details. Later, a lot of improved median algorithm was raised, such as recursive median denoising algorithm, switching median denoising algorithm, multistage median denoising algorithm, median denoising algorithm variable window length, etc.

2) the transform domain image denoising algorithm. The main ideas of this kind of algorithm is based on some sort of transformation to get the image on the transform domain, then the image processing on the transform domain coefficient, the final image in spatial domain is obtained by inverse transformation to form, to achieve the purpose of denoising. This said, often can appear to be more intuitive image structure characteristics, is more advantageous to noise separation. Based on Fourier transform, wavelet transform, wavelet packet transform and discrete cosine transform image denoising algorithm is one of the important members of the transform domain image denoising algorithm. Wavelet change can be a very good portrait non-stationary characteristics of one dimensional signal, has the advantages of the multiresolution, after the signal wavelet decomposition coefficient is sparse distribution, this is helpful

to extract the signal feature, remove the signal to noise. At the same time, the different signal can choose different wavelet base for its treatment in order to obtain good effect. However, the one dimensional wavelet generated by tensor product of two dimensional wavelet base does not meet the relationship of the scale of the anisotropy, sparsely said can't contain line or face strange two-dimensional images. Therefore, Donoho et al proposed the multi-scale geometric analysis (Multiscale GeometircAnalysis, mga.to) method, mainly including Contourlet, Curvelet, Wedgelet, Bandlet transform. Relative Yu Xiaobo transformation, can mga.to to more sparse representation of image, and get better denoising effect. But a multiscale geometric analysis method can only some of the characteristics of image sparse representation, and usually contains various characteristics in natural images, therefore, only use effectively for the all the characteristics of a certain kind of transformation is hard to say. Since the concept of sparse representation based on a complete atom libraries mentioned, this area is developing rapidly, in a period of time in the past, researchers have proposed many signal sparse representation for approximation method, and used for image denoising, image denoising algorithm has achieved a lot better than ever.

3) other denoising algorithm. In addition to the above image denoising algorithms, there are many scholars from the Angle of intelligent algorithm, mathematical morphology, information theory, to explore the image denoising algorithm, the image denoising algorithm based on mathematical morphology, image denoising algorithm based on fuzzy theory, the image denoising algorithm based on information entropy and so on.

3. Based on SVD Decomposition Method of Noise

A complete atom library is very important in image sparse representation, it decided to a great extent the image sparse representation can be effectively. K - SVD algorithm combined over complete dictionary to build and optimize, used to decompose the image of the sample to train the atomic library, can effectively build reflect the characteristics of the images of various atoms library. In image denoising based on sparse representation, the structure of the useful information of the image has certain characteristics, and the structure characteristics in conformity with the atomic structure, and the noise is do not have this feature, thus by sparse representation can separate the useful information and noise effectively, so as to achieve the goal of denoising. For low SNR images, the traditional way is to hard threshold as a sparse representation of termination conditions. When the image SNR is very low, the variance of noise in the image variance is larger than the useful signal, using hard threshold as sparse decomposition iterative termination conditions will produce: decomposition of residual error threshold is not easy to setup, introduced a lot of noise in the process of reconstruction derived ingredients, seriously affected the accuracy of image reconstruction problem. To be better denoising image visual effect, according to the ideas of the literature [7], this paper puts forward a kind of based on K - SVD and residual error than the sparse representation of image denoising algorithms. The algorithm residual error than the threshold value as termination conditions of denoising algorithm.

This algorithm can be described as a specific steps:

1) using a complete DCT dictionary as the initialization of the dictionary D K - SVD algorithm, the dictionary is shown in figure 1. With the OMP algorithm for noise image sparse decomposition in initial D dictionary. In this process, T_0 will be the OMP

algorithm iterative termination conditions, it indicates that the maximum number of iterations, reference [8] in this paper, the step to complete the goal is to:

$$\min\left\{\left\|y_i - Dx_i\right\|_2^2\right\} \quad s.t. \quad \forall i, \left\|x_i\right\|_0 \le T_0, i = 1, 2, \cdots, N \tag{1}$$

By solving (1) to obtain the sparse coefficient matrix X K - SVD algorithm.

2) In the image with noise from image matrix vertex by certain step length to the finish order extraction 8 x 8 pixel blocks the training sample set. Over access to the training sample set and after step 1) sparse coefficient matrix X, with K - SVD algorithm to train initial dictionary D generated is shown in figure 2 after the optimization of the dictionary, the detailed process for the individual atoms in the dictionary for g (t) ∈ L to translation, scaling, rotating, modulation can generate a complete atom library. The first step is to use fixed dictionary are used to expand the image; the second step, according to the expansion coefficient, update the atomic library. Is shown in figure 2 is a K - SVD algorithm, DCT dictionary be trained to become a new dictionary, the new dictionary each atom is a linear combination of the original DCT dictionary of atoms. Look from the composition of the dictionary, both differences is bigger, that K - SVD algorithm effectively improves the dictionary structure.

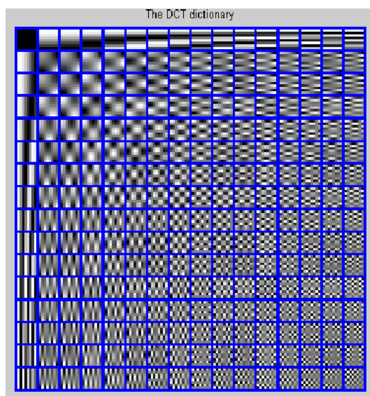


Figure 1. DCT Dictionary

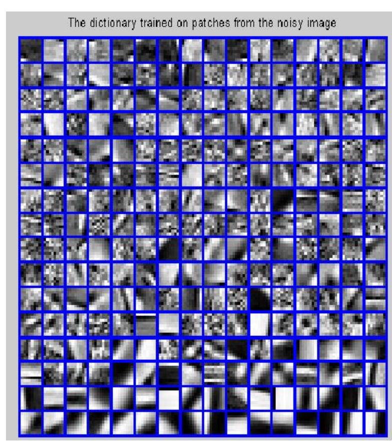


Figure 2. Using SVD Dictionary after Training

3) On the image sparse decomposition denoising with noise. Set a column vector y_i containing noise image transformation, for the useful information $\hat{y}_i$, as Δw the

frequency bandwidth, $\hat{e}_{\Delta w}$ as the noise inside the band, $e_{\Delta w}$ as the noise outside the band. $\hat{e}_{\Delta w}$ can be considered to be with all the atoms in the dictionary of orthogonal, expression is the first step k sparse decomposition can be expressed as follows:

$$\left\|R^k y_i\right\|_2^2 = \left\|R^k\left(\hat{y}_i + \hat{e}_{\Delta w}\right)\right\|_2^2 + \left\|e_{\Delta w}\right\|_2^2 \quad (2)$$

Due to a new step of k + 1 iteration atoms, under low signal-to-noise ratio will be affected by a certain amount of noise, can cause $\left\|R^k y_i\right\|_2^2$ and $\left\|R^{k+1} y_i\right\|_2^2$ the mean different, this will affect the convergence. In order to enhance the robustness of the terminating condition, selects the residual ratio as the terminating condition here, it is defined as:

$$Q\left(R^k f\right) = \frac{\left\|R^k y_i - \tau R^{k+1} y_i\right\|}{\left\|\tau R^k y_i\right\|_2^2} \quad (3)$$

Where

$$\tau = \sqrt{\frac{E\left(R^{k+1} y_i\right)^2}{E\left(R^k y_i\right)^2}} \quad (4)$$

E to get expected value, which is used to eliminate noise in the iterative process of the influence of the residual signal. By type (3), (4), after denoising image sparse representation of the coefficient matrix.

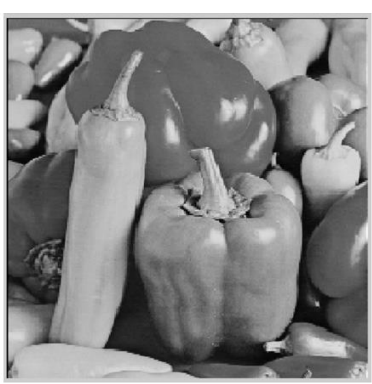
4) Finally, obtained by type (5) after denoising image

$$Y' = \tilde{D}X' \quad (5)$$

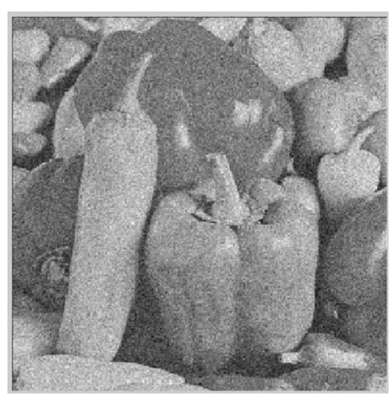
4. Simulation Results and Analysis

For the validation of this algorithm in low SNR image denoising effectiveness and superiority of this respectively by using three kinds of denoising algorithm with gaussian white noise image denoising for comparison. These algorithms including Symlets hard threshold wavelet based image denoising algorithms, image denoising algorithm based on Contourlet transform, and based on DCT complete atomic library and OMP sparse representation of image denoising algorithms.

To test the effectiveness of the algorithm, here to carry different noise intensity image denoising for comparison. Besides the denoised image is up from visual effect evaluation, also use common PSNR (Peak Signal to Noise thewire) as the objective indexes, to measure different algorithm of image denoising effect. Figure 3 shows the above four kinds of denoising image denoising method.



a) original image



b) Noise image with $\sigma = 25$

c）Symlets wavelet denoising

d）Contourlet transform denoising effect

e）The traditional DCT sparse denoising effect

f）The proposed method

Figure 3. Different Algorithms of the Image with Noise Denoising Effect of Peppers

At present, both at home and abroad for application of sparse decomposition of image denoising has had certain achievements, but for low SNR image denoising research is not deep enough. Low signal-to-noise ratio means that the noise intensity bigger, wider distribution of spectrum, therefore, with the traditional method is not easy to achieve good results. In this paper, the low SNR cases, image denoising is proposed, based on the idea of sparse decomposition, combined with DCT complete atomic library,

K - SVD algorithm and OMP algorithm based on the residual error than the terminating condition is tried, the result shows that this algorithm has good low SNR image denoising effect and strong robustness. The algorithm need to make sure that there are three main parameters: the original complete atomic library D, frequency decomposition

And residual error than the threshold. If the D, the larger the redundancy of the atoms in the library, the greater the atomic coherent than the smaller. On the one hand, doing so can provide a more complete for K - SVD of atomic library, then after training by atomic libraries can more precisely describe the structure of the image information, on the other hand it will increase the amount of calculation of the algorithm. Should be considered to determine the image decomposition of sparse and noise of the image intensity, means that the greater the decomposition of the more sophisticated, on the one hand, such doing can get more effective information of the image, but on the other hand it will increase the amount of calculation, reduces the sparse decomposition results, and the noise could be mistaken for effective information extracted, affect the accuracy of image reconstruction. The determination of residual error than the threshold value has certain empirical, should fully consider algorithm calculation problems, on the premise of satisfying de-noising effect, residual error than the threshold value should not be set too low, otherwise it will waste a lot of computing resources.

5. Conclusion

Algorithm in this paper, with the increase of noise components, K - the average coefficient of SVD training process showed a trend of rapid decline, the algorithm is faster and faster. This is because, according to the understanding of the noise signal sparse decomposition, along with the increase in noise components (signal to noise ratio is more and more low), useful signal components in gradually reduce, namely structural components in gradually reduce, thus in the process of sparse decomposition, atomic number less and less, to match the signal signal said more and more sparse, then calculation also fell sharply. In view of this, optimize the structure of the dictionary, use of K - SVD algorithm processing low SNR image shows great potential.

References

[1] M. N. Do and M. Vetterli, "Framing pyramids [J]", IEEE Transaction on Signal Processing, vol. 9, no. 51, (**2003**), pp. 3736-3745.
[2] E. Candes, L. Demanet and D. Donoho, *et al.* "Fast discrete curvelet transforms [D]", Stanford, California, USA: Department of Statistics, Stanford University, (**2005**).
[3] D. L. Donoho, "Wedgelets: nearly minimax estimation of edges [J]", Annals of Statistics, vol. 7, no. 3, (**1999**), pp. 859-897.
[4] G. Peyre and S. Mallat, "Discrete bandelets with geometric orthogonal filters[C]", Proceedings of ICIP. Los Alamitos, USA: IEEE Computer Society, (**2005**), pp. 65-68.
[5] S. Mallat and Z. Zhang, "Matching pursuits with time-frequency dictionaries [J]", IEEE Transaction on Image Processing, (**1993**), vol. 41, no. 12, pp. 3397-3415.
[6] S. Mallat and Z. Zhang, "Matching pursuits with time-frequency dictionaries [J]", IEEE Transaction on Image Processing, (**1993**), vol. 41, no. 12, pp. 3397-3415.
[7] A. Gilbert, S. Muthukrishnan and M. Strauss, *et al.* "Improved sparse approximation over quasi-coherent dictionaries[C]", ICIP, Barcelona, Spain, vol. 1, (**2003**) September, pp. 37-40.
[8] E. Gandes and D. Donoho, "New tight frames of curvelets and optimal representations of objects with C2 singulatities [J]", Comm. on Pure and Appl. Math, vol. 57, (**2004**), pp. 219-266.

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