International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol. 8, No. 1 (2015), pp. 203-212
http://dx.doi.org/10.14257/ijsip.2015.8.1.18

Compressed Sensing Method Application in Image Denoising

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Abstract

In order to improve the work of a single path network reliability failure case, this chapter put forward a set of a single backup path algorithm based on the path. In this algorithm, using two disjoint paths as work path to transmit data, and USES the path does not intersect with the job of a set the path as the backup path. Then, this algorithm, is proposed based on a single - a single backup path algorithm of shortest path set to ensure data under the case of the second work path of effective transmission. Theoretical derivation and numerical simulation results show that in a single work path failure cases, and the calculation of DMP - compared to BP algorithm, this scheme can greatly improve network reliability, and save the network resources.

Keywords: *Sparse Representation; Over-complete Dictionary; Image Decomposition; Generalized Principal Component Analysis,Compressive Sensing*

1. Introduction

The characteristics of image information with visual image, is one of the most commonly used information carrier of people's daily life. With the development of science and technology, all kinds of digital products and digital instrument is more and more popular, a cross research hotspot of digital image processing [1-3] as computer science and mathematics, caused the wide attention of scholars. Digital image processing technology, as the name suggests is the use of computer processing of the image information, in order to meet the demand of various. With the continuous progress of science and technology, the scope of human activity is expanding, created the application fields of digital image processing is increasing. At present, the digital image processing has been in the military, aerospace, industrial and agricultural production, medical and many other fields of application plays a very important role. Because of the influence of internal and external environment of equipment limitations, image in various stages of generation, transmission and acquisition are inevitably affected by external factors, which we called interference noise [3].

According to people's intuitive feelings, noise can be understood as "factors that prevent the human sense organs to receive and understand the source of information". The noise in the image will degrade image quality, influence the visual effect of image, or even cover up some specific features of the image, this will have a direct effect on the subsequent image processing have great influence. Therefore, denoising as an important technology of image pretreatment image, can effectively increase the signal-to-noise ratio, improve the quality of the image, which is more helpful for the subsequent image processing. Because of the importance of image denoising, image denoising method has been one of the focuses in the field of image processing, the researchers have proposed many kinds of denoising schemes. But with the demands of continuous development and application of continuous extension, denoising algorithm still has a long way to go to seek the effective image. Sparse representation is proposed and its successful applications in many fields theory, has become a new idea and direction of research in the field of image denoising.

ISSN: 2005-4254 IJSIP

Research on image denoising is carried out around this effect, make them be well balanced, to ensure the maximum degree of original image after denoising approach without noise. Image denoising technology has had certain development, and commonly used in image denoising method has many kinds, but with the new problems emerged, the existing methods can not satisfy higher requirements for image processing. Therefore, the image denoising technology still has a very important research significance.From the point of view of technology of digital image processing, image denoising processing belongs to the category of image restoration technology; from the analysis of the entire image process, image denoising belongs to the pre-processing stage of image processing. It is important to study the image denoising method, mainly in the:

(1) To get rid of the noise with noise image processing, can effectively guarantee the correct identification of image information. When the noise in the image contains more serious, image blur, the image has lost the practical significance of stored information.

(2) Denoising image not only can improve the recognition accuracy of visual information, but also provides a basis for further image processing. If directly on the image feature extraction and fusion processing signals with noise, it is hard to obtain satisfactory processing results.

(3) At present, people have proposed many image denoising methods, but these methods are not perfect, further improve the existing image denoising methods, or research new image denoising method is still important. Traditional data or image acquisition method based on Nyquist sampling theorem, it can ensure the information by sampling to completely restore the original signal, otherwise the signal spectrum aliasing, unable to accurately recover the original signal. This theory, the signal (image) affect all aspects of the collection, storage, processing, transmission and other major. However, due to the demand for the amount of information is increasing, which makes the sampling theorem restricts the signal (image) the development of all aspects of the collection, storage, processing, transmission, people need to put some more effective sampling methods. It can be seen that: on the one hand, it need the sampling rate and the processing speed with the information bandwidth increases also increase, will also improve the equipment cost and the difficulty of hardware implementation; on the other hand, for the collection of large amounts of data using traditional sampling, storage, compression, transmission process, only a small part of the massive effective transmission in the sample data, instead of the most sampled data. This caused a waste of resources and low efficiency, in this paper the urgent need to introduce new technology concepts, to promote the development of the field of information processing.

In recent years, Candès, Tao and Donoho proposed the concept of compressed sensing, points out that the complete compression for data at the same time sampling of sparse signal, combines the traditional data acquisition and compression, then constructs a specific algorithm, studies show that the theory has a good application prospect. Compressed sensing technology can be traced back to the Kashin functional analysis and approximation theory, the theory that: under certain conditions, the sparse signal with much lower than the Nyquist sampling standard way, still can reconstruct the well original signal. The theory breakthrough Nyquist sampling law restrictions on sampling, so the proposed by many researchers attention, hope that through research and application of this technology, the field of information processing to obtain a better development. According to the theory of compressed sensing the compressible image, use a small amount of measurement data and the appropriate reconstruction algorithm, the original image information is accurate. This greatly reduces the data quantity of image sampling, image can recover the high accuracy, the compressed sensing technology has become a powerful tool in image processing field. At present, the compressed sensing theory mainly studies the one-dimensional signal, for relatively less research of image, video and other multidimensional signal. This paper mainly to the application of compressed sensing theory to image denoising research, collect the noisy reality image by sparse matrix, design the appropriate reconstruction algorithm, reconstruct the noise reduction effect is obvious, the SNR of image greatly increased.

2. Related Research

The existing traditional image denoising methods can be broadly divided into two categories: one is in spatial domain, the main use of various smoothing template and image deconvolution processing, in order to achieve the purpose of noise suppression or elimination; Another is the transform domain method, we transform the image, and then choose the appropriate frequency band pass filter, the inverse transformation to obtain the image denoising. Spatial domain denoising method often uses the mean filter, median filtering, Wiener filtering and image average method. The median filtering method is a method of nonlinear signal processing, its basic thought is in digital image, a point value by the median neighborhood of the point in the template instead of several point. Is simply to use a window, the mobile at various points along the image pixel values, window center points of using the median of all pixels in the window for replacement. The shape and size of the window will have obvious influence on the filtering effect. Because standard median filter is a kind of non parameter estimation, so there will be a certain blindness. As a kind of adaptive denoising method, Wiener filter according to the local variance of the image value, output to adjust the filter, to restore the image of the original image is the ultimate goal of the minimum mean square error. But because of the interference signal, input process depends on the external environment, and these statistics are unknown and changing factors. Aiming at the defects of the algorithm, the researchers still need further research and exploration. The basic idea of transform domain is: first, some noise on the image transformation, transformation to transform domain; then, according to the transform coefficients in the transform domain processing; finally, the inverse transform of the image to the original space, achieve the purpose of removing noise. The low-pass filter is: in the spatial domain, two-dimensional convolution by using a low pass convolution template, so as to achieve the purpose of image denoising. Methods of image space common conversion transform domain are: Fourier transform, Walsh Hadamard transform, discrete cosine transform, wavelet transform and the recent development of multiscale geometric analysis method. Because many signal can not be effectively analysis in spatial domain, and after the transformation coefficients distribution becomes obvious, in the frequency domain signals can be effectively analyzed. This can be used to all kinds of image processing tasks, and also makes this method becomes a hot image denoising research.

In recent years, wavelet analysis technique was also applied to the field of image processing, and the application effect is good. At present, the wavelet method is widely used in image denoising, main methods: wavelet transform modulus maximum denoising, wavelet coefficient correlation denoising and threshold shrinkage denoising. The basic principle of wavelet denoising is: the first step is to decompose the noisy image using wavelet; the second step to extract the wavelet coefficients of image wavelet coefficients and noise removal; third step transform reconstruction image noise removal.

More used in the denoising process. Although wavelet denoising method has become a main research direction of image denoising, but it is also inadequate, with one kind of noise is very similar to that of image, then wavelet analysis method is very difficult to distinguish between the image information and noise information, of course this case removal effect is not very satisfactory. Therefore, to further expand the research field of denoising method. At the same time, by using the method of partial differential equation for image processing, is a newly emerging area developed in the recent years. Stronger local adaptability and flexibility makes PDE method has become an effective image processing technology. This method in image denoising can protect the edge of the image better. Through research, we can found that the following two questions are the key and difficult problems in the field of signal processing: one is due to the Nyquist sampling high sampling frequency, resulting in a large number of sample data; two is the sampling and compression mode, make a large number of datas utilization rate is not high, resulting in the waste of sensing element, time and memory space. To some extent these problems restrict the development of signal and information processing. Aiming at these problems, in recent years, the birth of a new theory of compressed sensing. The methods used to obtain the signals at the same time, the data below the Nyquist frequency sampling, compression, need to use reconstruction algorithm appropriate restore enough data points.

The utility model has the advantages of reducing sampling data, the storage space is saved enough amount of information under the premise, and combined the traditional data acquisition and compression, but there is no complex data encoding, it is very suitable for the small equipment occasions, so the compressed sensing in the field of signal processing has become a new research direction. Compressed sensing theory as the signal processing in the field of a new research direction, since 2006 the formal papers, soon it is paied more attention by the research in related fields at home and abroad. At present, the area is mainly focused on the research work of theory, research foundation for: Terence Tao, Emmanuel Candès, David Donoho who have the theory framework of compressed sensing, a sensing matrix Φ is given to satisfy the sufficient condition, which is consistent with the Uniform Uncertainty Principle(UUP); between the sensor matrix's row number M and the signal sparsity K must meet $M \geq K \log(N)$, and published a series of important papers. In addition, there are many specific problems about solving the sensing matrix and reconstruction algorithm of two major aspects of the research results. Study on the sensing matrix, matrix of the current selection is random, such as Gauss matrix or Bernoulli matrix. How to construct the sensing matrix is an open problem in this field at present.

DeVore using polynomial method to obtain satisfy UUP feature matrix, but it only for sparse K smaller case, the problem is far from solved. When it comes to reconstruction of the signal, there are many documents will match tracking and optimization method is introduced to solve the problem, but the discussion on the algorithm convergence and stability problems. Hardware implementation, Rice university professor Baraniuk *etc.*, developed single pixel camera and A/I converter, attract the attention of the domestic and international numerous media. Reports of hardware subsequently, such as, MIT professor Wald *etc.*, developed MRI RF pulse instrument, MIT professor Freeman developed a coded aperture camera, Illinois State University Milenkovic *etc.*, developed a DNA microarray sensors, however, in addition to single pixel camera Rice University (the expensive hardware cost, low efficient reconstruction algorithm), other hardware are lack of strict and effective theory of compressed sensing matrix discriminant analysis. After nearly two years of development, the compressed sensing has achieved many important results in the theory, many researchers have begun to put into practical applications, such as information, medical science *etc*.

3. The System Model and the Proposed Scheme

Compressed sensing theory is a theory of information retrieval that is based on sparse representation theory. Now, the compressed sensing theory achieves good effect in the study of signal denoising reconstruction. Compressed sensing can use a small amount of measurement data to restore the original signal, and almost no signal loss. According to the compression theory, first, transform are used to get the sparse representation which includes noise image, then using the algorithm to reconstruct the original image and achieve the purpose of removing noise.

Compared with the traditional denoising method, the image denoising based on compression perception [6] has more superiority, it collects less amount of data and the recovery effect is more accurate. However, a classic compression perception does not use a priori knowledge of the image information (such as image features, texture, etc.), therefore it has not the adaptability and can't get satisfied denoising effect at some time. The adaptability of compressed sensing is mainly decided by the sparse representation, in order to achieve this kind of adaptability, we must use an adaptive sparse representation method. As is known to all, the principal component analysis algorithm is a kind of commonly used methods of adaptive data analysis. Therefore, how to apply principal component analysis algorithm to compressed sensing to improve the adaptability of compressed sensing and apply the adaptive compressed sensing to image denoising becomes the focus of research in this chapter. The principal component analysis algorithm is mainly for multivariate analysis of one dimensional signal, but it's analysis ability is not strong for multidimensional, multiscale signal. In addition, the principal component analysis consider all the sampled signal in the same model and it often need forced map different high dimensional space vector to the same low dimensional space. This single linear no classification algorithm will cause an incompleteness of wiping off relevance and limitations on the analysis of the sampling signal of high dimension. In order to solve this problem, Yi Ma and others proposed a principal component analysis algorithm that is more universality in 2005. This algorithm dynamicall projecte the high-dimensional sampling signal to different low dimensional space, each sample point in space has higher correlation, better able to achieve the demand of the dimension reduction, also can satisfy the need for high dimension signal analysis. On the basis of predecessors' research, therefore, the generalized principal component analysis (GPCA) will be introduced to the CS framework to get a denoising method based on adaptive compression perception. Compared with traditional denoising method and classical compression perception method, the adaptive denoising method of compression perception can remove the noise at the same time to effectively retain more image details, has a good denoising performance.

Generalized principal component analysis is a kind of data clustering and dimensionality reduction algorithm, it cluster according to the sample of subspace, each type of data can be obtained indicate in its low-dimensional space. A data set $X \in S$, and K is the space S, set to, respectively, $S^{(1)}$, $S^{(2)}$, . . . , $S^{(K)}$, X can be represented as $X = \left(X^1, X^2, \cdots, X^K\right)$, among them $X^i \in S^{(i)}$, at the same time assume that $X^i \in R^N$,then for the data set any element X^i,

$$b_i^T X^i = 0 \tag{1}$$

Among them, $1 \le i \le K, b_i = (b_{i1}, ..., b_{iN})$ is X^i's normal vector of subspace $S^{(i)}$.

For $S^{(1)}, S^{(2)}, ..., S^{(K)}$, the subspace to meet

$$\bigcup_{i=1} S^{(i)} = S \tag{2}$$

Multiplication operation for type (1) can be arbitrary X^i

$$\prod_{j=1}^{K} (b_j^T X^i) = 0 \tag{3}$$

Namely

$$\prod_{j=1}^{K} (b_{j1} x_{i1} + b_{j2} x_{i2} + ... + b_{jN} x_{iN}) = 0 \tag{4}$$

Because the polynomial one and only one solution, thus subspace number K content

$$K = \min\{i : rank(L_i) = M_i = 1\} \tag{5}$$

When the K value was determined, the problem can be transformed into a polynomial decomposition, the decomposed each child polynomial is a child space model. GPCA to data in high dimension space projection separately to low dimensional space, Figure 1 to Barbara image.

Figure 1. Subspace Application Example

Generalized principal component analysis (GPCA) can effectively protect the image of the original texture information. And compression perception for containing noise signal reconstruction algorithm also has the small coefficient as zero and the characteristics of filtering noise. Based on these two points, we can take advantage of the GPCA and compression perception for image noise removal work.

The image denoising algorithm consists of four processes: GPCA dimension reduction, compression perception sampling, compression perception reconstruction and GPCA recovery. For noise image I, using GPCA dimension reduction in the first place, get the image feature information of all the parts dimension reduction, remember to

$$D = GPCA(I) \tag{6}$$

Then select the appropriate measurement matrix to compress image information D, get measured value of Sample, remember to

$$Sample = \varnothing D \tag{7}$$

Then based on the measured value is compressed perception reconstruction, using compression perception reconstruction has the characteristics of small coefficient as zero noise and filtering noise in images, to remember

$$\tilde{D} = \arg\min_D \| D \|_1 \ s.t. \| Sample - \varnothing D \|_2 \le T \tag{8}$$

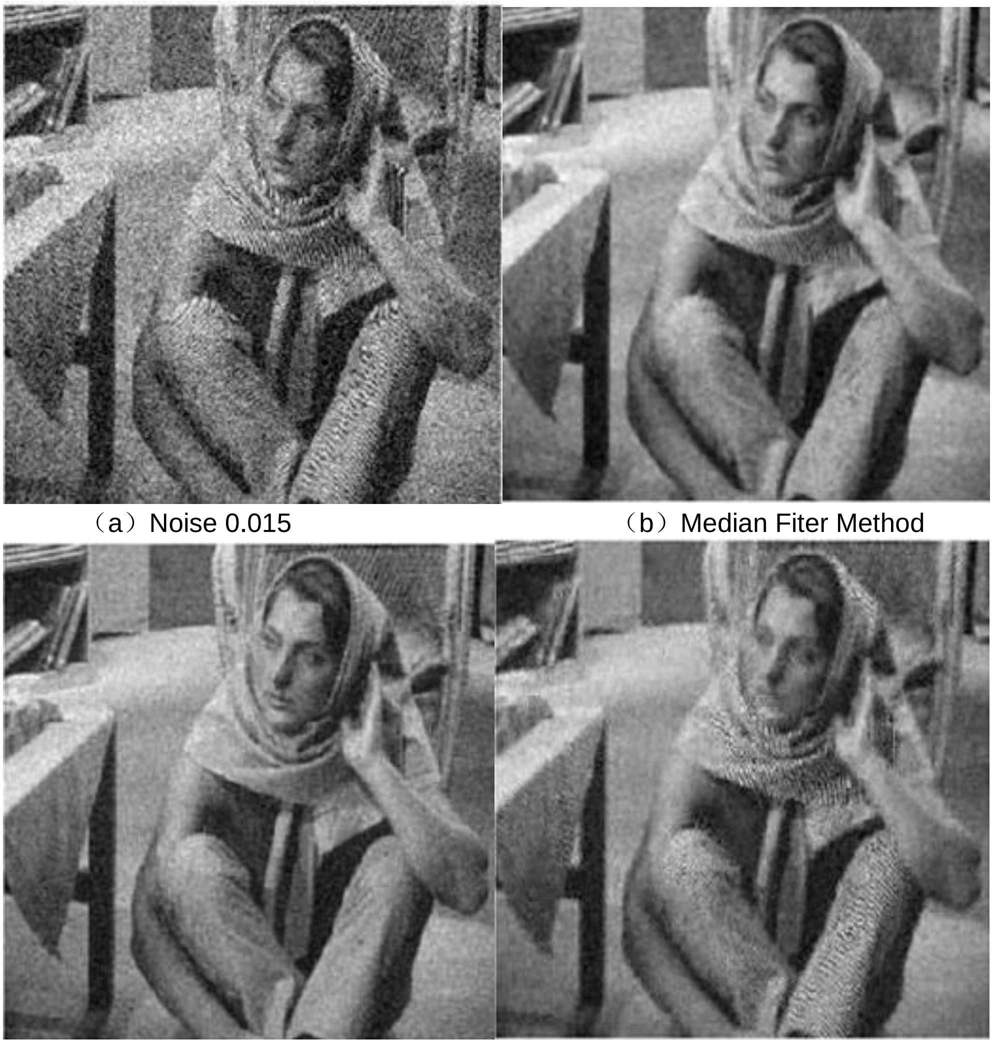
Where the parameters T and standard deviation σ noise-related. Finally to the reconstruction of image information make GPCA inverse transformation, get the image $\tilde{I}$ of removed noise.

$$\tilde{I} = GPCA^{-1}(\tilde{D}) \tag{9}$$

4. The Results of Simulation

Experiments to contain rich texture information of Barbara image as an example, the proposed denoising method based on adaptive compression perception experiment. The control group including median filtering method, DCT denoising method, wavelet denoising method and classical method of compression perception in the experiment. The sampling matrix use parameters of 10 random sparse matrix, refactoring decoding using SSMP algorithm. Type of additive white gaussian noise, noise intensity are 0.01 and 0.005 is divided into two, the experiment results are shown in Figure 2, Figure 3, respectively. We can see from the Figure 3, compared with low noise image, median filtering method, DCT noise removal method, wavelet denoising method of noise removal effect and its texture damage effect basic on the same level. However, based on the compression of GPCA perception model can under the condition of the premise of protecting the texture to remove noise very well. In the same way, the classic compression perception method due to its adaptability limits the denoising performance. For low noise image, therefore, this paper puts forward the method of adaptive compressed sensing based on GPCA has obvious advantages.

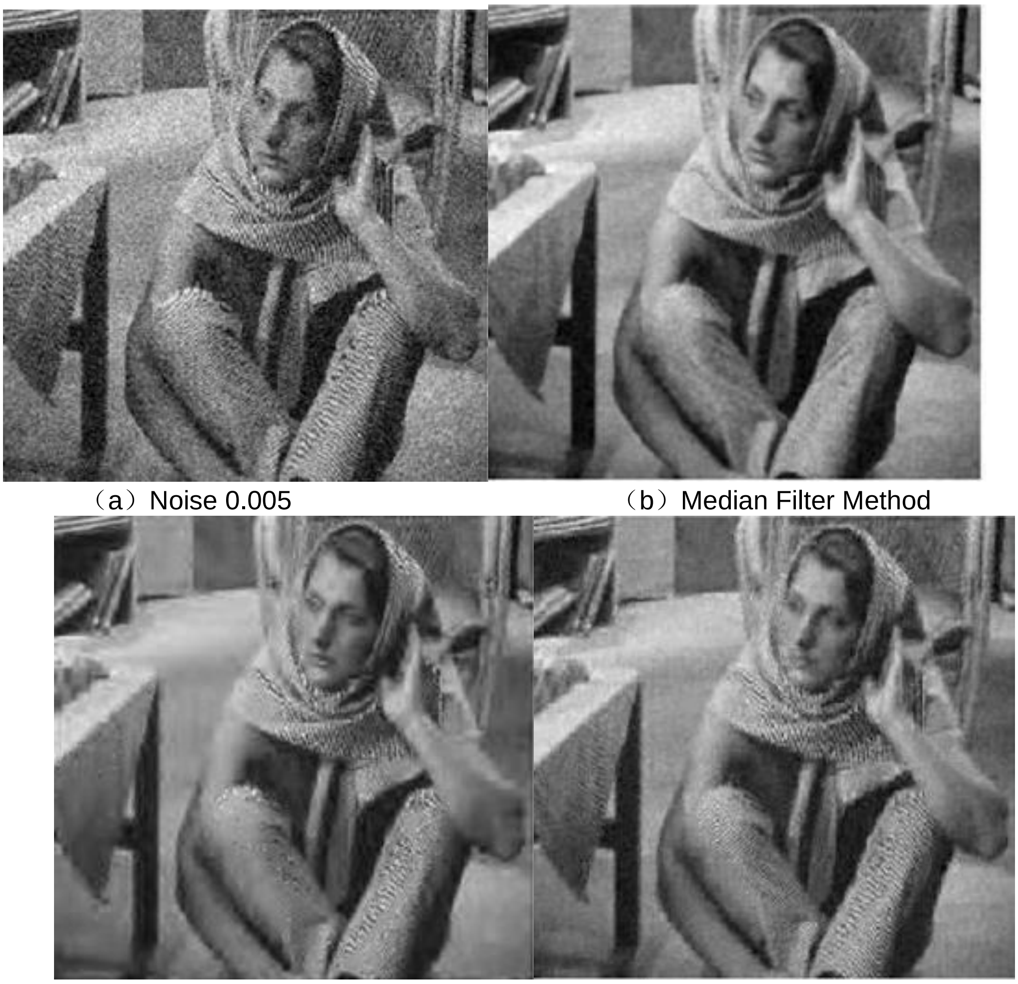
No matter for high noise or low noise image, based on the generalized principal component analysis method of adaptive compression perception is better than the traditional denoising method, and it has a very big improvement on the basis of classical CS model. Especially for low noise with complex texture images, the traditional methods have do not possessed noise removal ability, however the adaptive compression perception model still has good effect of noise removing.



（a）Noise 0.015 （b）Median Fiter Method

（c）Wavelete Method （d）The Proposed

Figure 2. Four Schemes Compared with High Noise



（a）Noise 0.005 （b）Median Filter Method

（c）Wavelete Method （d）The Proposed

Figure 3. Four Schemes Compared with Low Noise

5. The Conclusion

This paper proposes a new image denoising method based on adaptive compression perception. On the basis of classical compression perception, we introduce adaptive high-dimensional data analysis method GPCA and increase the adaptability of the compression perception model. At the same time, we make the proposed denoising method an experiment contrast with the traditional denoising method (such as median filtering method, DCT denoising method, wavelet denoising method, *etc.*,) as well as the classic of compressed sensing method .We can see that based on adaptive compression perception of generalized principal component analysis method has good performance in removing image noise, the method can remove noise while protecting the texture information of the original image.

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