An Improved Algorithm for Image Switch Median Filtering based on Grey Entropy and Noise Discrimination

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***Abstract* — The key of the switch median filter is to find a way to identify the noise point and the normal point effectively. In this paper, we first calculate the grey entropy of the twelve groups of pixels in the neighborhood window, and then use the median of twelve grey entropy values as the measure of whether the center pixel is noise or not. By setting the threshold, Median filtering can be applied to the center pixel that is judged as the noise point in the current neighborhood window, and the pixel judged as the non-noise point remains unchanged. The simulation results show that the algorithm proposed in this paper has good effect both on the classical experimental image and the real road surface image.**

Keywords - switch median filter, grey entropy, noise discrimination.

I. INTRODUCTION

Median filtering is a very classic nonlinear filter proposed by Turky in 1971. Compared with the classical mean filter, median filter is a better method to remove salt and pepper noise. Median filter principle is very simple. With the window traversing on the image, it contains the image pixels in accordance with the gray value of the ascending order, and take the median pixel instead of the center pixel in the window, then the median filter is completed. Since median filtering is the process of removing noise for each pixel in the image, the result is that even if the point is not contaminated, the same operation is performed, so that the noise is removed and a part of the normal pixels are also blurred. In order to change this situation, the concept of switch median filter was proposed. The idea is to first effectively identify each pixel of the image, then median filtering is performed for pixels that are judged to be noise points, and remain unchanged for pixels judged as normal. For switched median filters, the key is to find an efficient way to identify which pixels are noise and which pixels are normal as accurately as possible.

Thus, many scholars have improved the switch median filter from different aspects. By using the local mean value, some scholars proposed adaptive median filters to filter salt and pepper noise [1], and some scholars combined mean and median filters to remove high-density impulse noise and achieved good results [2], and some people using neural network [3], edge recognition [4], morphology [5], fuzzy mathematics [6,7,8], local threshold computing [9] and other technologies and methods, achieved good results in the process of noise recognition. But there is still some problems needing further improvement. In recent years, the grey system theory [10] has been applied to the image denoising process, and has achieved good results. Grey entropy [11] is an important part of grey system theory.

When the image pixel is contaminated, since the real gray value information of the current pixel is the closest to the eight neighboring pixels around the centre pixel of the window. Therefore, the decision whether the current pixel is noise or not has the attribute of “poor information, less data”, which is just the problem being good at solving by grey system theory. So, it is feasible to use grey entropy theory to deal with the image noise decision part.[12-14]

The full text is divided into five parts: The first part is the background and significance of the introduction, the second part is on the brief introduction of grey entropy theory, the third part will elaborate switch median filter algorithm based on noise decision by using grey entropy, and apply it to the experimental image and real road surface images to carry out inspection and analysis. The last part is the summary and prospect of this algorithm.

II. BRIEF INTRODUCTION TO GREY ENTROPY

Entropy originated in the thermodynamic concept. So far, it has about 140 years of history. Shannon introduced the concept of entropy into information theory field, and it is a measure of uncertainty of information system. The smaller the entropy is, the greater the information is, the smaller the uncertainty of the system is, and contrarily, the greater the entropy is, the smaller the information is, the greater the certainty of the system is. Grey entropy is an important concept which combines classical entropy theory with grey system theory.

Definition 1 [11] Let $X = \{x_i \mid i=1,2,\cdots,n\}$ be a finite discrete sequence, $\forall i, x_i \geq 0$, and $\sum_{i=1}^{n} x_i = 1$, and we call

$$H(X)=\begin{cases}-\sum_{i=1}^{n}x_i\ln x_i & x_i\neq 0\\ 0 & x_i=0\end{cases} \tag{1}$$

the grey entropy of the sequence.

As can be seen from the definition of grey entropy, grey entropy originates from finite information space, and Shannon entropy originates from infinite information space.

Theorem 1 [11]: Grey Entropy Augmentation Theorem: Let $X=\{x_i \mid i=1,2,\cdots,n\}$ be a finite discrete sequence, $\forall i, x_i \geq 0$, $\sum_{i=1}^{n}x_i=1$,and that any change in the components of X , even if the components of X tend to change into the constant column, the grey entropy increases.

From the grey entropy increasing theorem, it can be found that the larger the grey entropy of the sequence is, the more balanced the components of the sequence is; the smaller the grey entropy of the sequence is, the higher the degree of the components of the sequence is. We can use grey entropy to measure the degree of equalization of sequence.

III. SWITCH MEDIAN FILTERING ALGORITHM OF IMAGE BASED ON GREY ENTROPY

A. *Idea of Algorithm*

In a noise-recoverable image, the number of noise points will generally be less than the number of real pixels, otherwise the quality of image restoration will be very poor, even without a certain visual effect and lose the value of being processed . Noise and image edge both will lead to the image local area not smooth, and the difference is that the noise points are generally isolated, generally do not have any continuity in any direction, and the image edge is expressed in a certain direction with a certain continuity , which is the biggest difference between image noise and the edge.

If the current point is a noise point for the center point of the image neighborhood window, the fluctuation of gray scale value of any group of pixels passing through the center point will be large, and the grey entropy value of each group will be smaller , then the median grey entropy of the 12 directions (as shown in the following formula) must be relatively small; Conversely, if the current point is a normal point, at least in a certain direction the pixels will show a certain continuity, and the grey entropy will be relatively large, then the median of grey entropy of the 12 direction of pixels will be relatively large.

B. *Algorithm steps*

The procedure of the algorithm is divided into two stages.

The first stage is the noise detection phase:

In step 1, assuming that the image has a total of M rows and N columns of pixels, let the gray value of the current pixel in the ith row and jth column be $g(i,j)$ （$i=2,\cdots,M-1, j=2,\cdots N-1$) . The whole image is mapped to the space [0,1], that is

$$f(i,j)=g(i,j)/255, \tag{2}$$

In step 2, a median value of 9 pixels in the window is selected as a reference sequence in a window region of 3×3 with the current point as the center point, and the gray values of the pixel groups in the 12 main directions are selected as 12 groups of comparison sequences:

$$\begin{aligned}&X_0=\{x_0(1),x_0(2),x_0(3)\}=\{v,v,v\},\\ &v=median\{f(i-1,j-1),f(i-1,j),f(i-1,j+1),f(i,j-1),f(i,j),\\ &f(i,j+1),f(i+1,j-1),f(i+1,j),f(i+1,j+1)\}\end{aligned} \tag{3}$$

$$X_1=\{x_1(1),x_1(2),x_1(3)\}=\{f(i,j-1),f(i,j),f(i,j+1)\}, \tag{4}$$

$$X_2=\{x_2(1),x_2(2),x_2(3)\}=\{f(i-1,j),f(i,j),f(i+1,j)\}, \tag{5}$$

$$X_3=\{x_3(1),x_3(2),x_3(3)\}=\{f(i-1,j-1),f(i,j),f(i+1,j+1)\}, \tag{6}$$

$$X_4=\{x_4(1),x_4(2),x_4(3)\}=\{f(i-1,j+1),f(i,j),f(i+1,j-1)\}, \tag{7}$$

$$X_5=\{x_5(1),x_5(2),x_5(3)\}=\{f(i-1,j-1),f(i,j),f(i,j+1)\}, \tag{8}$$

$$X_6 = \{x_6(1), x_6(2), x_6(3)\} = \{f(i-1, j+1), f(i, j), f(i, j-1)\}, \tag{9}$$

$$X_7 = \{x_7(1), x_7(2), x_7(3)\} = \{f(i+1, j-1), f(i, j), f(i, j+1)\}, \tag{10}$$

$$X_8 = \{x_8(1), x_8(2), x_8(3)\} = \{f(i+1, j+1), f(i, j), f(i, j-1)\}, \tag{11}$$

$$X_9 = \{x_9(1), x_9(2), x_9(3)\} = \{f(i-1, j-1), f(i, j), f(i+1, j)\}, \tag{12}$$

$$X_{10} = \{x_{10}(1), x_{10}(2), x_{10}(3)\} = \{f(i-1, j+1), f(i, j), f(i+1, j)\}, \tag{13}$$

$$X_{11} = \{x_{11}(1), x_{11}(2), x_{11}(3)\} = \{f(i+1, j+1), f(i, j), f(i-1, j)\}, \tag{14}$$

$$X_{12} = \{x_{12}(1), x_{12}(2), x_{12}(3)\} = \{f(i+1, j-1), f(i, j), f(i-1, j)\}, \tag{15}$$

In step 3, the difference sequence is calculated, respectively.

$$\Delta_{0l} = \{\Delta_{0l}(1), \Delta_{0l}(2), \Delta_{0l}(3)\} = \{|x_l(1) - x_0(1)|, |x_l(2) - x_0(2)|, |x_l(3) - x_0(3)|\}, \ (l = 1,2,\cdots,12) \tag{16}$$

In step 4, we calculate the simplified B-type correlation coefficient [14] between the reference sequence and the comparison sequence, which is also called the image relational coefficient.

$$\xi_{0l}(k) = \frac{1}{1 + \Delta_{0l}(k)} \ (l = 1,2,\cdots,12, k = 1,2,3) \tag{17}$$

In step 5, normalize the image relational coefficient.

$$e_{0l}(k) = \frac{\xi_{0l}(k)}{\sum_{r=1}^{3} \xi_{0l}(r)} \ (l = 1,2,\cdots,12, k = 1,2,3) \tag{18}$$

In step 6, the grey relational entropy of the reference sequence and the comparison sequence is calculated respectively

$$H_l = -\sum_{r=1}^{3} e_{0l}(r) \ln e_{0l}(r) \ (l = 1,2,\cdots,12) \tag{19}$$

In step 7, the median of the 12 grey entropy values is calculated (ie, the 12 group of grey entropy values are arranged in ascending order, and the average of the entropy values in the middle 6 and 7 are taken)

$$\mathrm{P}(i, j) = median\{H_1, H_2, \cdots, H_{12},\} = 0.5(H_6' + H_7') \tag{20}$$

Where $H_1', H_2', \cdots, H_{11}', H_{12}'$ are the sequence of $H_1, H_2, \cdots, H_{11}, H_{12}$ arranged in ascending order.

In step 8, the median value is compared with a set threshold value to obtain a markup table indicating whether each pixel in the image is a noise point or not.

$$T(i, j) = \begin{cases} 1 & P(i, j) > \theta \\ 0 & P(i, j) \le \theta \end{cases} \tag{21}$$

Here we can find the minimum p_1 and maximum p_2 in the entire markup table, and then set the step size, and finally use the computer search to find the most appropriate threshold θ.

The second stage is the image filtering process:

In step 9, if the current point is a non-noise point, the image pixel remains unchanged;If the current point is a noise point, then in the neighborhood window of 3×3, if at least one pixel in the window is non-noise point, then we can carry out the median filtering for all the pixels in the window. If the pixels of the 3×3-neighborhood window are all noise points, median filtering is performed for all the pixels in a new larger window by expanding the neighborhood to a 5×5 window for the same current center pixel point .

$$\hat{g}(i,j)=\begin{cases} g(i,j), & T(i,j)=1 \\ S(i,j), & T(i,j)=0 \end{cases}$$

$$S(i,j)=\begin{cases} median\{g(i+a,j+b)\,|\,a=-1,0,1,b=-1,0,1\} & if \sum_{p=-1}^{1}\sum_{q=-1}^{1}T(i+p,\ j+q)>0 \\ median\{g(i+c,j+d)\,|\,c=-2,-1,0,1,2,d=-2,-1,0,1,2\} & if \sum_{p=-1}^{1}\sum_{q=-1}^{1}T(i+p,\ j+q)=0 \end{cases} \tag{22}$$

The frame structure and algorithm flow chart is as follows:

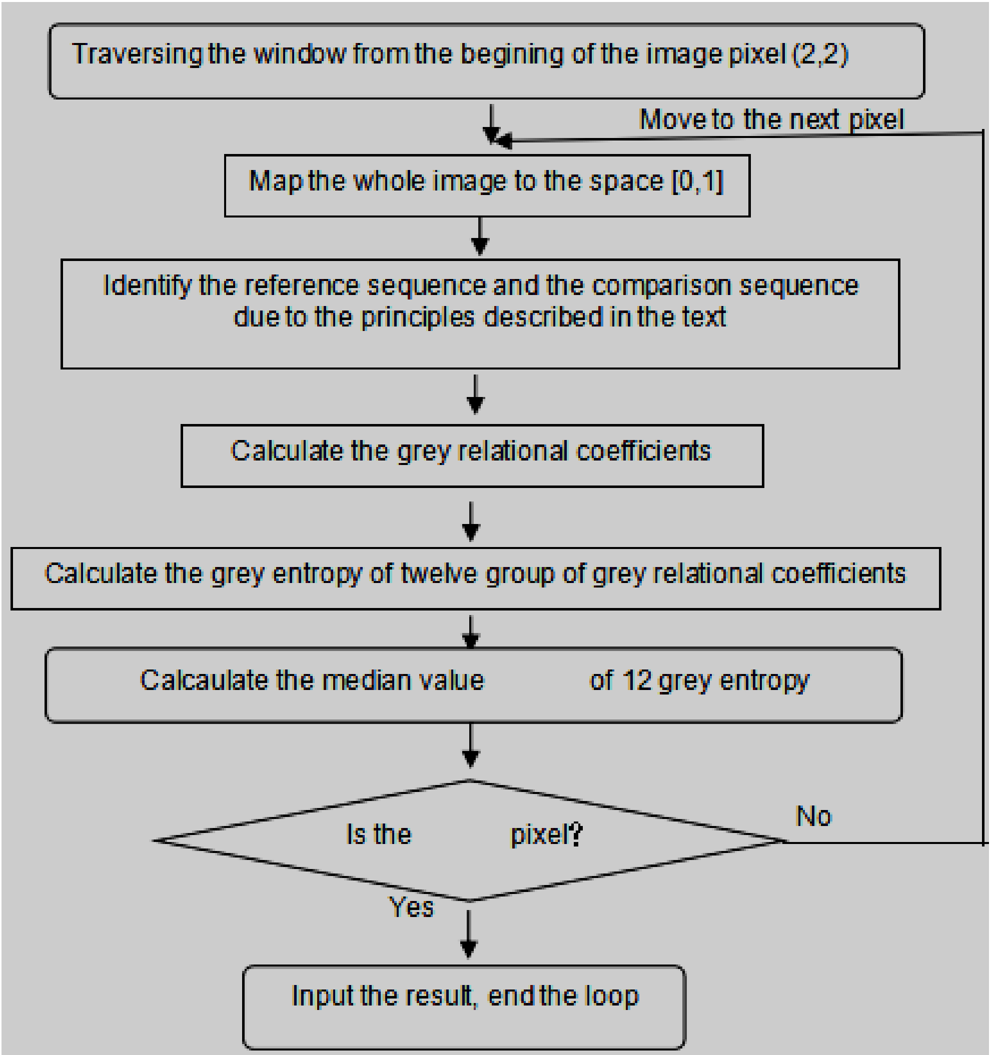

Fig.1 Diagram of grey entropy method

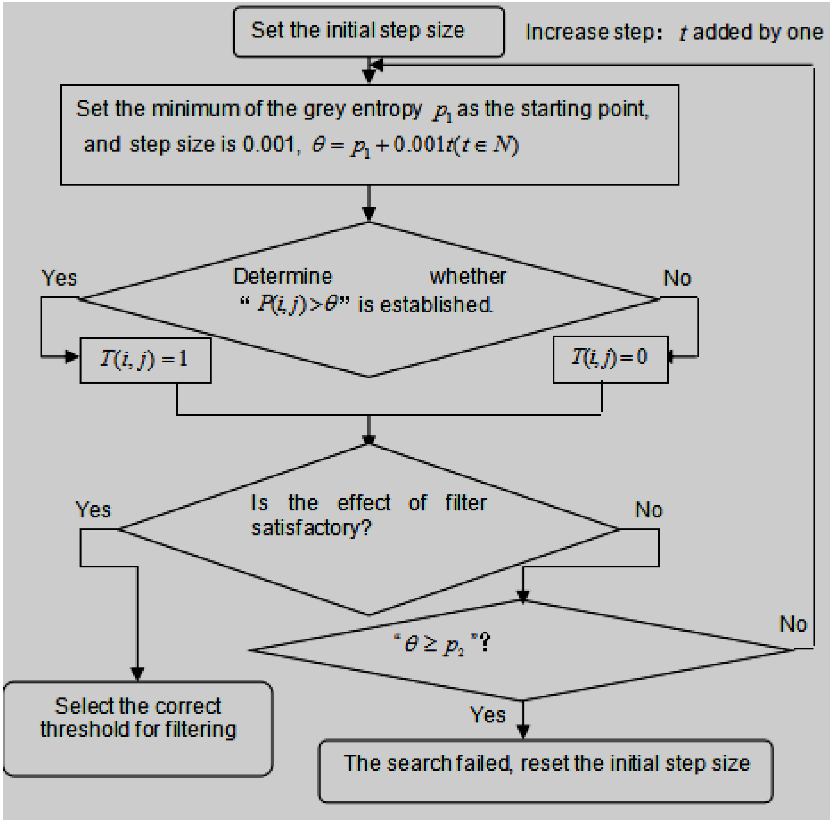

Fig. 2 Diagram of looking for the appropriate threshold

C. *Algorithm Results and Analysis*

1) Subjective analysis

First, use the experimental image camera man.tif with 30% salt and pepper noise in the MATLAB2012b environment (θ = 1.0944), and we can get the results as follows:

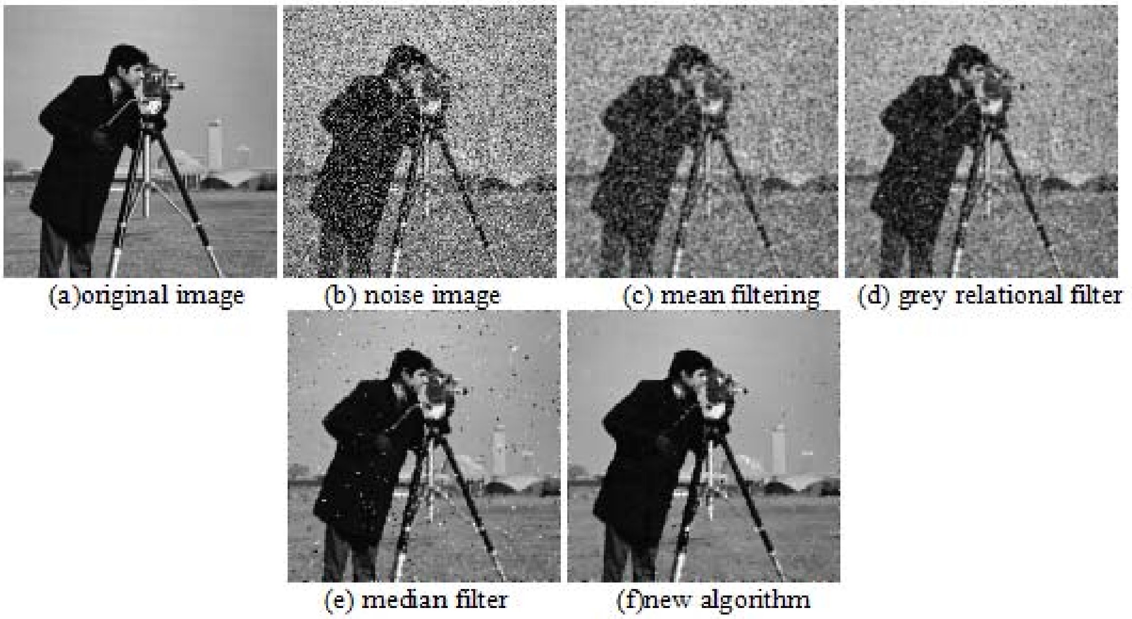

Fig. 3 algorithm results of the experimental image

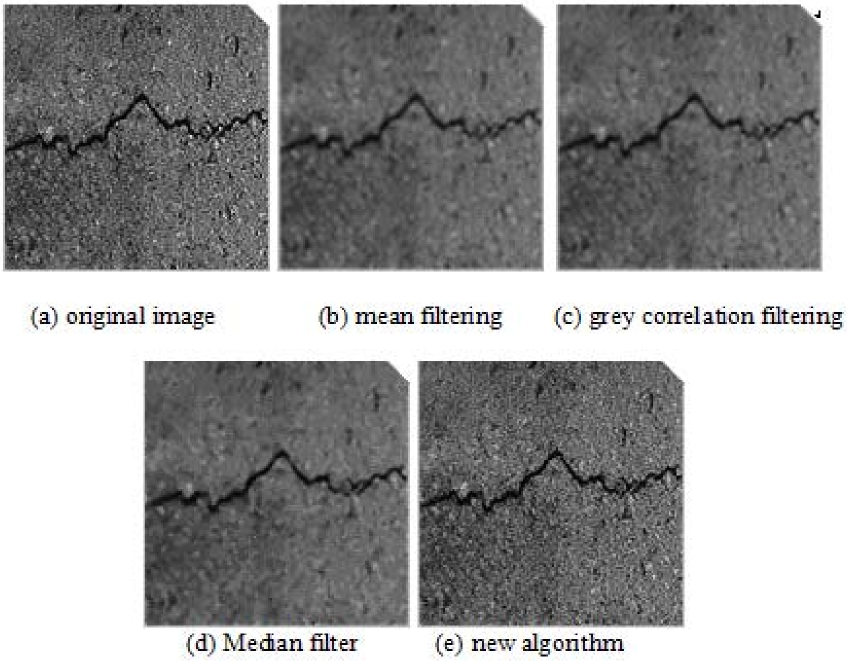

Fig. 4 algorithm results of the road surface image

From the results of simulation experiments, we can see that the effect of mean filter and grey relational filter is common, and the effect quality of image is improved generally. Although the traditional median filter on the salt and pepper noise removal effect is better, but still left some noise block, and the overall image detail also filtered out a lot. The algorithm proposed in this paper, while removing the noise is still very good to save most of the image details. Similar results can be obtained by applying the algorithm to real pavement images. The algorithm proposed in this paper has a good effect on the preprocessing of pavement images.

2) Objective analysis

From the results of the comparison on PSNR it can be seen that the performance of the proposed algorithm is superior to that of the other methods in terms of the relatively high noise intensity. Therefore, this algorithm has a certain comparative advantage in high-density noise.

TABLE 1. COMPARISON ON PSNR AMONG MENTIONED ALGORITHMS UNDER DIFFERENT NOISE INTENSITY

Noise density	0.2	0.25	0.3	0.35
Mean filter	19.1342	18.0507	17.1624	16.3859
Grey relational filter[15]	21.3344	20.0294	18.9092	17.9107
Median filter	23.7489	22.1060	20.7833	19.1754
grey entropy filter	24.1439	23.0039	22.1385	21.0325

IV. SUMMARY

In this paper, grey entropy is used to measure the degree of the current point belonging to the noise point in the image local window. By setting the threshold value, We can distinguish the noise point from the normal point, and just carry out median filtering on the pixels which are judged as noise. If the pollution in the window is very serious, we can expand the window for median filtering, and this approach to the high noise density of the image has a certain comparative advantage.

In short, the effect of filtering result is still dependent on the selection of the threshold. In this paper, we use the computer search method to combine with the subjective observation of the human eyes to determine the appropriate threshold. The difference of the threshold is also great for different images. If we can find a completely adaptive method to judge the threshold, it will be a great promotion for this algorithm and have a great significance.

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REFERENCES

[1] Osama S. Faragallah, , Hani M. Ibrahem, Adaptive switching weighted median filter framework for suppressing salt-and-pepper noise,International Journal of Electronics and Communications, Volume 70, Issue 8, Pages 1034‑1040,August 2016.

[2] Chengbin Zhang, Kaifu Wang, A switching median–mean filter for removal of high-density impulse noise from digital images, International Journal for Light and Electron Optics, Volume 126, Issues 9–10,,Pages 956–961, May 2015

[3] Nair Madhu S., Shankar Viju, Predictive-based adaptive switching median filter for impulse noise removal using neural network-based noise detector, Signal, Image and Video Processing,7(6):1041-1070,2013.

[4] Pei-Eng Ng , Kai-Kuang Ma , A switching median filter with boundary discriminative noise detection for extremely corrupted images ,IEEE Transactions on Image Processing Volume: 15, Issue: 6, Page(s): 1506 - 1516,June 2006.

[5] Yuan, Cao,Li Yaqin, Switching median and morphological filter for impulse noise removal from digital images, Optik,v 126, n 18, p 1598-1601,2015

[6] Toh Kenny Kal Vin, Isa Nor Ashidi Mat, Noise adaptive fuzzy switching median filter for salt-and-pepper noise reduction, IEEE Signal Processing Letters, v 17, n 3, p 281-284,2010

[7] Meher Saroj K, Singhawat Brijraj, Adaptive, noise-exclusive and assessment-based fuzzy switching median filter for high intensity impulse noise,International Journal of Uncertainty, Fuzziness and Knowlege-Based Systems, 23(6):949-963,2015

[8] How-Lung Eng, Student Member, IEEE, and Kai-Kuang Ma, Senior Member, IEEENoise Adaptive Soft-Switching Median Filter,IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 10, NO. 2, FEBRUARY Page:242-251,2001

[9] Akkoul, Smaïl, Lédée, Roger, Leconge, Remy, Harba, Rachid, A new adaptive switching median filter, IEEE Signal Processing Letters, v 17, n 6, p 587-590,2010.

[10] ulong Deng, 2002, The Basic of the Grey System, Huazhong University of Technology Press, Wuhan, China.

[11] Qishan Zhang, Weiyou Han, Julong Deng,1994, Information Entropy of Discrete Grey Number, Journal of Grey Systems 6(4), 303-314.

[12] [Hongjun Li, ChingY.Suen, A novel Non-local means image denoising method based on grey theory,Pattern Recognition, 49:237–248,2016.

[13] Gui Yufeng, Su Peng, Chen Xianqiao, Image Segmentation based on Genetic Algorithms and Grey Relational Analysis, JOURNAL OF GREY SYSTEM,,28(1):45-51,201.

[14] Miao ma, Yanning Zhang, and Jian Zhao, grey theory and Its Application in Image Engineering[M],Beijing:Tsinghua University Press,2011

[15] Yufeng Gui, Guantao Chen, Hai Dong,Gang Li , Shengqiang Lu,Jianfeng Tao,Xiaoying Xu. The Noise Reduction of Digital Image Based on Grey RelationalAanalysis.// Proceedings of dynamics of continuous discrete and impulsive systems-series a-mathematical analysis, 13: Part 3 Suppl. S,pp. 1423-1425,DEC ,2006.