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An Image Impulsive Noise Denoising Method Based on Salp Swarm Algorithm

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Abstract

Image noise denoising is a very important task in image processing. Aiming at the shortcomings of traditional median filtering to handle image impulse noise, an approach based on Salp Swarm Algorithm (SSA) to eliminate image impulse noise is presented in the paper. In this method, the improved extremum method is used to detect the position of impulse noise pixels, and then the Salp Swarm algorithm is used to find the optimal pixel value instead of the noise pixel to complete the denoising process of the image. Experimental results testfies that image impulse noise could be effectively filtered out through the proposed method and the manipulated image is clear and more detail could be revealed for human vision.

Index Terms: Image enhancement, Salp Swarm Algorithm, Median filtering, Noise elimination

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1. Introduction

Here introduce the paper, and put a nomenclature if necessary, in a box with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 10 pt. Here follows further instructions for authors.

Image is an important source of information. Digital imagesare subjectto a wide variety of distortionsduring acquisition, processing, compression, storage,transmiss-ion and reproduction, any of which may result in a degradation of visual quality [1]. Image denoising is one of the important steps in the early stage of image processing. The purpose of image denoising is to weaken the noise and improve the quality of the image. The quality of the image processing results directly affects the subsequent analysis of the image.

Impulse noise is a common noise in image processing. Median filtering [2] is the most commonly used method to deal with impulse noise. It is a non-linear signal processing technology based on the ordering statistics theory, which can effectively suppress the noise, and can effectively filter the impulse noise in the image. The MF can achieve reasonably good performance for low corrupted images, but it will not work efficiently when the noise rate climbs above 0.5 [3]. In few decades, many median filtering methods have been proposed,such as weighted median filter [4], adaptive median filters [5], tri-state median filter [6], adaptive soft-switching median filter [7], switching median filters [8], fast switching median filter [9], extremum median filter [10], modified directional weighted median filter [11], adaptive switching weighted median filter [12]. Their advantage is that noise can be labeled without processing noise-free images and they have attracted much attention due to their simplicity and capability. However, when the noise density is high, the quality of the restored image is poor.

Swarm intelligence algorithm is a new evolutionary computing technology. The most popular ones are Particle Swarm Optimization (PSO) and Ant Colony algorithm (ACO) . More and more swarm intelligence algorithms are used in image processing.Liu proposed image segmentation method based on Improved PSO [13].Wang proposed image enhancement based on improved PSO [14]. Mirjalili proposed a new intelligent algorithm,named Salp Swarm Algorithm(SSA) [15].It was shown in [15] that SSA is superior to the traditional swarm intelligence algorithm in solving optimization problems. According to the above,an image noise denoising method based on Salp Swarm Algorithm is proposed in this paper. The proposed algorithm is divided into noise detection phase and noise filtering phase. In the filtering stage, SSA algorithm is used to remove noise pixels. The experimental results show that the filtering algorithm is effective.

The structure of the article consists of the following parts.Section 2 introduces the model of salt and pepper noise and the principle of SSA algorithm.Section 3 proposes a method of noise detection and a model of SSA based optimization.Section 4 gives the experimental data. Finally,the conclusion is made in Section 5.

2. Related Theroy Model

2.1. Impulsive Noise

Impulsive noise alters pixels randomly making their values very different from the true values, and very often, very different from those of neighboring pixels as well [16]. The model of impulsive noise pollution image is as follows:

$$X_{i,j} = \begin{cases} n(i,j), & p \\ u(i,j), & 1-p \end{cases} \quad (1)$$

where $X_{i,j}$ is the polluted image by noise, $n(i,j)$ is the impulsive noise pixels, $u(i,j)$ is uncorrupted pixels,and p represents the probability of impulse noise.

Impulsive noise can be divided into random-valued impulsive noise and bipolar impulsive noise, in which bipolar impulsive noise is also called salt and pepper noise. Salt and pepper is a white pixel and a black pixel randomly scattered in an image. The noise pixel in the dynamic range takes one of the maximum or minimum values.Its probability density function can be given by the following formula:

$$P(z)\begin{cases} P_a, \ z = a \\ P_b, \ z = b \\ 1 - P_a - P_b, others \end{cases} \tag{2}$$

If $a > b$, the gray value *b* will appear as a bright spot in the image, and instead, the value of *a* will appear as a dark dot. For 8-bit grayscale images, *b* = 255 represents a white dot and *a* = 0 represents *a* black dot. In the paper,we mainly focus on the disposal of salt and pepper noise.

2.2. Salp Swarm Algorithm

Salp Swarm Algorithm is a new type of swarm intelligence algorithm.In the deep sea,the salps usually move and forage in the form of chains,which we can call SSA chains.The SSA chains can be regarded as the adaptive mechanism of the population, which is formed in order to promote the population to coordinate the change more quickly and more effective foraging movement, and gradually approach to the global optimal.

Similarly to other creatures in nature,we can divide salp swarm to two groups,leader and followers.In SSA chains,the first individual in the chain generally acts as a leader, and the leader is generally the most accurate individual in the group to judge the environment, which guides the movement and predation of the whole group. The rest of salps are considered as followers. Unlike other groups, however, leaders no longer directly affect the direction of movement of the entire group, but rather directly affect the next immediate individual.In other words, each follower is the leader of the next follower.As a result,the influence of the leader on the latter individual decreases layer by layer, and the latter individual can maintain their diversity well.

As can be seen in the document [15], compared with other swarm intelligence algorithms,SSA has strong exploration ability and fast convergence speed.In each iteration, the best position and future direction are retained, it deal with multi-modal and single-objective problems with superior performance.

The position of salp is defined in an j-dimensional search space, and the population size is *N*.We can define the position of food is $F = [F_1 \ F_2 \ \dots \ F_j]^T$, the position of salps can be expressed as $X_n = [X_{n1} \ X_{n2} \ \dots \ X_{nj}]^T$,n=1,2,…,$N$. The upper bound of search space is $ub = [ub_1, ub_2, \dots, ub_j]^T$, and the lower bound is $lb = [lb_1, lb_2, \dots, lb_j]^T$. Randomly initialize the population:

$$X_{N\times j} = lb + (ub - lb) \times rand(N, j) \tag{3}$$

To update the positon of the leader the following equation is proposed:

$$X_j^1 = \begin{cases} F_j + C_1\left((ub_j - lb_j)c_2 + lb_j\right) & c_3 \geq 0 \\ F_j - C_1\left((ub_j - lb_j)c_2 + lb_j\right) & c_3 < 0 \end{cases} \tag{4}$$

where X_j^1 shows the position of the first salp (leader) in the *j*-dimension, In order to enhance global search ability and individual diversity,C_2 and C_3 are random numbers between 0 and 1.

The coefficient C_1 is the most important parameter in SSA.it can be named convergence factor and it balances exploration.When the convergence factor is greater than 1, the algorithm performs global exploration whereas the convergence factor is less than 1, the algorithm starts to explore the local and obtain accurate estimates.The exploitation defined as follows:

$$C_1 = 2e^{-\frac{4l^2}{L}} \tag{5}$$

where *l* is the current iteration and *L* is the maximum number of iterations.

To update the position of the followers, the following equations is utilized:

$$X_j^i = \frac{1}{2}(X_j^i + X_j^{i-1}) \tag{6}$$

when $i \geq 2$, X_j^i shows the position of *i*-th follower salp in *j*-dimension.

3. The Proposed Algorithm

where shows the position of the first salp (leader) in the j-dimension, In order to enhance global search ability and individual diversity, and are random numbers between 0 and 1.

The coefficient is the most important parameter in SSA.it can be named convergence factor and it balances exploration.When the convergence factor is greater than 1, the algorithm performs global exploration whereas the convergence factor is less than 1, the algorithm starts to explore the local and obtain accurate estimates.The exploitation defined as follows:

In our algorithm,we solve the problem of image denoising in two steps: noise detection and noise filtering.First,the position of noise and noisy matrix can be obtained by processing noise image.Then,we use SSA algorithm to estimate the original value at the noisy pixel to restore the image.

3.1. Noise Detection

In an image, if the value of a pixel is equal to the extreme value in its domain, then we can regard this pixel as a possible noisy point, but this method will produce large errors.For example, the pixels in the edge part of the image may be judged as noisy points. Therefore, we make a further judgment on the noisy pixels. In the estimated noisy pixel,if the difference between the median value of the noisy pixel and the value of the non-noisy pixel in its domain is greater than a threshold, we determine that the point is the noisy pixel, otherwise it is a vaild signal pixel.

Suppose X_{ij} represents the gray value of a point in a digital image at (i, j),and $W_{ij}(n)$ represents its neighbors, which is in the range $n \times n$.$max(W_{ij}(n))$ is maximum value in $W_{ij}(n)$, $min(W_{ij}(n))$ is minimum value in $W_{ij}(n)$. E_{ij} is the noisy candidate.Set

$$m_{ij} = min(W_{ij}(n)) \tag{7}$$

$$M_{ij} = max(W_{ij}(n)) \tag{8}$$

$$E_{ij} = \begin{cases} 1, & (X_{ij} = m_{ij}) \ or \ (X_{ij} = M_{ij}) \\ 0, & others \end{cases} \tag{9}$$

u_{ij} is the mean value of non-noisy pixels in the neighbors. Make a comparison between the X_{ij} that satisfying $E_{ij}=1$ and u_{ij},

$$n_{ij}=\begin{cases}1, (|X_{ij}-u_{ij}|>th)\ and\ (E_{ij}=1)\\ 0, \quad others\end{cases} \tag{10}$$

where th is threshold, and its value is determined by the experiment. n_{ij} is the set of noisy pixels,represents noisy matrix.

3.2. SSA Based Optimization

The main principle of optimization is to find the appropriate value to replace the noisy pixels by SSA algorithm, in which the noisy pixels are determined by the noisy matrix we had obtained. We choose SSIM function as the evaluation model,it defined as follow [1]:

$$SSIM(f,g)=\frac{(2\mu_f\mu_g+c_1)(2\sigma_{fg}+c_2)}{(\mu_f^2+\mu_g^2+c_1)(\sigma_f^2+\sigma_g^2+c_2)} \tag{11}$$

where f is the original image and g is the corrupted image. Symbol μ stands for mean value,σ stands for variance, σ_{fg} stands covariance between f and g.

In order to make the SSA pre-search process have better globality and randomness, this paper selects more than one leader to search. The more leaders, the stronger the randomness of the algorithm, but the stability of the algorithm will also decrease. Considering the random-ness and stability of the algorithm, half of the salps are selected as the leader.

The specific steps to restore the value of the noisy pixel through the SSA algorithm are as follows:

Step 1:Initialize the population according to formula (3). In image processing, the value of the population is the gray value.So,we can set $lb=0$,$ub=255$,and $rand$ represents a random number between 0 and 1.

Step 2:Calculate fitness value according to formula (11).

Step 3:Arrange the fitness values, selecting the first half of the fitness value as the leaders, and the second half as the followers.

Step 4:Update the position of the leader and the position of the follower according to formulas (4) and (6).

Step 5:Determine whether the maximum num-ber of iterations is reached.If not, return to Step 2,otherwise,the global optimal solution is output as the value of the noise pixel.

Step 6: Repeat the above steps until all noise pixels are restored.

4. Experimental Results

An 8-bit gray image with a size of 256 256 is used to remove the noise with different densities under the salt and pepper noise model to verify the effectiveness of the filtering algorithm proposed in this paper.

4.1. Noise Detection Result

We add salt and pepper noise to the gray image (cameraman) with 256×256 pixels. The noise density is 10% and 70%, and the corresponding noisy matrix is shown in the Fig. 1. Black dots represent noisy pixels, and white dots represent original pixels.

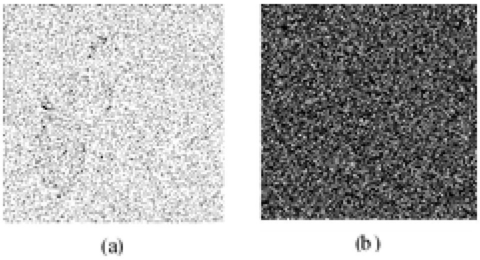

Figure 1 Different density noisy matrix.(a) Noise density is 10%.(b) Noise density is 70%

At 10% noise density, the number of noise pixels detected is 6824 and at 70% noise density, the number of noise pixels detected is 45990, accounting for about 10 .4

% and 70.2% of the total number of pixels in the image. It can be seen from the detection results that the noise can be detected effectively both at low noise density and high noisy density.

4.2. Comparison of Filtering Performance

The proposed filtering algorithm is compared with the median filter (MF), adaptive median filters (AMF) and extremum median filters (EMF). Fig. 2 and Fig. 3 show the filtered effects of four filtering methods with noisy densities of 40% and 80%, respectively.

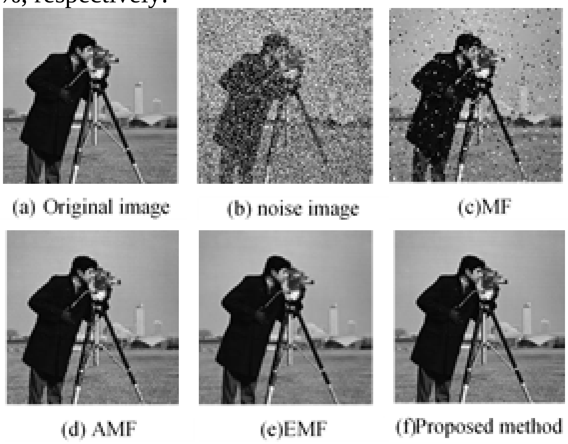

Figure 2 Filtering effect of adding 40% noise density image with each algorithm

From the experimental results we can find that in the case of low noise density or high noise density, the proposed method shows better results than the other four filtering methods. Even if the noise density is as high as 80%, the image can be restored well.

To compare the filtering performance of different filtering methods, the Peak Signal-To-Noise Ratio (PSNR) is used as the objective evaluation standard.

$$PSNR = 10\log_{10}\left(\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}255^2}{\sum_{i=1}^{M}\sum_{j=1}^{N}[A(i,j)-B(i,j)]^2}\right)dB \tag{12}$$

A is the input noise image, B is the filtered image, (i, j) represents the coordinates of pixel points in the image, M and N represent the length and width of the image. The larger the PSNR value, the better the image quality.

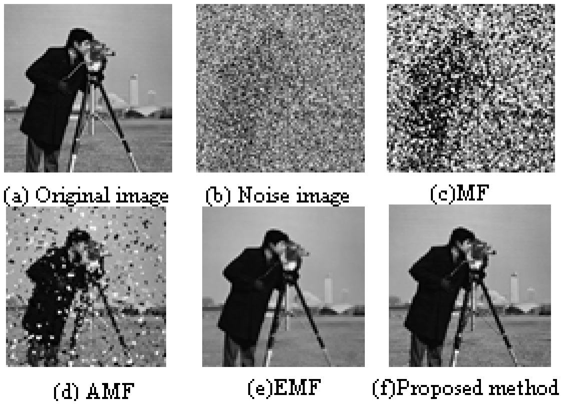

Figure 3 Filtering effect of adding 80% noise density image with each algorithm

TABLE 1.PSNR FOR DIFFERENT FILTERING METHODS

Noise Density(%)	Denoising Method			
	MF	AMF	EMF	Proposed
10%	26.27	30.32	32.15	46.12
20%	24.11	28.52	30.52	42.60
30%	21.25	26.90	28.98	30.56
40%	17.82	25.52	27.96	28.93
50%	14.25	24.01	26.72	27.87
60%	11.67	22.47	25.89	26.80
70%	9.52	19.31	24.98	26.20
80%	7.73	14.69	24.03	25.96
90%	6.28	9.71	22.81	24.73

5. Conclusion

An image denoising algorithm based on SSA was proposed in this paper, which can effectively remove the salt and pepper noise existing in the image. Compared with the traditional filtering algorithm, this method can extract the noise points, obtain the noise matrix, and then use the SSA algorithm to restore the value of the noise point. Furthermore, SSA has a stronger global search capability than traditional swarm intelligence algorithms, and its performance is stable, which brings more advantages in image denoising.

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