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Research on Denoising of Hybrid Noise

Xianghong Tang *[a,b], Yang Zheng [a], Quanwei Yang [a]

[a]Key Laboratory of Advanced Manufacturing Technology (Guizhou University), 550025, Guiyang, China
[b]School of Mechanical Engineering, Guizhou University, 550025, Guiyang, China
txhwuhan@163.com

Present denoising algorithms of hybrid noise usually filter out Gaussian noise after removing pepper-noise and have many problems such as inaccurate image restoration and insufficient protection of image edge. In order to get rid of these problems, this paper presents an algorithm to remove the hybrid noise based on grid division. The algorithm introduces the definition of the edge grid cell and takes different methods to deal with the hybrid noise in edge grid cells and non- edge grid cells according to location of the noise. Experimental results show the proposed algorithm outperforms the existing algorithms in eliminating the hybrid noise and preserving the image details and has good performance for the single noise.

1. Introduction

Images as important media and a method of passing information carry along rich information. How to obtain and deal with the image information is a focus of study of the image. But the ideal environment that has not any interference in acquiring and processing image information cannot exist. Image acquisition is unavoidably interfered(Brini and Marmo, 2011). At the same time, transmission and storage of images is also affected by various noises (Minowa et al., 2014).Interference and damage of noises may reduce visual effect and quality of images and influence the follow-up image processing such as edge parameters, image segmentation, classification and so on. Salt & pepper-noise and Gaussian noise are common noises and often occur in images. The noise which consists of Salt & pepper-noise and Gaussian noise is called the hybrid noise. It is not easy to filter the hybrid noise. The previous researches have only focused on filtering the single noise. Recently there are some researches about the hybrid noise. They include the modified mean filter algorithm (MTM)(Zhu and You , 2013), the self-adapting median weighted mean filter algorithm(Zhu et al., 2013) and the self-adapting fuzzy weighted mean filter algorithm(AFWM) (Hu et al., 2002).In filtering noises, these algorithms have their shortages such as high misjudgment ratio, loss of the edge detail information of images and not removing grain noises. Moreover, a denoising algorithm based on noise separation and self-adapting wavelet threshold is mentioned (Wan and Xue, 2011) and an algorithm of filtering the hybrid noise (AFHN) is proposed (Wang, 2010). The two algorithms first separate the noise by noise detection and then execute filtering procedure. This kind of algorithm is easy to misjudge the image edge point as the noise point and damage the image edge. Some researchers use PCNN to deal with the hybrid noise (Zhang et al., 2013). An algorithm based on the simplified PCNN (SPCNN) is proposed to remove the hybrid noise. But the time complexity of the algorithm is high and the algorithm cannot well protect the image edge detail information. Because the methods employed by the algorithm are too many. At present, the existing methods to deal with the hybrid noise usually filter out the salt & pepper-noise first and then remove the Gaussian noise. After filtering out the salt & pepper-noise, the image already differs from the original image but the image which has already filter the salt & pepper-noise is treated as the original image in filtering the Gaussian. It may result in the secondary error and make a negative influence on the image restoration.

To handle above problems, a mixed noise filtering algorithm based on grid division is put forward in this paper. The algorithm defines the edge grid cells and the non-edge grid cells by grid division. It pretreats the image area which is contaminated by noises with simplified PNCC and positions the location of noises. The algorithm takes two different measures to deal with the edge grid cells and the non-edge grid cells. Since the algorithm handles the salt & pepper-noise and the Gaussian noise in the grid cell simultaneously, it avoids the

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secondary error and a negative influence on image restoration. At the same time, the algorithm takes a full consideration about the edge of images and can protect the image edge detail information.

2. The related definitions

Definition 1: Edge grid cells. They are defined to be the grid cells which the pixels of the image edge belong to. The concept of the edge grid cells is put forward to protect the detail and edge character of the images and it helps to process edge pixels fast and well. In an image, the area where the local gray scale varies significantly is usually the image edge. This paper employs the gravity edge detection(Zhang and Chen, 2011) to determine whether the grid where the noise is in is the edge and the method is simple and effective. The method first calculates the gravitational resultant force $F^x$and $F^y$of the pixel points in the horizontal and vertical direction from their neighborhood and then computes the magnitude of the total resultant force$|F| = \sqrt{(F^x)^2 + (F^y)^2}$. A threshold of resultant force is set. If the total resultant force of a pixel point is bigger than the threshold, the pixel point will be defined as an edge point .If not, the pixel point will be defined as a non-edge point. The edge grid cell is the grid cell where there are many edge points.

Definition 2: Noise location. The method first uses simplified PNCC to pretreat the images contaminated by the Gaussian noise and positions the location of the noise point. The method then employs the method of mathematical morphology (Shih and Cheng, 2004) to maintain the integrality of the target and judges the type of noise after morphological processing. N_{ij} stands for the situation of the noise contamination and is defined as follows:

$$N_{ij} = \begin{cases} 1\,, & max\{W_D(S_{ij})\} - \delta \geq S_{ij} OR\ S_{ij} \leq min\{W_D(S_{ij})\} + \delta \\ 0, & oterwise \end{cases} \tag{1}$$

If the contamination degree N_{ij} of the noise point p_{ij} is 1, the point p_{ij} will be the salt & pepper-noise point. If the contamination degree N_{ij} of the noise point p_{ij} is -1, the point p_{ij} will be the Gaussian noise point. $W_D(S_{ij})$ is the area which is the setting neighborhood centering around the pixel p_{ij} . δ is a range parameter. $min\{W_D(S_{ij})\}$ is the minimum value of pixel's gray scale in $W_D(S_{ij})$ and $max\{W_D(S_{ij})\}$ is the maximum value of pixel's gray scale in $W_D(S_{ij})$.

Definition 3: Peak signal to noise ratio (PSNR). It is a common parameter to measure the fidelity of the image. The bigger the value of PSNR is, the closer the reconstructed image is to the original image. Its definition is as follows.

$$P_{PNSR} = 10lg\frac{M\times N\times 255^2}{\sum_{m=1}^{M}\sum_{n=1}^{N}[F(m,n)-F'(m,n)]^2} \tag{2}$$

Where M and N is the size of the image, $F(m,n)$ is the gray scale of the original image and $F'(m,n)$ is the gray scale of the de-noised image.

3. A method of grid division in images

This paper presents a method of grid division in image as shown in Figure 1. The main idea of this paper is described as follows. The size and number of the grid cells is determined by the number of pixels in gray level images and pixels in images are divided into the grid cells. Each grid cell defines the neighborhoods scope of pixels. The center of each grid cell is the location of a corresponding pixel point and it helps to guarantee the location accuracy of pixels generated. Since all pixels are divided into the grid cells, calculation of each pixel's gray scale does not need traversal of all pixels in the image and the computation complexity is reduced. The following provides specific steps：

1) The size of a gray level image is assumed to be $n \times m$ and a two-dimension array of $n \times m$ called $Arry - P$ is defined. Each unit in the array is a container called p and the container is used to store the pixels which have been divided into the grid cell.

2) all pixels in the image is traversed to find the pixel boundary values $max(x)$, $min(x)$, $max(y)$, $min(y)$.

3) The length of two sides of the image is calculated by $xlength = max(x) - min(x)$ and $ylength = max(y) - min(y)$. L expresses the longer side and is defined as $L = max(xlength, ylength)$.Then The grid cell is defined as a square with side length t and $t = min(L/_n, L/_m)$.

4) A square with side length L is drawn and the X direction starting position is acquired when $start_x = min(x)$.

5) For any pixel point$p$in the image, the grid location of p need be calculated according to $tn = (p[x] - start_x)\%\, t + 1$ and $tm = (p[y] - start_y)\%\, t + 1$. Then p is put into $Array - P[tn][tm]$.

In the above method, the number of execution times is $2 \times n$ and n is the number of pixels in the image. The method of grid division in this paper would make the grid cells uniform and provide a good foundation for denoise of hybrid noise, because the method draws a square with side length L as the grid cell such as Figure 1 and the side length of each grid cell is smaller.

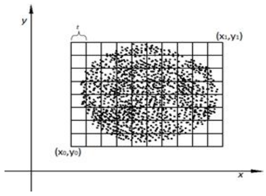

Figure 1: A divided grid

4. The algorithm of removing the hybrid noise

This paper presents an algorithm of removing the hybrid noise based on the above grid division. The main idea of the algorithm is described as follows. Firstly，the hybrid noise is located and is classified according to Definition 2. The grid cells the noise points belong to are traversed and are judged with Definition 1, whether they are the edge grid cells or not. If the grid cell with the salt & pepper noise points is the non -edge grid cell, the pixels in the grid cell will be classified to compute the mean values of different classes by the linear classifier and the nearest mean values will be used to replace the salt &pepper noise points. If the grid cell with Gaussian noise points is the non -edge grid cell, mean values and variance of gray scale of non- noise points in the grid cell are calculated to figure out gray scale values which are used to replace Gaussian noise points. If the grid cell with the noise points is the edge grid cell, it is necessary to find edge points of the grid cell for removing salt &pepper noise points. The nearest edge points are selected as references and their gray scale values are compared with the noise point's gray scale values. If the noise point's gray scale values is more than the edge point's value, K-nearest pixel points of the noise point whose gray scale values are more than the edge point's value need to be found in the grid cell . If K-nearest pixel points cannot be found in the grid cell, pixel points whose gray scale values are more than the edge point's value will be found in adjacent grid cells. A'_{ij} stands for the mean gray scale value of K-nearest pixel points and is used to replace the noise point. If the noise point's gray scale values are less than the edge point's value, K-nearest pixel points of the noise point whose gray scale values are less than the edge point's value need to be found in the grid cell or adjacent grid cells. A'_{ij} which expresses the mean gray scale value of K-nearest pixel points is also calculated and is used to replace the noise point. For Gaussian noise points, edge points can be used to divide the pixel points in the grid cell into two classes and then replace Gaussian noise points with the non- edge grid method. The detail description is shown in Figure 2.

The algorithm of removing the hybrid noise deals with the hybrid noise in edge grid cell and non- edge grid cells by two different methods. The specific steps of the algorithm are as follows:

1) If the contamination degree N_{ij} of the noise point p_{ij} is 1, the point p_{ij}will be considered as a salt & pepper-noise point. If the contamination degree $N_{ij}$of the noise point p_{ij} is -1, the point p_{ij} will be considered as a Gaussian noise point. $G_D(p_{ij})$ is used to express the collection of gray scale values of non-noise points in the grid area $G_D(p_{ij})$ where p_{ij} belongs to and $G_D(p_{ij})$ is defined as $G_D(p_{ij}) = \{ p_{mn} | N_{mn} = 0, p_{mn} \in G(p_{ij})\}$.

2) If the grid cell of point $p_{ij}$is the non-edge grid cell, the feature vector $x = (x_1, x_2, \dots x_d)^T$ is the linear combination which is employed to get rid of the salt &pepper noise and the expression of the it linear discriminant function is defined as

$$g_i = w_{i1}x_1 + w_{i2}x_2 + \cdots + w_{id}x_d + w_{i0} = \sum_{k=1}^{d} w_{ik} + w_{i0} \quad (3)$$

$$g_i(x) = W_i^T x + w_{i0}, i = 1,2, \dots, d \quad (4)$$

where $W_i = [w_{i1} \dots w_{id}]^T$is a full-vector and w_{i0} is the weight threshold. The discriminant function is $g(x) = g_1(x) - g_2(x)$ and the decision-making equation is $g(x) = g_1(x) - g_2(x) = 0$. According to the above formula, the pixel points in the grid cell are divided into two classes.

3) The mean gray scale values $A_{ij}$of two classes pixel points in the grid cell of p_{ij} is calculated and$A_{ij} = average\{G_D(p_{ij})\}$. The gray scale value G_{ij} of p_{ij} is replaced by A_{ij}.

4) If the contamination degree N_{ij} of the noise point p_{ij} is -1, the averages (μ， μ_1， μ_2) and variances(σ'， σ_1， σ_1) of the pixel points in $G_D(p_{ij})$ and two classes pixels are calculated and the gray scale values $R_1(i,j)$ and $R_2(i,j)$ are computed after removing the noises. The gray scale value ofp_{ij} is replaced by $R(i,j)$. μ,σ and R is defined as follows.

$$\mu = \frac{1}{XY}\sum_{i,j}^{X,Y} s(i,j)\,, \sigma^2 = \frac{1}{XY}\sum_{i,j}^{X,Y} s^2(i,j)\,, R(i,j) = \mu + \frac{\sigma^2 - \sigma'^2}{\sigma^2}(s(i,j)) \quad (5)$$

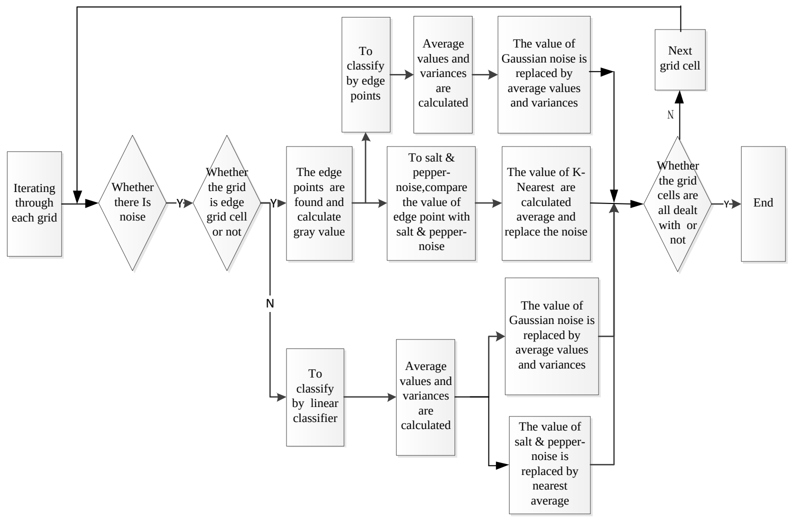

Figure 2: The flow chart of the algorithm of removing the hybrid noise

5) If the grid cell of the noise point p_{ij} is the edge grid cell, the edge point b_{ij} in the grid cell can be found and the gray value M_{ij} of b_{ij} is calculated. For the salt& pepper-noise in the edge grid cell, the gray scale value G_{ij} of p_{ij} needs to be compared with M_{ij} and the boundary of K-nearest neighbors' value of p_{ij} is determined. If $G_{ij} > M_{ij}$,K-nearest neighbors' value of p_{ij} is the mean value of non-noise points in the edge grid cell and is more than M_{ij}. If $G_{ij} < M_{ij}$, K-nearest neighborhoods' value of p_{ij} is the mean value of non-noise points in the edge grid cell and is less than M_{ij}.
6) Average gray scale value of all pixel points in K-nearest neighborhood of p_{ij} is computed and is expressed as A'_{ij}. A'_{ij} is used to replace G_{ij} .
7) For the Gaussian noise point, the nearest edge point b_{ij} is found and the gray scale value M_{ij} of b_{ij} is used to divide the pixel points of the grid cell into two classes. If the number of pixel points in one of two classes is less than the threshold T, the nearest pixel points in adjacent grid cells will be collected and it will make the sum of the nearest pixel point reach T.
8) $R'(i,j)$ is calculated like Step 5 and is used to replace the gray scale value of p_{ij}.
In the above description about the algorithm, Step 2-4 depict the method of noise filtering in the non-edge grid cell and Step 5-8 illuminate the method of removing noise in the edge grid cell. The algorithm employs the grid to deal with pixel points and need not consider the area size of the image to reduce the time complexity.
Current hybrid noise researches usually filter out the salt and pepper noise first and then remove the Gaussian noise. After filtering out the salt & pepper-noise, the image already differs from the original image. But the process of removing the Gaussian noise treats the image which has already filtered the salt & pepper-noise as the original image. It may generate the secondary error and have a negative influence on the image restoration. From Step 3, 4, 6 and 8 in the above description, the algorithm in this paper gets rid of the salt &pepper noise and the Gaussian noise simultaneously to avoid the secondary error and it helps to restore the images accurately. Moreover, the algorithm proposes a denoising method of the noise points in the edge grid cells. The method can protect the image edge and detail information.

5. Experimental Result

In this paper, the experimental denoising algorithms are simulated in an Intel(R) PENTIUM(R) PC of 2.7 GHz CPU and 4.0 GB memory. To evaluate performance of the algorithm in this paper, the self-adapting fuzzy weighted mean filter algorithm (AFWM) (Hu et.al,2002), the algorithm of filtering the hybrid noise(Wang, 2010) and the algorithm based on the simplified PCNN(Zhang, Li and Li , 2013) are chosen as comparative with algorithm in the paper(HDMN).
The image of lena is chosen as the basic image of experiments. Objective and subjective evaluation criteria are both employed to assess the performance of the algorithm in this paper (Manenti and Buzzi-Ferraris, 2002)

Objective evaluation of restoration quality of the image usually use the deviation that the image restored has from the original image and the peak signal-to-noise ratio is often chosen as a measure parameter of objective evaluation. Subjective evaluation of restoration quality of the image usually takes comparison of the image before and after denoising.

5.1 Experiment 1 Objective Evaluation

In the experiment, the image with the hybrid noise is generated by artificially adding the hybrid noise to the basic image and the peak signal-to-noise ratio is the contrast parameter.

Table 1: The comparison of PSNR values of four kinds of filtering algorithm

Hybrid noise	AFWM	AFHN	SPCNN	HDMN
p=0.1,σ=10	26.1137	25.6372	26.4735	27.8533
p=0.1,σ=15	25.9477	25.5698	26.3512	27.7101
p=0.1,σ=20	25.8651	25.4736	26.1460	27.5349
p=0.15,σ=10	25.8354	25.5189	26.2631	27.6389
p=0.15,σ=15	25.6173	25.4810	26.1573	27.4277
p=0.15,σ=20	25.4536	25.4275	26.0983	27.3345
p=0.2,σ=10	25.7873	25.4632	26.1943	27.5965
p=0.2,σ=15	25.5992	25.3276	26.0391	27.3615
p=0.2,σ=20	25.3170	25.2198	25.9784	27.1436

Table 2: The results of filtering Salt and Pepper noise

salt&pepper-noise	Adaptive median filter	HDMN
p=0.05	29.5471	30.7245
p=0.1	28.9326	29.6532
p=0.15	28.1032	28.8735
p=0.2	26.0378	26.4734

Table 3: The results of filtering Gaussian noise

Gaussian noise	Wiener filtering	HDMN
σ =5	26.1574	25.8727
σ =10	25.9711	25.5196
σ =15	24.7862	25.0522
σ =20	24.3245	24.1523

Table 1 shows comparison of PSNR values of four filtering algorithms under different hybrid noise conditions. To demonstrate the filtering ability of salt and pepper noise, the comparison algorithm is an adaptive median filtering algorithm (Wang and Li, 2010) which has strong filtering ability of the salt and pepper noise. Table 2 shows PSNR values of the algorithm proposed by this paper and the comparison algorithm after removing the salt and pepper noise. Table 3 reflects filtering performance of the Gaussian noise of the algorithm proposed by this paper and Wiener filtering algorithm(Yin and Su, 2010).From Table 1, the hybrid noise filtering algorithm based on the grid proposed by this paper has the biggest PSNR value in various proportion hybrid noise, compared with other methods. It is to say, the denoising effect of the algorithm of this paper is better than other algorithms.

From table 2 and table 3, it can be concluded that the algorithm of this paper has good performance of removing the single noise which is the salt and pepper noise or the Gaussian noise. Because the algorithm uses the grid to deal with the salt and pepper noise and Gaussian noise simultaneously and it can make accurate image restoration and effectively protect image edge and detail information.

5.2 Experiment 2 Subjective Evaluation

In the experiment, the hybrid noise (the salt and pepper noise $p=0.15$ and the zero mean Gaussian noise $\sigma=15$) is added to the basic image of lena.

In Figure 3 , (a) is the image with the hybrid noise and (b),(c),(d) and (e) are respectively the results of AFWM, AFHN, SPCNN and the algorithm of this paper on the image with the hybrid noise. In order to validate the proposed algorithm's ability to protect the image edge, the experiment takes the hat's local area of the basic image of lena as the reference object as shown in Figure 4. In Figure 5, (a), (b),(c) and (d) are respectively the results of AFWM, AFHN, SPCNN and the algorithm of this paper on the hat's local area after the above four algorithms filter out the noise. Figure 3 shows that the algorithm of this paper has the best filtering effect of the hybrid noise in four algorithms. Figure 5 indicates that the algorithm of this paper is superior to other filtering algorithms in protecting the image edge. Through the two aspects of subjective and objective effect of filtering performance comparison, the hybrid noise filtering algorithm based on the grid is superior to other hybrid noise filtering algorithms in removing the hybrid noise. It can better restore image detail and protect the image edge and detail information. At the same time, it has good denoising effect on filtering the single noise.

Figure 3: The output image after filtering in Mixed noise and four algorithm

Figure 4: Lena hat's local area

Figure 5: The local area image of Lena hat after filtering

6. Conclusion

To resolve the existing problems of hybrid noise filtering algorithms, this paper puts forward a hybrid noise filtering algorithm based on the grid. From objective and subjective evaluation of experimental results, it is concluded that the proposed algorithm of this paper has good ability of image restoration and can protect the image edge information in filtering the hybrid noise. At the same time, the algorithm has good denoising performance of removing the single noise. The future research will focus on the optimization algorithm of detailed images.

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