A noise estimation approach by assembling fast edge detection and block based methods

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Abstract

Noise estimation is one of the most important research topics in image processing. Aishy and Eric had proposed a variance estimation method used in Gaussian white-noise, in which, a measure was provided to determine the homogeneous blocks and an analyser was used in calculating the homogeneities. The approach should present two shortcomings corresponding to structures and textures. One is that the blocks with edge textures should be considered as intensity-homogeneous blocks that could have an effect on estimation accuracy. The other is that some special blocks with high variance but low homogeneity could result in over estimation. In order to avoid the two shortcomings, in this paper we have proposed an improved noise estimation approach by combining fast edge detection and block based methods. The blocks hold continuous points were firstly excluded rejected by using fast edge detection method. The experimental results indicated that our method can avoid over estimation effectively in special conditions and can obtain more accurate results than the Aishy and Eric's method did.

Keywords: Guess Noise, noise variance estimation, edge detection, image processing

1 Introduction

Noise is described as the random variation of brightness or colour information in image. Denoise plays the most important role in image processing due to the performance should easily be corrupted by noise. In many denoising methods [1], the noise was used as a parameter but it was unknown in fact, so noise estimation approaches could have great effects on the qualities of denoising methods. Noise estimation has two mainly approaches, Filter-based [2] and Block-based methods [3]. The main idea of Filter-based methods is to calculate the noise variation from the high frequencies information, which are separated from the noise images and include textures and structures, so Filter-based methods can perform well for high noise levels but they are tending to overestimate in the images with large textures or details. Masoud [4] have proposed a Filter-based method that was suit for images with abundant textures, however, the method has a huge time complexity due to many times of flitting processing. The idea of the Block-based method is to calculate the noise variation of the intensity-homogeneities determined from the blocks obtained by dividing a noise image into many blocks. Block-based methods were tending to overestimate when noise levels are low [5].

Aishy and Eric [6] have proposed a novel method which fulfil well for both high noise level and low noise level, and also perform well for images with abundant textures. This method firstly determines the intensity-homogeneous blocks in the noisy image using an effective structure analyser and then estimates the noise from these blocks. The approach should present two shortcomings. One is that the blocks with textures should be considered as intensity-homogeneous blocks that could have an effect on estimation accuracy. The other is that some special blocks have high variance but low homogeneity could result in over estimation. The two problems were due to that the non-homogeneous blocks recognized as homogeneous ones, and the problems could be solved by excluding the blocks with strong textures by some edge detection approaches.

In order to avoid the two shortcomings mentioned above, we have proposed a modified method to improve the performances of the method in [7] by combining fast edge detection and block based methods. The blocks with continuous points were firstly excluded by using fast edge detection method and then the noise variance was estimated from these intensity-homogeneous blocks. The experimental results indicated that our method can avoid over estimation effectively in special conditions and can obtain more accurate results than the Aishy and Eric's method did.

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2 Detection method

2.1 AISHY AND ERIC METHOD

Given an adding Gaussian image with unknown noise variance σ_n^2, there exists the following model:

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$$I(x,y) = S(x,y) + \eta(x,y) , \quad (1)$$

where the $I(x,y)$ is the noise image, $S(x,y)$ is the original image and $\eta(x,y)$ is adding Gaussian noise. The purpose of the noise estimation is to obtain the evaluative parameter for noise variance σ_n^2. A intensity-homogeneous block centred by pixel $I(i,j)$ and with the size of $S \times S$, was presented in Equation (2).

$$B_{kl} = \{I(i,j) \mid (i,j) \in S_{kl}\}$$
$$S_{kl} = \{(i,j) \mid |i-k| < (S-1)/2, |j-l| < (S-1)/2\} . \quad (2)$$

The variance and the mean of sub-block B_{kl} are defined as $\sigma_{B_{kl}}^2$ and $\mu_{B_{kl}}$, respectively. The variance of an intensity-homogeneous block mainly presented as noise variance and satisfied with Equation (3).

$$\lim_{S\to\infty} \sigma_{kl}^2 = \sigma_n^2 . \quad (3)$$

From the Equation (3), it can be found that the variance σ_n^2 could be estimated accurately if there have enough intensity-homogeneous blocks. The homogeneity ζ_{kl} of sub-block B_{kl} was obtained from a structure analyser. The analyser employed high throughput arithmetic operators with coefficients {-1,…,W-1,…,-1} to calculate the homogeneity from eight directions showed in Figure 1(with size of 3×3 pixels), and the ζ_{kl} was the sum of the absolute values of the eight templates and the convolutions of B_{kl}.

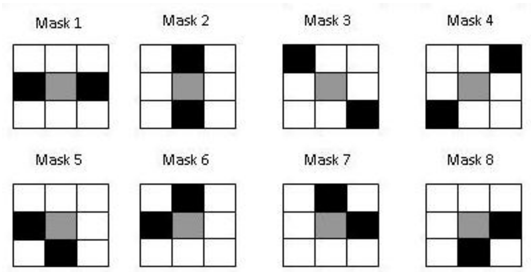

FIGURE 1 Directions of homogeneity analyser for 3×3 blocks

The block based method is difficult to confirm the all intensity-homogeneous blocks. A self-adaptive method had proposed in [8] to select intensity-homogeneous blocks. Three blocks with minimal homogeneities were found firstly and then the referential variance σ_r^2 was estimated as the mean of the variances calculated on the three sub-blocks mentioned above. Each block B_{kl} was included in the V, which was the aggregate of all intensity-homogeneous blocks, and must be satisfied with Equation (4), in where, the σ_i^2 was the variance of the i-th block, PSNR was Peak Signal to Noise Ratio, t_{PSNR} was threshold.

$$\left|PSNR_{B_r} - PSNR_{B_{kl}}\right| < t_{PSNR}$$
$$PSNR_i = 10\log_{10}\frac{255^2}{\sigma_i^2} . \quad (4)$$

After the aggregate V was determined, the variance was estimated as following:

$$\sigma_e^2 = \frac{\sum_{(k,l)\in V} \sigma_{B_{kl}}^2}{m} , \quad (5)$$

where m was the number of blocks selected into V.

From above, we can get two conclusions:

1) When the sub-blocks B_{kl} with size greater than 3×3, there could be exist some special sub-blocks with very small homogeneities ζ_{kl} and very high variance σ_{kl}^2 as showed in Figure 2. If there was one special sub-block in the image, the σ_{kl}^2 should be determined as the referential variance σ_r^2, so it should result in serious over estimation due to the σ_r^2 was much higher than noise variance σ_n^2.

2) To determine that whether the sub-block B_{kl} was an intensity-homogeneous block or not, is corresponding to σ_{kl}^2, so the sub-blocks determined as intensity-homogeneous one should have structures and textures that should take bed effects on the calculating accuracy.

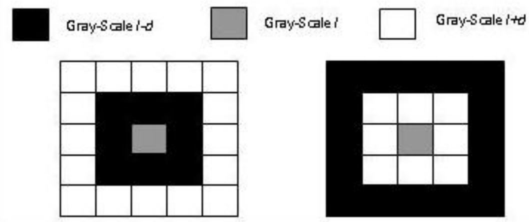

FIGURE 2 Two special sub-blocks with I-d>=0,I+d<=255

2.2 OUR METHOD

The two problems mentioned above could be voided effectively by excluding the sub-blocks with continuous points, in this paper, a simple edge detection method was employed to accomplish the task. Firstly, the Sobel arithmetic operators [1] were used in calculating the gradient of image as showed in Equation (6).

$$G = \sqrt{G_x^2 + G_y^2}$$
$$G_x = I(x,y) * \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}, \; G_y = I(x,y) * \begin{bmatrix} -1 & 0 & -1 \\ -2 & 0 & -2 \\ -1 & 0 & -1 \end{bmatrix} . \quad (6)$$

A gradient threshold G_{th} was selected and used in detecting the boundary according to the following rules:

1. Given a settled threshold p, value of gradient G_{th} was determined by if the gradients which were higher than G_{th} took p% of the all gradients.
2. A point had a gradient G, which was higher than G_{th} was confirmed as a boundary point.

So if a sub-block B_{kl} had N continuous points could be excluded as an intensity-homogeneous block. In our method, the approach mentioned in this section was used firstly as a filter to get rid of the sub-blocks, than the method [1] was employed to estimate the noise variance of the remainders of sub-blocks.

3 Results and Discussions

In order to make compressions between the two methods, a ratio [1] was employed and showed in equation (7):

$$\text{Estimation ratio} = \frac{\sigma_{estimation}}{\sigma_{added}}, \quad (7)$$

where $\sigma_{estimation}$ was standard deviation of estimated noise, σ_{added} was the standard deviation of added noise. We had made tests on several images with the size of 512×512 and under different level of noise as showed in Figure 3. The image was decomposed into a series of sub-blocks and each of the blocks was not overlapped and with the size of 5×5. The parameters, thresholds t_{PSNR} and p were initialized with values of 3dB and 10, respectively. The parameter N was initialized to three; it means that if the number of continuous points detected in a sub-block was greater than N, the block was rejected to be an intensity-homogeneous block.

Tables 1 and 2 showed the estimation ratios (defined in Equation (6)) obtained from the eight images showed in Figure 3 between our method and Aishy method [1]. The results listed in the two tables were the mean values of 20 times noises variance estimations under the same experimental condition. From the results, we could find that our methods have better performances at many conditions. At the range of lower noise like σ_{added} <=3, our method obtained the same performances as method Aishy method [1]. Under this condition, the sub-blocks were hardly determined to be homogeneous because of variance of the block which had continuous points was much higher than the noise variance. At the range of middle noise like 10< σ_{added} <30, our method showed superiority because the self-adaptive method [1] had high probability to select the sub-blocks which hold continuous points.

At high noise range of σ_{added} >=30, the two method Showed great performances when σ_{added} was at 30, 40 and 50. But our method had superiority on the images wih abundant edge textures (see results listed in Table 2 of the images Mandrill and Hyderabad).

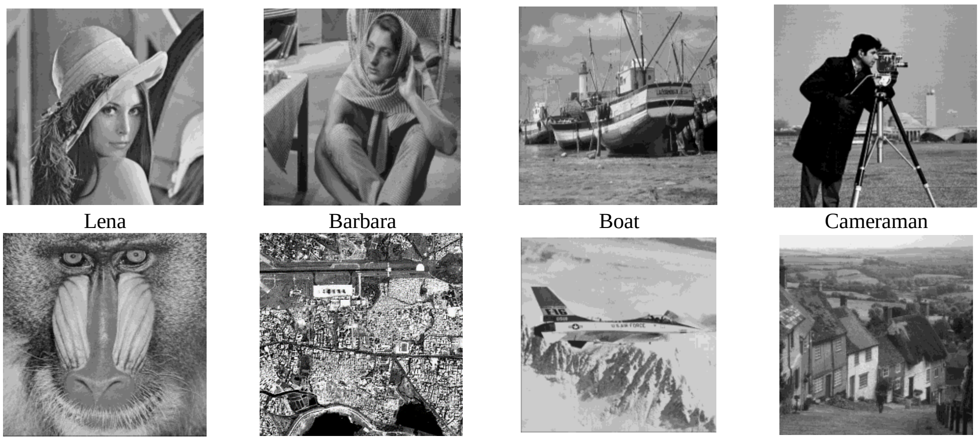

FIGURE 3 Eight images with size of 512X512

TABLE 1 The results obtained by our method and Aishy [1] on the images of Lean, Barbara, Boat and Cameraman

	Lena		Barbara		Boat		Cameraman	
σ added	*Method [1]*	*Ours'*	*Method [1]*	*Method [1]*	*Method [1]*	*Method [1]*	*Method [1]*	*Method [1]*
0.5	3.7740	3.7740	4.3330	4.3330	3.1730	3.1730	1.9430	1.9430
1	2.3235	2.3235	2.3785	2.3785	2.1215	2.1215	1.3940	1.3940
2	1.5660	1.5660	1.4890	1.4890	1.6495	1.6490	1.2063	1.2063
3	1.2860	1.2858	1.2892	1.2892	1.3873	1.3872	1.1003	1.1003
4	1.1596	1.1595	1.1951	1.1951	1.2993	1.2990	1.0609	1.0579
5	1.1429	1.1420	1.1281	1.1281	1.2389	1.2386	1.0312	1.0306
6	1.1139	1.1106	1.0847	1.0847	1.2039	1.2030	1.0407	1.0388
7	1.1031	1.1018	1.0656	1.0655	1.1416	1.1409	1.0034	1.0027
8	1.0489	1.0479	1.0761	1.0758	1.1176	1.1166	0.9989	0.9992
9	1.0646	1.0624	1.0792	1.0785	1.1056	1.1022	0.9969	0.9998
10	1.0294	1.0281	1.0361	1.0357	1.0937	1.0885	1.0128	1.0071
12	1.0539	1.0489	1.0251	1.0244	1.0895	1.0869	1.0023	0.9999
14	1.0188	1.0157	1.0291	1.0280	1.0493	1.0462	1.0072	1.0034
16	1.0128	1.0073	1.0147	1.0136	1.0713	1.0536	1.0075	1.0026
18	1.0164	1.0037	0.9882	0.9924	1.0363	1.0303	0.9817	0.9905
20	1.0062	1.0004	1.0191	1.0107	1.0184	1.0065	1.0101	1.0002
30	1.0005	0.9992	1.0107	0.9994	1.0199	0.9940	0.9836	0.9824
40	0.9906	0.9899	1.0009	0.9960	0.9999	0.9919	0.9817	0.9806
50	0.9875	0.9870	1.0266	0.9951	0.9870	0.9858	1.0041	0.9978

TABLE 2 Results obtained by our method and Aishy's on the images of Mandrill, Hyberabad, Airplane and Goldhill showed in Figure 3

	Mandrill		**Hyberabad**		**Airplane**		**Godhill**	
σ added	*Method [1]*	*Method*	*Method [1]*	*Method*	*Method [1]*	*Method*	*Method [1]*	*Method*
0.5	5.5770	5.5770	0.9860	0.9860	1.1990	1.1990	1.5120	1.5120
1	3.1825	3.1825	0.9895	0.9895	1.1530	1.1530	1.3380	1.3380
2	2.5780	2.5780	0.9953	0.9953	1.1293	1.1293	1.1770	1.1770
4	1.8380	1.8380	0.9999	0.9999	1.0381	1.0379	1.1926	1.1924
5	1.8477	1.8476	0.9999	0.9999	1.0304	1.0301	1.1508	1.1401
6	1.7128	1.7125	0.9972	0.9972	1.0479	1.0471	1.1748	1.1738
7	1.6258	1.6254	1.0051	1.0051	1.0304	1.0295	1.1874	1.1814
8	1.5097	1.5093	1.0200	1.0200	1.0078	1.0042	1.1641	1.1607
9	1.5442	1.5436	1.0317	1.0317	1.0086	1.0071	1.1210	1.1128
10	1.4886	1.4878	1.0280	1.0280	1.0051	1.0002	1.1068	1.1019
12	1.3148	1.3140	1.0469	1.0469	0.9925	0.9954	1.0489	1.0437
14	1.2979	1.2962	1.0893	1.0891	0.9927	0.9952	1.0829	1.0719
16	1.2451	1.2422	1.1151	1.1103	0.9862	0.9919	1.0640	1.0476
18	1.2279	1.2228	1.0682	1.0679	1.0191	1.0072	1.0501	1.0378
20	1.1814	1.1753	1.1284	1.1080	0.9943	0.9965	1.0445	1.0223
30	1.1098	1.0967	1.1257	1.1198	1.0035	0.9969	1.0212	1.0022
40	1.0786	1.0585	1.1672	1.1590	0.9790	0.9753	1.0113	0.9970
50	1.0448	1.0238	1.1164	1.1016	0.9955	0.9885	0.9824	0.9816

4 Conclusions

Our method was improved one based on the method [1], compared with which there were two superiorities of our method. One is that our method could get more accurate performances at lover and middle noise range. The other one is that our method could avoid over-estimations effectively, as we know that over-estimation could produce inestimable effects at later image processing. We hope that our method could play an important role in the noise estimation research.

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