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Research Article

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Comparison Study on Different Filtering Techniques for Gaussian Noise Reduction in Gray Images

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Abstract The purpose of this study is to find an optimal filtering method among existing filtering methods to remove Gaussian noise from image reproduction devices such as digital TV. We used Bilateral, BM3D, Guided, Non-local means, Median, Gaussian, and Bitonic filtering techniques to find the optimal filtering techniques for Gaussian noise reduction. In order to derive the optimal filtering technique according to the image components, we use images that show different characteristics. In this study, we used Mean Square Error (MSE), Signal-to-Noise Ratio (SNR), Peak Signal-to-Noise Ratio (PSNR), and structural similarity (SSIM) to quantitatively evaluate noise reduction performance. Experimental results show that the Gaussian filtering method has the best performance in the images containing high frequency components and the Bitonic filtering method has the best performance in the images including low frequency components.

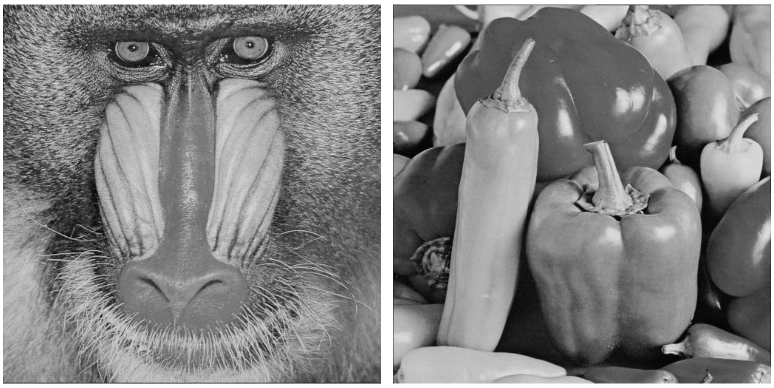
Keywords Gaussian noise, Denoising, Image filtering

Introduction

With the development of IT technology, there is a growing demand for image reproduction devices such as digital TVs. Noise generally occurs in the process of acquiring, processing, and transmitting digital images [1]. For example, when acquiring an image through a Charge Coupled Device (CCD) camera, noise is generated by ambient brightness and sensor temperature. In addition, when data is transmitted, noise is generated due to the surrounding environment or channel interference. The noise reduces image processing effects such as image quality, feature extraction, super resolution processing, and image segmentation. CCD camera sensors using the latest manufacturing process technology are known to exhibit high noise levels. Therefore, image noise reduction method is an important technique for digital image processing. In this paper, we compare the conventional filtering techniques to find optimal filtering method for Gaussian noise in image. In order to quantitatively evaluate the performance of existing representative filtering techniques according to the characteristics of the image, the Mean Square Error (MSE), Signal-to-Noise Ratio (SNR), Peak Signal-to-Noise Ratio (PSNR), and structural similarity (SSIM)were used and subjective evaluation was made by comparing the images of the existing filtering results.

Materials and Methods

In this paper, an experiment was performed by adding Gaussian noise to 8-bit gray image *Baboon* and *Peppers* of 512 X 512 size (Fig. 1).All image processing was performed with MATLABR2015a.In order to inference an optimal filtering technique for noise in image, we compared the noise reduction performance using Bilateral [2], block-matching 3-D (BM3D) [3], Guided [4], Non-local means [5], Bitonic [6], Median, and Gaussian filtering techniques. Experiments were conducted using the filtering technique provided by the author to avoid unnecessary mistakes. In this experiment, noise reduction performance of different filtering methods was quantitatively evaluated using Mean Square Error (MSE), Signal-to-Noise Ratio (SNR), Peak Signal-to-Noise Ratio (PSNR), and structural similarity (SSIM).



(a) (b)

Figure 1: The Original test images (a) Baboon, (b) Peppers

Results &Analysis

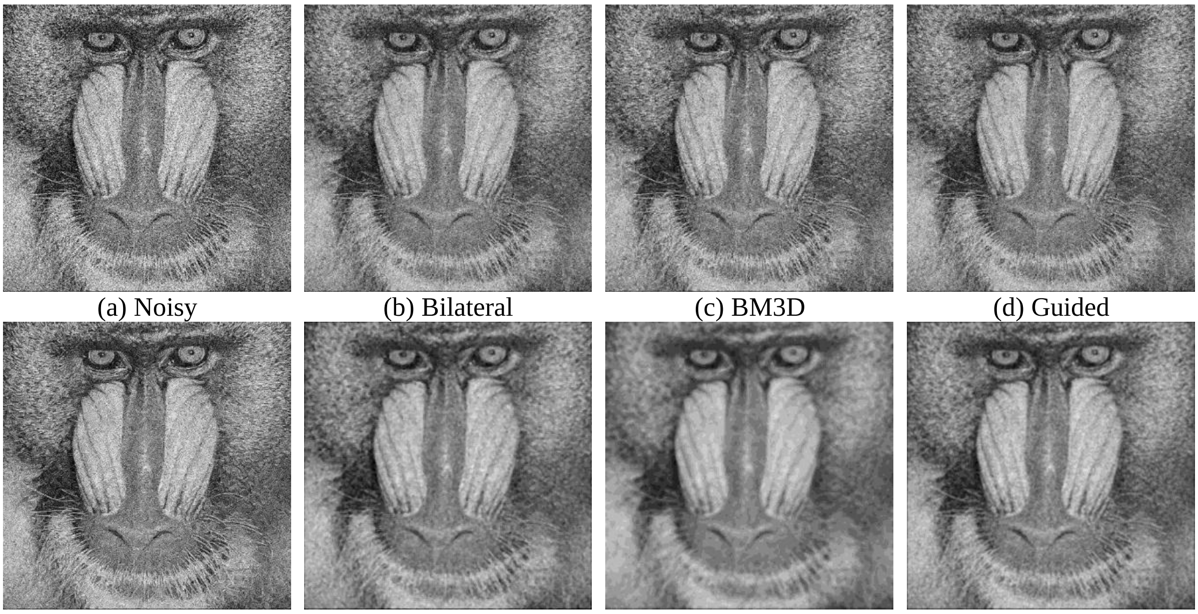
Tables 1 and 2 show the result of different filtering techniques for *Baboon* image containing many high frequency components and *Peppers* image containing many low frequency componenets. Table 1 represents the results of applying existing filtering techniques to *Baboon* image. From the results in Table 1, it is confirmed that the Gaussian filtering technique has superior noise reduction performance compared to other conventional filtering techniques (RMSE = 23.03, SNR = 15.45, PSNR = 20.89, SSIM = 0.45).The Gaussian filtering method as compared with the Bilateral filtering method, which has the lowest noise reduction performance has improved RMSE = 17.16, SNR = 4.84, PSNR = 4.53, and SSIM = 0.12, respectively. Table 2 represents the results of applying the existing filtering techniques to the *Peppers* image. From the results of table 2, it is shown that noise-free image obtained by Bitonic filtering was superior to the conventional filtering methods with RMSE = 11.76, SNR = 20.17, PSNR = 25.91, and SSIM = 0.65. This filtering method compared with the lowest performance Bilateral filtering method among the existing filter methods has improved RMSE = 26.39, SNR= 9.41, PSNR = 9.41 and SSIM = 0.50, respectively.

Table 1: RMSE, SNR, PNSR and SSIM results for *Baboon* image with different filtering techniques

	RMSE	**SNR (dB)**	**PSNR (dB)**	**SSIM**
Noisy	43.78	9.87	15.31	0.32
Bilateral	40.19	10.61	16.05	0.33
BM3D	39.90	10.67	16.11	0.33
Guided	38.68	10.95	16.38	0.34
Non-local means	35.21	11.76	17.20	0.36
Median	25.09	14.70	20.14	0.37
Bitonic	23.85	15.15	20.58	0.40
Gaussian	**23.03**	**15.45**	**20.89**	**0.45**

Table 2: RMSE, SNR, PNSR and SSIM results for *Peppers* image with different filtering techniques

	RMSE	**SNR (dB)**	**PSNR (dB)**	**SSIM**
Noisy	42.83	9.76	15.50	0.13
Bilateral	38.15	10.76	16.50	0.15
BM3D	36.56	11.13	16.87	0.16
Guided	36.14	11.23	16.97	0.16
Non-local means	32.66	12.11	17.85	0.18
Median	13.52	19.77	25.51	0.57
Gaussian	12.92	19.77	25.51	0.57
Bitonic	**11.76**	**20.17**	**25.91**	**0.65**

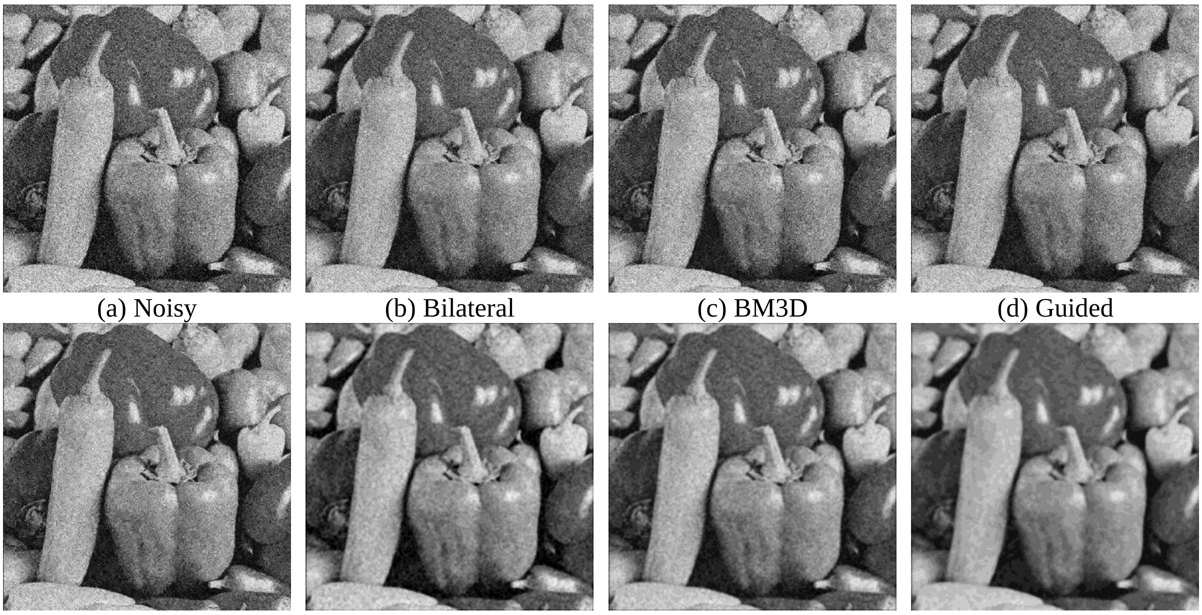


(a) Noisy (b) Bilateral (c) BM3D (d) Guided

(e) Non-local means (f) Median (g) Bitonic (h) Gaussian

Figure 21: Simulation results of Gaussian noise reduction in Baboon image

Figures 2 and 3 exhibit the experimental results for subjective evaluation of the noise reduction performance of existing filtering techniques according to the characteristics of the image. Figure 2 was the results of applying the existing filtering techniques to *Baboon* image containing many high frequency components. From Fig. 2, filtering techniques such as Bilateral, BM3D, Guided, Non-local means, and Median represented low noise reduction performance and Bitonic filter technique showed blurring phenomenon as a whole. The Gaussian filtering method exhibited better noise reduction performance than the other conventional methods. Figure 3 shows the results of applying the existing filtering techniques to *Peppers* image containing many low frequency components. It is confirmed that the existing filtering techniques exhibit lower noise reduction performance than the Bitonic filtering technique.



(a) Noisy (b) Bilateral (c) BM3D (d) Guided

(e) Non-local means (f) Median (g) Gaussian (h) Bitonic

Figure 3: Simulation results of Gaussian noise reduction in Peppers image

Conclusion

This paper quantitatively and qualitatively compared images degraded by Gaussian noise in image reconstruction devices such as digital TV to find an optimal filtering technique among existing filtering techniques. In order to evaluate the performance of existing filtering techniques (Bilateral, BM3D, Guided, Non-local means, Median, Gaussian, and Bitonic) according to the characteristics of images, *Baboon* image containing high frequency components and *Peppers*image including low frequency components were selected. Experimental results showed that the Gaussian filtering method had the best performance for *Baboon* image including high frequency components and the Bitonic filtering method had the best performance for *Peppers*image containing many low frequency compenents. Based on these results, future research will propose a filtering technique that shows excellent Gaussian noise reduction performance according to the characteristics of the image.

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