Bulletin of Networking, Computing, Systems, and Software – www.bncss.org, ISSN 2186-5140
Volume 8, Number 1, pages 41–44, January 2019

A Study on Effective Repetition of Bilateral Filter for Medical Images

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***Abstract*—Recently, a camera has the function of gain brightness that makes a bright photo from the dark photo. The function is realized by amplifying an attenuated signal from a photosensor in a digital camera. But it amplifies noise with signal. The noise makes salt-pepper-noise on a monochrome photo; Gaussian noise on a color picture. In the previous study, the bilateral filter was used for denoise on a picture. The bilateral filter is a nonlinear filter that is able to denoise and save important corner, edge, and contours. The bilateral filter needs two or three parameters that are different to do best for each input pictures. The previous study searches the optimum parameter, but the method needs to be run the bilateral filter for each suggested parameter and the execution time was long. The bilateral filter has a character is able to remove noise effectively by filtering several times than search optimum parameters. In this article, our purpose is considered of the effective number of repetitions of Bilateral Filter. We estimate how many repeat filtering by using SSIM and PSNR for image quality measuring.**

***Index Terms*—Medical Images, Bilateral Filter, PSNR, SSIM, Noise Reduction**

I. Imaging Filters

Image gained brightness get salt-pepper-noise. Image Filter used to remove the noise [1], [2]. In this article, we explain moving average filter that is easy to implement, bilateral filter that used in this paper. The moving average filter change the pixel located in the center of filter kernel to average the filter kernel pixels. Fig.1 shows the how pixels replaced by moving average filter. The moving average filter removes noise, but it

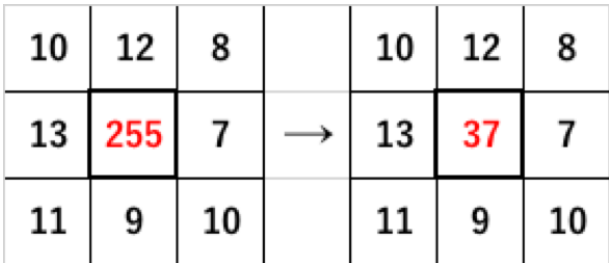

Fig. 1: Function of moving average filter

blurs all area of picture and loss important corner, edge and contours. Figure 2 shows 2 image of original lenna and image of noise on original lenna. Figure 3 shows result of moving average filter executed noised lenna. The Image of lenna after

Fig. 2: Images of lenna(left) and noised lenna(right)

Fig. 3: Results of smoothed moving average filter

moving average filter executed, gaussian noise is removed on Image. However, not only the gaussian noise but also the high frequency components of the original lenna image are lost, resulting in an overall blurred image. The bilateral filter is an image processing filter that overcomes the drawback of blur which is too strong. The bilateral Filter is a nonliner smoothing filter that proposed Tomasi et al [3]. That is a kind of imageing filter that is able to remove noise without blur important edges and corners. The filter is widely used in the field of signal processing and image processing [4]. Equations

1 and 2 show equation of bilateral filter and weights of bilateral filter respectively.

$$O_{BF}(x,y) = \frac{\sum_{i=-r}^{r}\sum_{j=-r}^{r} IN(x+i,y+j)W(x+i,y+j)}{\sum_{i=-r}^{r}\sum_{j=-r}^{r} W(x+i,y+j)} \tag{1}$$

$$W(x,y) = \exp\left(\frac{-\|i^2+j^2\|}{2\sigma_d}\right) \times \exp\left(\frac{-\|IN(x,y)-IN(x+i,y+j)\|^2}{2\sigma_r}\right) \tag{2}$$

Equation 2 is composed of space terms and luminance terms. As a result, it is possible to suppress only pixels having large luminance difference. σ_r and σ_d are parameter of space and luminance. Bilateral filter uses these parameters and output restored image. If we know best parameter for each input image, we can obtain most remove noise from image. Figure 4 shows image of executed bilateral filter of lenna. Bilatral filter is less overall blurred image and clearly between background and center woman than moving average filter. In Fig.5 let left

Fig. 4: The smoothed bilateral filter

output of moving average filter, let right output of bilateral filter, to compare moving average filter and bilateral filter. Restore of bilateral filter is reduced noise than moving average filter, and clarity the boundary woman and background. It seems to be understand that bilateral filter save edges than simple smoothing filter.

II. Image quality evaluation method

In this section, we explain 2 image quality evaluation method, PSNR and SSIM. Peak Signal-to-Noise Ratio(PSNR)

Fig. 5: The moving average filter(left) and bilateral filter(right)

is a ratio of peak signal that affect reproducibility of image quality to noise that deterioration in image quality. The PSNR is defined from Eq.3 and Eq.4. In most cases, the MAX in Eq.4 is 255 that is most higher pixel value. Mean Square Error(MSE) is the comparison of 2 input images 's mean square error. The PSNR is consist of MSE, the more MSE, the loss PSNR. Structural SIMilarity(SSIM) is close to subjective evaluation to humans that is consist of pixels average, standard deviation and covariance of 2 input images. The SSIM can be obtained from Eq.5. μ_x, μ_y are pixels average of input images X and Y. $\sigma_x, \sigma_y, \sigma_{xy}$ are standard deviation and covariance of input images X and Y.

$$PSNR = 10log_{10}\left(\frac{MAX^2}{MSE^*}\right) \tag{3}$$

$$MSE^* = \frac{1}{N\times M}\sum_{i=0}^{N}\sum_{j=0}^{M}(I_1(i,j)-I_2(i,j))^2 \tag{4}$$

$$SSIM = \frac{(2\mu_x\mu_y+C_1)(2\sigma_{xy}+C_2)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_x^2+\sigma_y^2+C_2)} \tag{5}$$

III. Previous Method

In previous research, parameter of bilateral filter is brute force search σ_d for all from 2 to 50 step 1 and σ_r for all from 0.5 to 2.5 step 0.1. As a result, best range of σ_r and σ_d was found. In this range, there is peak of PSNR for each images. The range is $0.5 \sim 2.5$ of σ_r and $10.0 \sim 35.0$ of σ_d. But, this method requires to execute filter process about 500 times as all combination of σ_r and σ_d. So if execute 500 times, execution time is increases in proportion to the input image size. Figure 6 shows input image size versus execution time of conventional searching method. When input image size larger than 2048^2, execution time of search method is over 1 hours when PSNR used, and 6 hours over when SSIM used. We need parameter search method less execution times than conventional method.

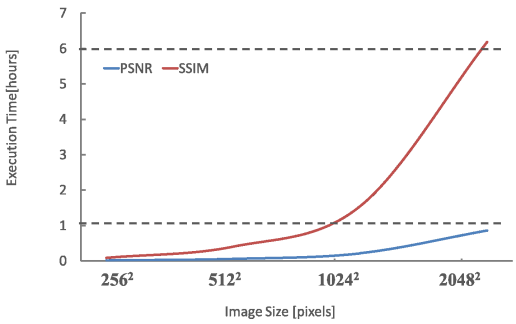

Fig. 6: Results of PSNR and SSIM for image size and execution time

IV. Proposed Method

Bilateral Filter has a feature that be able to remove noise effectively by filtering several times than searching optimum parameter. In this article, we confirmed that feature is valid for medical image which are monochrome images as well. We experiment how times repeat bilateral filter for noised medical images to check how increase image quality evaluation. Used medical image is Computed Radiography(CR) image from NCC-CIR(National Cancer Center - Cancer Image Reference database). The CR image is an X-ray image of human lung [5]. Figure 7 shows noised CR image that is lung with cancer. Figure 8 shows smoothed Fig.7 with purpose method. It can be seen that the cancer located under the tip of the collarbone is preserved even after smoothing with purpose method.

Fig. 7: The Noised lung CR image

V. Experimental Results

We made images with noise ratio between 10% and 30% as like Fig.8, and repeated bilateral filter from 1 to 10 times for each figures. Figure 9 shows the result. The X-axis of the graph

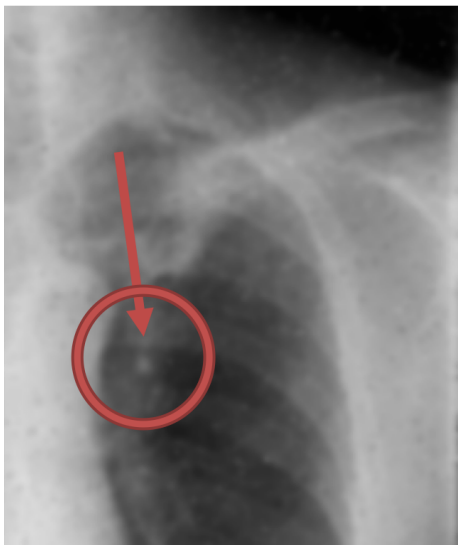

Fig. 8: The smoothed image for Fig.7

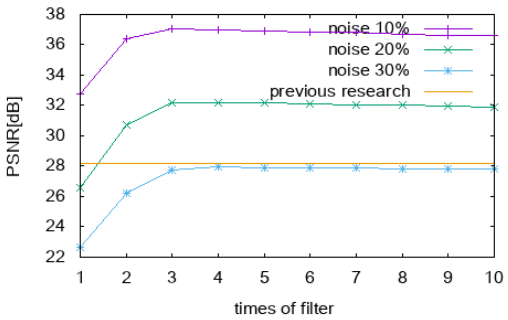

Fig. 9: Results of each noise ratio

Fig.9 is how many times execute filter. The Y-axis is PSNR score. The curve plots noise ratio $10\%{\cdot}20\%{\cdot}30\%$ in order from the top. The liner plot is the PSNR score of the conventional research. It can be seen PSNR peaks on 3 or 4 times repetition noise ratio 10% to 30% from Fig. 9. Moreover, the PSNR score of 2 times repetition when noise ratio 20% and 4 times repetition when noise ratio 30 % are better than conventional method. From the result, better PSNR score can be obtained by repeating the bilateral filter 3 or 4 times without search parameter that 500 times execution bilateral filter. Figure 10 shows comparison PSNR and SSIM of experimental results. It can be seen that for the PSNR, SSIM peaks when repetition 2 or 3 times is the same from Fig.10. By compare the 2 image quality evaluation methods, we got the result that 3 times of repetition of the bilateral filter is sufficient. We conducted an experiment execute bilateral filter by fixing σ and varying r, and by varying σ and fixing r, to examined the effective range parameters the σ and r. Figure 11 shows result of experiment with varying r. It can be seen that for the SSIM peaks when repetition 2 or 3 times is same in r range of $9 \sim 19$. Figure

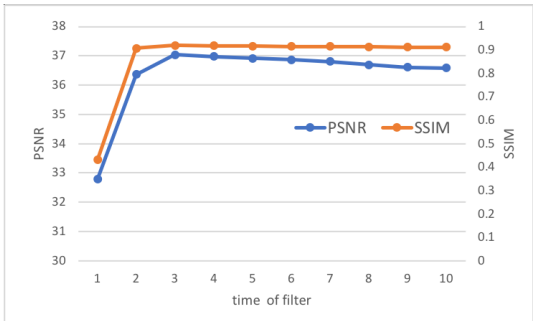

Fig. 10: Result of PSNR and SSIM for repetition

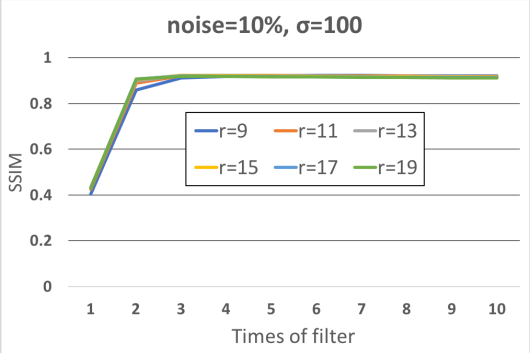

Fig. 11: Results of variable r

12 shows result of experiment with varying σ. It can be seen that for the SSIM peaks when repetition 2 or 3 times is same in σ range of $100 \sim 400$, except $\sigma = 50$.

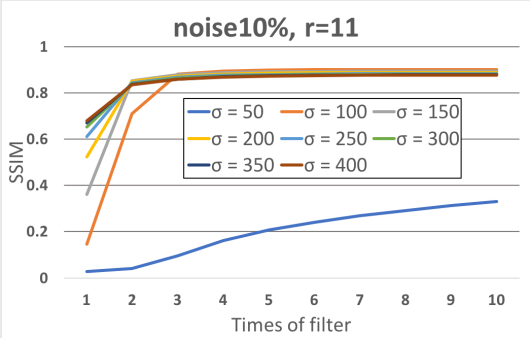

Fig. 12: Results of variable σ

VI. CONCLUSIONS

We shown how to reduce processing times of bilateral filter that filtering several times with same parameter in experiment of how many repeat smoothing process reach the PSNR, SSIM score peaks to much reduce for medical images. The result of experiments shows effective range of parameters. The repetation times is between $3 \sim 4$, r is between $5 \sim 19$, σ is between $100 \sim 400$. Based on this result, we will construct parameter search algorightm for bilateral filter. In the conventional research, reducing range of parameters by result of brute force search. In this research, reduce the overall processing steps by repeat the bilateral filter smoothing. As a result, we found how to improve image quarity, from result experiment.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI Grant Number JP17K01063.

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