

Dynamic Performance Testing of Excluded Spectra Range of Band-Stop-Filter

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Abstract

This paper studies about band-stop-filter which attenuates certain areas, and passes very high and very low band of frequencies. We study the influence of excluded spectra range by evaluating MSE and PSNR performance. Simulation results confirm that accepting more high frequency energy improves image details, and accepting more low frequency energy enriches image intensities.

Keywords: *band-pass-filter, band-stop-filter, digital image, frequency domain, spectra*

1. Introduction

The low-pass, high-pass, band-pass, and band-stop filtering processes are basic operations, which can be in the domains of spatial or frequency [1]. In this paper, we apply frequency domain band-pass-filter and evaluate the performance according to the range of spectrum [2]. The low-pass-filter is also known as filters for blurring or smoothing process, while the high-pass-filter is known as edge extraction. The most straightforward low-pass-filter process is average filter which average of neighbor pixels for its result pixel and the result pixel replace the original pixel. In image processing, a band-stop-filter is a filter that approves most frequencies without any changing, but attenuates those in a certain range to very low levels. Thus, this is opposite operation of a band-pass-filter. A good example of band-stop-filter is the notch filter which only passes narrow stopband [3].

Frequency domain filters operate an image in the frequency domain. First of all, the image is transformed by some kernel (usually Fourier transform), multiplied with the filter function (average, low-pass-filter, high-pass-filter, band-pass-filter, *etc.*) and then re-transformed into the spatial domain. Normally, weakening low frequencies intensifies the edges and weakening high frequencies makes images blur.

In this paper, we investigate the influence between excluded spectra range and the image performance. The paper is divided as follows. In Section 2, Fourier transform is described. The simulation results are presented in Section 3. Finally, in Section 4, we present our conclusions.

2. Fourier transform

The Fourier transform was invented by Joseph Fourier, which is a mathematical transform with many applications in physics, engineering, and image processing. Fourier transform is a

crucial image processing method which is employed to decompose an image into its kernels, sine and cosine components [4-6]. The output of the Fourier transform shows the image in the frequency domain, where the intensity represents the power of its kernels [7-28]. This Fourier transform can be used in numerous image applications such as filtering, analysis, compression, reconstruction and restoration. Since we are only dealing with digital images, we only study the case of discrete Fourier transform (DFT). The DFT is the decimated Fourier transform, thus DFT does not include all image frequencies, while the DFT is only a group of components which must meet the condition: the number of components is large enough to entirely depict the spatial domain image. Let us assume an image with size $M \times M$, then 2D DFT is described by:

$$F(u, v) = \sum_{x=0}^{M-1} \sum_{y=0}^{M-1} f(x, y) e^{-j2\pi \left(\frac{ux+vy}{M} \right)}, \quad (1)$$

where $f(x,y)$ is an image in the spatial domain. The exponential term is the basis function pointing out each component $F(u,v)$ in the Fourier domain. Equation (1) is explained as follows. Each point $F(u,v)$'s intensity is computed by multiplying the image in spatial domain with the matching basis function and adding the results up. Two basis functions are sine wave and cosine wave with expanding frequencies. In other words, $F(0,0)$ stands for the DC energy of the image which tells the average intensities. $F(M-1,M-1)$ stands for the highest frequency. The inverse Fourier transform is described as Eq. (2).

$$f(x, y) = \frac{1}{M^2} \sum_{x=0}^{M-1} \sum_{y=0}^{M-1} F(u, v) e^{j2\pi \left(\frac{ux+vy}{M} \right)}. \quad (2)$$

3. The Effect of Excluded Spectra Range of Band-stop-filter

To evaluate the effect of excluded spectra range, we made an ideal band-stop matrix, which is binary matrix bm defined by:

$$bm(x, y) = \begin{cases} 1 & \text{if the position is in the specific band,} \\ 0 & \text{otherwise.} \end{cases} \quad (3)$$

Figure 1(a) is the Fourier transformed image of Baboon, and the circle in Figure 1(b) is matrix bm , with range=50. Then, the inverse Fourier transform (Φ) of the component-wise multiplication of $F(u,v)$ and bm is the result we obtain.

$$\Phi(F(u, v) \cdot bm) \quad (4)$$

Figure 1(c) shows the result image after we apply filter in Eq. (4) to an original Baboon image.

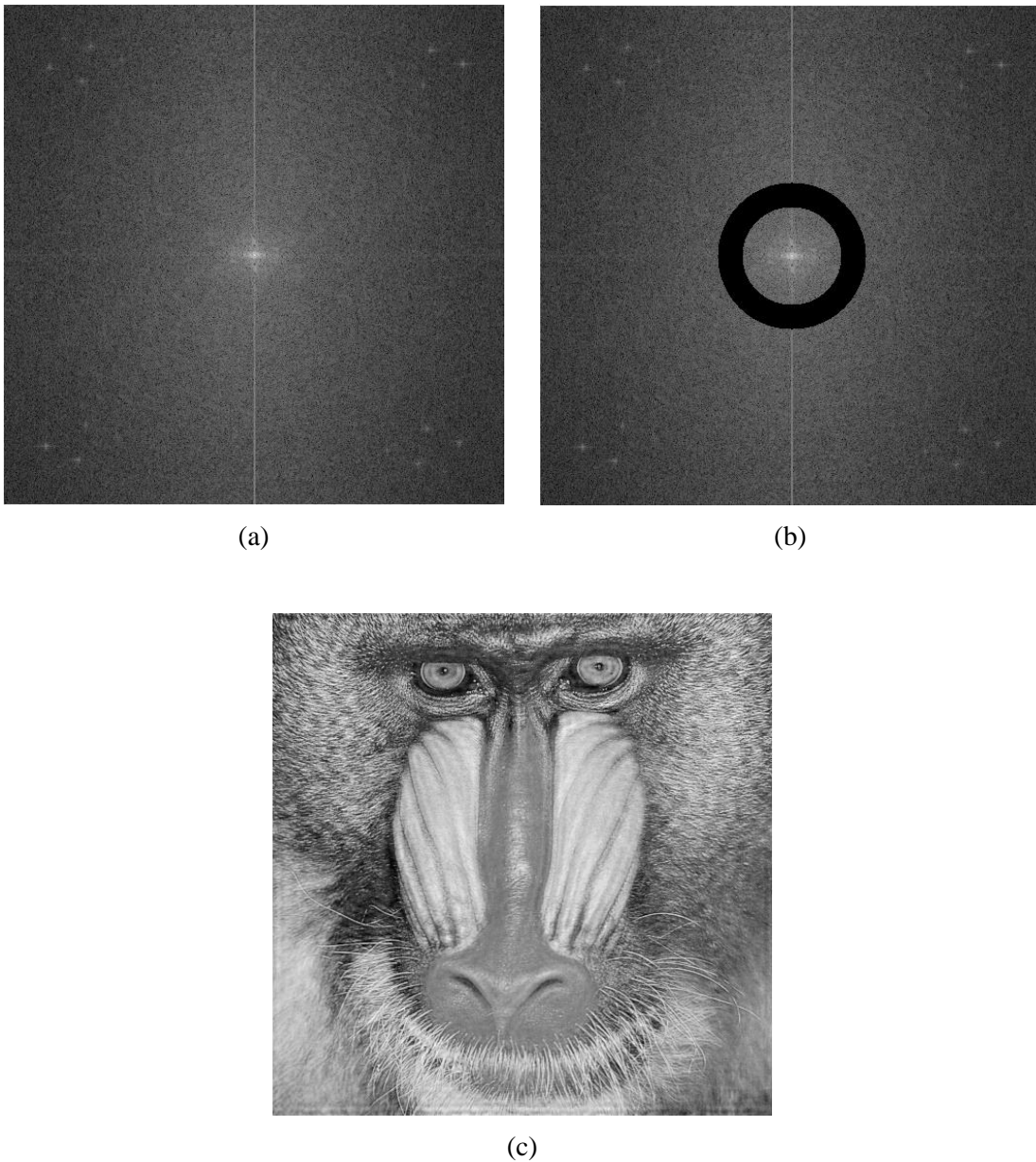


Figure 1. (a) Original Baboon image's DFT image, (b) DFT image's ideal band-stop-filtered image (range=50), (c) ideally filtered Baboon image

4. Performance investigation of excluded spectra range

In this section, we conducted experiments on 12 standard still images with the size of 512×512 . They are Airplane, Baboon, Barbara, Boat, Finger, Girl, Lena, Man, Milkdrop, Peppers, Toys, and Zelda. To obtain PSNR and MSE performances according to the excluded spectra range, we evaluated the performance when $0 \leq \text{range} \leq 250$, with the step size of 25. Figure 2 shows the MSE results according to the excluded spectra range 0, 25, 50, 75, 100, 125, 150, 175, 200, 225, and 250. Table 1 shows the PSNR results according to the excluded spectra range.

Figures 3-5 show the band-stop-filtered result images of Airplane, Girl, and Barbara. As we expected, when we removed low frequency energy we only obtained edge images as shown in Figure 3(a) and Figure 4(a). On the other hand, when we remove high frequency energy, we obtained blurred images.

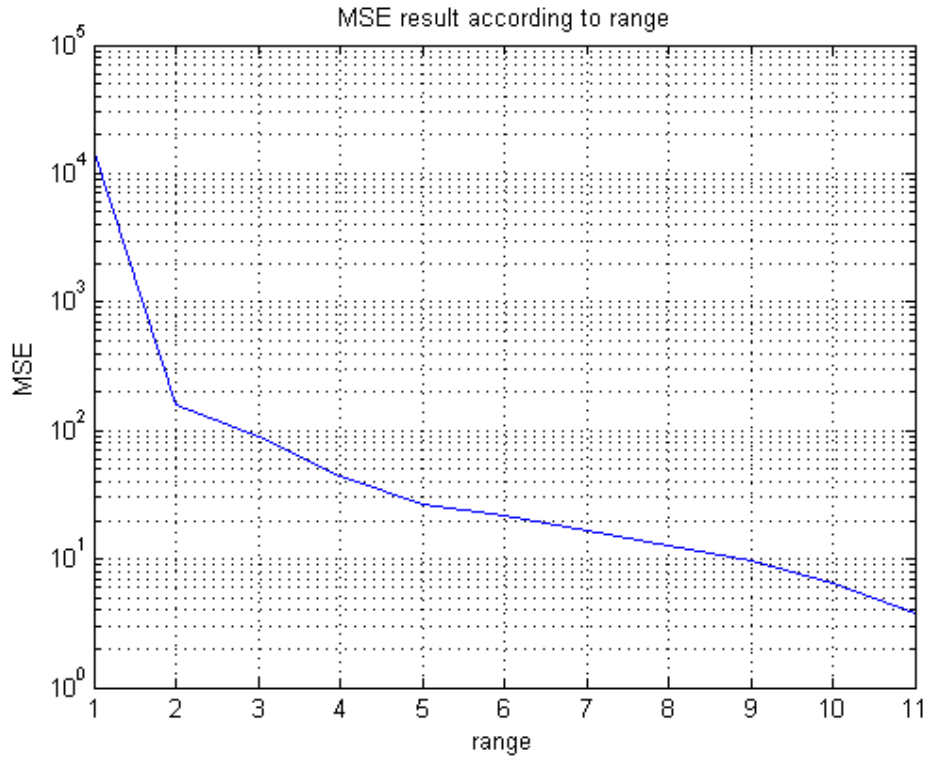


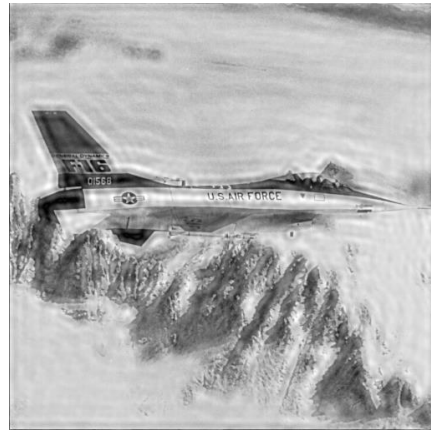
Figure 2. MSE results according to the spectra range

Table 1. Average PSNR according to the excluded spectra range

Range	0	25	50	75	100	125	150	175	200	225	250
Air	3.28	24.58	28.72	31.89	34.99	37.23	39.44	41.71	43.25	44.09	46.90
Bab	6.53	26.90	28.11	28.45	29.07	29.82	30.50	31.61	32.56	33.16	35.49
Bar	6.76	26.58	31.52	34.22	34.73	30.24	30.36	30.94	32.68	38.04	42.86
Boat	6.04	25.83	28.58	30.89	33.44	35.30	37.29	38.64	39.85	40.10	42.49
Finger	8.04	24.18	22.27	26.99	30.11	33.12	36.44	39.57	41.57	43.24	44.99
Girl	5.62	27.97	30.41	35.98	38.89	41.92	44.31	45.64	47.27	47.97	49.88
Lena	6.20	26.61	31.05	33.54	36.34	38.92	40.56	42.64	44.20	45.07	47.13
Man	8.62	24.70	28.42	30.68	32.30	33.57	34.72	35.48	36.20	36.72	38.22
Milk	7.34	28.36	34.82	37.77	40.44	42.81	44.44	45.18	45.82	46.42	49.25
Pepper	6.38	26.34	31.80	35.19	37.75	39.39	40.78	41.98	42.77	42.56	44.10
Toys	6.98	25.30	29.70	32.38	35.59	38.25	39.68	41.03	42.14	44.13	47.01
Zelda	7.22	29.87	35.31	38.04	41.22	44.01	46.02	47.21	48.37	48.69	50.95
Avg.	6.58	26.43	30.06	33.00	35.41	37.05	38.71	40.14	41.39	42.52	44.94



(a)



(b)



(c)



(d)



(e)



(f)

Figure 3. (a) Band-stop-filtered image of Airplane image with excluded spectra range=0, (b) excluded spectra range=25, (c) excluded spectra range=50, (d) excluded spectra range=75, (e) excluded spectra range=100, (f) excluded spectra range=125



(a)



(b)



(c)



(d)



(e)



(f)

Figure 4. (a) Band-pass-filtered image of Girl image with excluded spectra range=0, (b) excluded spectra range=25, (c) excluded spectra range=50, (d) excluded spectra range=75, (e) excluded spectra range=100, (f) excluded spectra range=125



(a)



(b)



(c)



(d)



(e)



(f)

Figure 5. (a) Band-pass-filtered image of Barbara image with excluded spectra range=0, (b) excluded spectra range=25, (c) excluded spectra range=50, (d) excluded spectra range=75, (e) excluded spectra range=100, (f) excluded spectra range=125

5. Conclusions

The band-pass-filter attenuates low and high frequency areas, and only passes a middle range band of frequencies. The band-pass-filter can be adopted to intensify details by stopping low frequencies. In this paper, we dealt with ideal band-stop-filter and evaluated its performance by excluding certain frequency area.

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