2021 IEEE 4th Advanced Information Management, Communicates, Electronic and Automation Control Conference (IMCEC) | 978-1-7281-8535-4/21/$31.00 ©2021 IEEE | DOI: 10.1109/IMCEC51613.2021.9482311

# Optimization of Target Artifact Under Diffuse Reflection

Sihan Wu[1], Yong Yi[2], Kai Zhu[1*]

1. Nanjing University Jinling College, Nanjing,China
2. China Academic of Electronics and Information Technology

wusihan9907@163.com, zhukai@jlxy.nju.edu.cn

Corresponding Author: Kai Zhu zhukai@jlxy.nju.edu.cn

***Abstract*—As a common way of information acquisition, digital image acquisition has a wide range of applications. In daily life, due to the limitation of the scene, there will be diffuse reflection in the process of image acquisition, which leads to the presence of artifacts or highlights in the process of image acquisition and affects the quality of image acquisition. In order to suppress the above situation, the suppression effect of homomorphic filtering on artifacts is studied, and the filtering effects of ideal low-pass, Gaussian low-pass and Butterworth low-pass are compared. In Butterworth low-pass filtering, the cut-off frequency has an obvious effect on the suppression, and an adaptive cut-off frequency is designed. Through experimental comparison, the designed adaptive cutoff frequency has a good effect on the suppression of artifacts.**

***Keywords—image optimization; artifact remove; homomorphic filtering; frequency adaptation***

## I. INTRODUCTION

With the rapid popularization of all kinds of digital products, digital images have changed into the most important information carrier in people's life. Photograph as a direct image acquisition method has a wide range of applications, but in practical application, reflection interference is inevitable, resulting in part of the image out of focus or high light pollution. When shooting objects with diffuse reflection, such as metal plates, glare or reflection will introduce a lot of noise, which will affect the analysis of the image. In view of this situation, some scholars at home and abroad have carried out research to improve the imaging quality.

Xuaner proposed an end-to-end full convolutional network based on two visual perception networks and anti-loss networks. Chang et al. proposed to synthesize multiple reflected images from a single input image based on a ghost model and relative intensity. Renjie proposed the use of concurrent reflection removal network (CRRN) under the unified framework[1]. Jun proposed to construct a multi-mode CNN, which used the depth of field information of the reflected image to separate the reflection. Sun et al. proposed that, first of all, the image can be divided into reflective region and non-reflective region according to the characteristics of reflection in the image[2]. Then, the intensity of the primary reflection was reduced to suppress the primary reflection. The gradient priori of the natural image was used to model the reflection removal problem, and the objective function was constructed to remove the residual and secondary reflection. Finally, the reflection removal result obtained by this step is superimposed with the non-reflection area to obtain the final reflection removal result[3]. Xiong et al. obtained a priori of gradient sparsity of natural images by analyzing the natural images. Gradient sparsity priori is used to illustrate our optimization problem. Finally, the iterative weighted least squares algorithm is used to solve the optimization problem to obtain the target transmission image and reflection image.

The technology of dereflection can be divided into hardware dereflection and software dereflection according to the different methods used[4]. The hardware dereflection is realized by installing polarizing lens on the camera. This method has the best effect, but it is expensive and does not have universality. The software method uses the algorithm to suppress the reflected light. According to the number of input images required by the algorithm, the algorithm can be divided into multi-image-based and single-image-based reflection removal algorithms. The mirror reflection removal technology of multiple images refers to that multiple images (more than two images) are taken as the experimental input of the research, and the difference between the background layer and the reflection layer in the image sequence is taken as the starting point of the research to achieve the purpose of removing the mirror reflection. When the shooting conditions are limited, there can only be one picture. The reflection suppression algorithm is based on the reflection removal of a single image, and the reflection removal algorithm of a single image is mostly realized through homomorphic filtering.

## II. Research on homomorphic filter optimization

Homomorphic filtering is based on a simple luminance imaging model. Everyday images are usually measured by the light reflected off objects in the scene. So it's basically determined by two factors:one is the amount of light incident on the visible scene, another is the rate at which an object in a scene reflects incident light[5]. An imaging model as follows:

$$f(x,y) = i(x,y) * r(x,y) \quad (1)$$

*i(x,y)* is illumination and *r(x,y)* is reflect. The unit of illuminance is *LX*, fine summer is in the illuminance of indoor good daylighting 100~ 500*LX*. Reflection has no units, just the ratio of the amount of reflection to the amount of incident, such as the ratio of stainless steel is 0.65, and painted white wall plane is 0.80.

The illumination component in the image changes slowly, while the reflection component tends to change violently, especially at the junction of different objects[7]. Because of this feature, the low frequency component of the Fourier transform of the natural logarithm of the image is related to the illumination component, while the high frequency component is related to the reflection component. The purpose of homomorphic filtering is to change the original multiplicative problem into additive problem according to the above principle, and optimize the image by designing a filter. The homomorphic filtering process based on the imaging model is shown as Fig.1.

$$f(x,y) \to [\ln] \to [FFT] \to [H(u,v)] \to [FFT^{-1}] \to [\exp] \to g(x,y)$$

Fig.1 Flow chart of homomorphic filtering

The idea of homomorphic filtering transforms the multiplicative model into an additive model through logarithmic transformation, and it as follows:

$$\ln f(x,y) = \ln i(x,y) + \ln r(x,y) \quad (2)$$

Take the Fourier transform of equ. 2 as equ3.

$$F(u,v) = I(u,v) + R(u,v) \quad (3)$$

Low-pass filter *H(u,v)* was designed to process *F(u,v)* as equ.4

$$H(u,v)F(u,v) = H(u,v)I(u,v) + H(u,v)R(u,v) \quad (4)$$

Inverse transform as equ.5

$$h_f(x,y) = h_i(x,y) + h_r(x,y) \quad (5)$$

In the process of shooting, the reflection component is concentrated in the high frequency part, so we can try to improve the reflection through the low-pass filter. The commonly used low-pass filters are ideal low-pass filter, Gaussian low-pass filter and Butterworth low-pass filter.

## III. Comparison of low- pass filters

In the frequency domain, the cut-off frequency $D_0$ is a key value, the frequency *D(u,v)* of the point *(u, v)* of the spectrum is the distance from the point *(u, v)* to the center of the spectrum, and *D(u,v)* is shown as equ.6.

$$D(u,v) = \sqrt{(u-\frac{U}{2})^2 + (v-\frac{V}{2})^2} \quad (6)$$

In equ.6, *(U,V)* is the width and height of the image spectrum.

The ideal low-pass filter is shown as equ.7. In equ.7, $D_0$ is Nonnegative integer.

$$H(u,v) = \begin{cases} 1, D(u,v) \le D_0 \\ 0, D(u,v) > D_0 \end{cases} \quad (7)$$

Butterworth low-pass filter is a kind of low-pass filter which can be realized in physics. It has the largest flat amplitude frequency response. The model of n-order Butterworth low-pass filter with cut-off frequency of $D_0$ is shown as equ.8.

$$H(u,v) = \frac{1}{1+(D(u,v)/D_0)^{2n}} \quad (8)$$

Gaussian low-pass filter is based on the shape of Gaussian function for linear smoothing of the image, so Gaussian low-pass filter can effectively suppress noise at the same time, the edge information of the aliasing degree is smaller, the image blur degree is lower[8]. The model of Gaussian low pass filter is shown in equ.9.

$$H(u,v) = e^{\frac{-D^2(u,v)}{2D_0^2}} \quad (9)$$

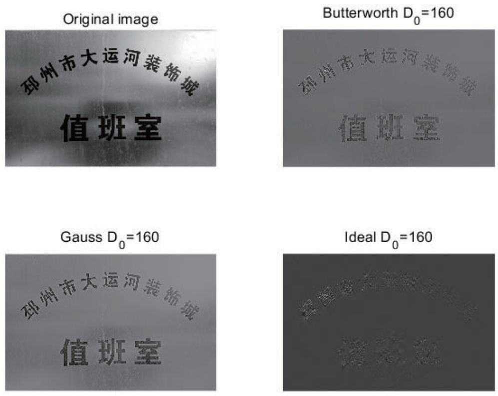


Fig.2 Comparison of three low-pass filters

In the case of cut-off frequency $D_0=311$ the effect of three low-pass filters is shown in Fig.2. As can be seen from Fig..2, the effect of ideal low-pass filter is not what we want, and the effect is very bad. The effect of Gaussian low-pass filter and Butterworth low-pass filter is similar.

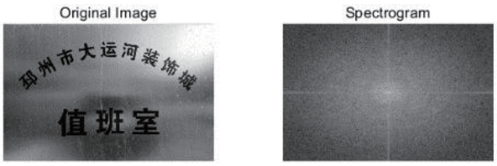


Fig.3 The original image and its spectrum

The original image and its spectrum are shown in Fig.3, and the spectrum diagram size is $654*1008$, take the reference radius $R = min(654,1008)$, the cut-off frequencies $D_0$ are $0.1R$(65), $0.2R$(131), $0.3R$(196), $0.4R$(262), $0.5R$(327), $0.6R$(392), $0.7R$(458), $0.8R$(523), $0.9R$(589). The effects of Gaussian low-pass filter, first-order Butterworth filter and second-order Butterworth filter are shown in Fig. 4, Fig. 5 and Fig. 6.

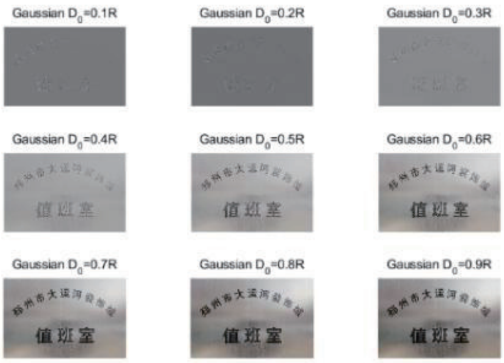


Fig.4 The effect of Gaussian low-pass filtering

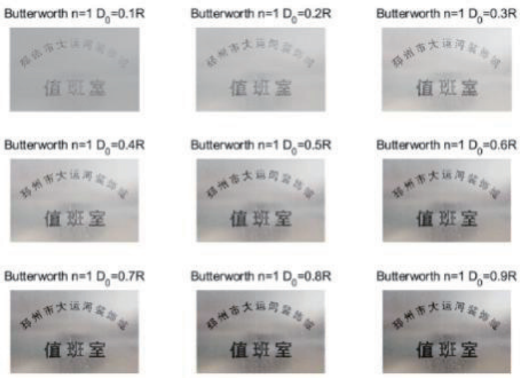


Fig.5 The effect of first-order Butterworth low-pass filtering

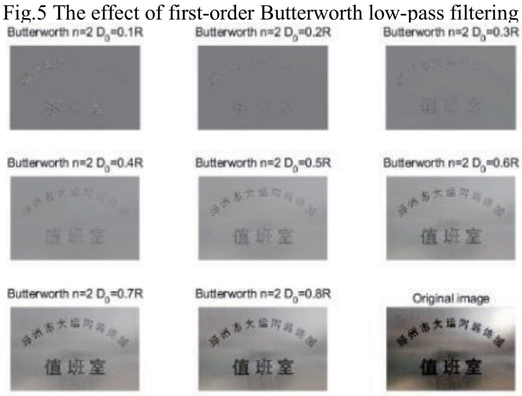


Fig.6 The effect of second-order -order Butterworth low-pass filtering

Comparing Figure. 4, Figure. 5 and Figure. 6, it is easy to see through subjective evaluation that under the Gaussian low-pass filter, when $D_0=0.4R$ or $D_0=0.5R$, it has better suppression effect; under the first-order Butterworth low-pass filter, when $D_0 = 0.4R$ or $D_0 = 0.5R$, it has better suppression effect; under the second-order Butterworth low-pass filter, when $D_0=0.6R$ or $D_0=0.7R$, the time consumption of three kinds of filtering is shown in Table 1.

TABLE I. THREE KINDS OF FILTERING TIME CONSUMING(MS)

| Consume time | Filter | | |
|---|---|---|---|
| | *Gaussian low-pass filter* | *first-order Butterworth low-pass filter* | *second-order Butterworth low-pass filter* |
| $D_0=0.1R$ | *0.94083* | *0.81042* | *0.88391* |
| $D_0=0.2R$ | *0.70411* | *0.74299* | *0.81434* |
| $D_0=0.3R$ | *0.80785* | *0.77192* | *0.80668* |
| $D_0=0.4R$ | *0.83887* | *0.83079* | *0.88511* |
| $D_0=0.5R$ | *0.87858* | *0.81566* | *0.77604* |
| $D_0=0.6R$ | *0.81994* | *0.77559* | *0.75932* |
| $D_0=0.7R$ | *0.83356* | *0.81134* | *0.83228* |
| $D_0=0.8R$ | *0.77942* | *0.75165* | *0.78464* |
| $D_0=0.9R$ | *0.77645* | *0.73055* | *0.79099* |

By comparison, the Butterworth first order low pass filter has the best efficiency in the three filters.

## IV. IMPROVEMENT OF FIRST ORDER BUTTERWORTH LOW-PASS FILTER

On the basis of Fig.5, further refine the cut-off frequency of the first-order Butterworth low-pass filter between $D_0=0.4R$ and $D_0= 0.5R$, the effect is shown in Fig.7.By comparison, when $D0 = 0.44R$~$0.45R$, the inhibition effect is better.

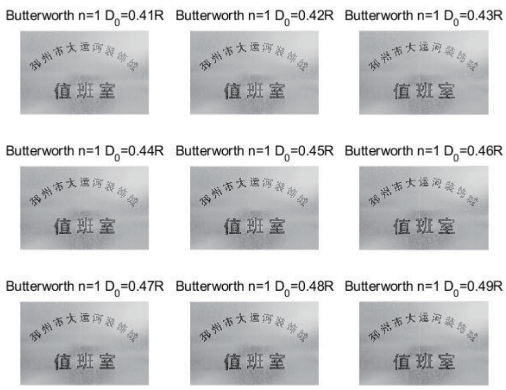


Fig 7 The effect of $D_0=0.41R$ to $D_0=0.49R$

The model transfer comparison is carried out by reconstructing the images with different resolution by Laplace pyramid. Firstly, the Gaussian pyramid is constructed, and each one is processed by homomorphic filtering. The pyramid after filtering is constructed and reconstructed. Finally, the reconstructed image is compared with the image after homomorphic filtering, and then compared with the image after single image processing Image comparison. The Gaussian kernel used is as follows：

$$\frac{1}{256}*\begin{bmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix} \quad (6)$$

Convolute the constructed Gaussian check image, and then do down sampling. Store the Gaussian image of each layer in cell, repeat the above operation, and then perform homomorphic filtering. The effect is shown in Fig.8. The image size and cut-off frequency are listed in Table 2.

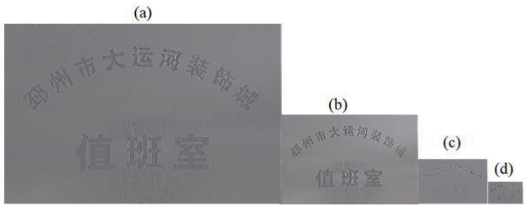

Fig.8 the effect at different scales

TABLE II. IMAGE SIZE AND CUTOFF FREQUENCY

| | *a* | *b* | *c* | *d* |
|---|---|---|---|---|
| *Size m*n* | *654*1008* | *327*5004* | *163*2502* | *81*1251* |
| *cutoff frequency* | *291* | *145* | *72* | *36* |

By comparison, at the cut-off frequency $D \approx 0.45*min(n,m)$, it has a better suppression effect under different image sizes. The cut-off frequency is migrated in other scenes, and the optimization effect is shown in Fig. 9.

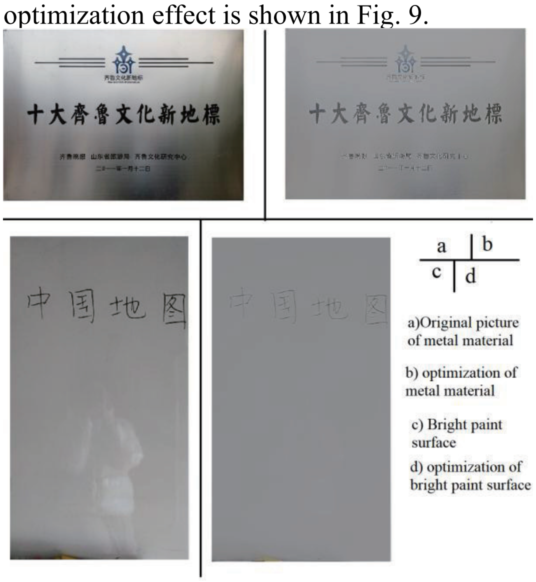

Fig.9 the effect at different target

## V. CONCLUSIONS

In this paper, aiming at the situation that the target has the characteristics of reflection in the process of shooting, which will produce artifacts on the imaging, a method based on homomorphic filtering is proposed to suppress the reflection, and the effects of ideal low-pass, Gaussian low-pass and Butterworth low-pass are compared. Then, the Gaussian low-pass and Butterworth low-pass are further compared, and an adaptive cut-off frequency selection method is proposed to eliminate the artifacts After that, the image quality of low-pass image is reduced, and enhancement technology is used to improve the suppressed image. After comparison, the suppression model designed in this paper has a good suppression effect on the artifacts produced by reflection.

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