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Fast and high-quality object reconstruction based on Fourier spectrum acquisition in single-pixel imaging

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Abstract: In single-pixel imaging, Fourier spectrum acquisition method is applied to generate an initial guess in Gerchberg-Saxton-like algorithm to reduce measurement number, improve convergence rate and recover high-quality object at the same time.

OCIS codes: (110.1758) Computational imaging; (110.3010) Image reconstruction techniques.

1. Introduction

In single-pixel imaging (SPI), a basic setup can be considered as the computational ghost imaging (CGI) setup [1]. In Ref. [2], it was demonstrated that a Gerchberg-Saxton-like algorithm based on SPI setup can improve the quality of recovered image greatly. Another SPI method, called Fourier spectrum acquisition method, can calculate the Fourier coefficients in Fourier domain by taking advantage of sinusoidal patterns [3]. However, these two methods need a large number of measurements, and are time-consuming.

In this paper, a fast and high-quality object reconstruction method is proposed in SPI. Firstly, partial Fourier coefficients are calculated to get an initial guess by using the Fourier spectrum acquisition method. Subsequently, the initial guess and the used sinusoidal patterns are applied in Gerchberg-Saxton-like algorithm. The proposed method can reduce measurement number, improve convergence rate and recover a high-quality object at the same time.

2. Theoretical analyses

The setup for SPI is shown in Fig. 1. The measurement process can be expressed as

$$B_i = \int dxdy I_i(x,y) O(x,y), \qquad (i = 1,2,3,...,M) \tag{1}$$

where the illumination patterns $I_i(x,y)$ is sinusoidal pattern, $O(x,y)$ is the object and B_i is the value detected by bucket detector.

The method in Ref. [3] is used to get an initial guess. With this initial guess and the sinusoidal patterns, a Gerchberg-Saxton-like algorithm in Ref. [2] is used to further improve reconstruction quality. The definition of SNR used in Ref. [4] is applied here.

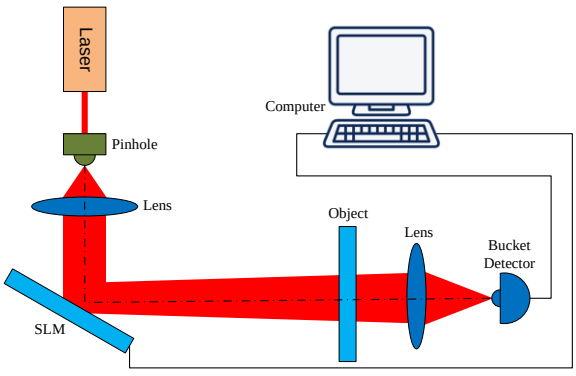

Fig. 1. The schematic setup for SPI.

3. Results and discusssion

Figure 2 shows typical results by using the proposed method. Figure 2(b) shows an initial guess obtained by using the Fourier spectrum acquisition method, and Fig. 2(c) shows the result obtained by using the proposed method. Table 1 shows more detailed information for the proposed method. The different ratios in the first column mean that

different ratios of Fourier coefficients are calculated by using the Fourier spectrum acquisition method. The second column represents the number of sinusoidal patterns used in different cases. As can be seen from the second column, the largest number is about half of the pixel counts of image. The third column and the fourth column represent initial SNR values obtained by using Fourier spectrum acquisition method and improved SNR values obtained by using the proposed method, respectively. It can be seen that the proposed method is feasible and effective, and the reconstructed objects are of high quality.

(a) (b) (c)

Fig. 2. (a) Original image with 64×64 pixels, (b) an initial guess obtained by using Fourier spectrum acquisition method with sampling ratio of 0.5, and (c) result with improved quality by using the proposed method.

Ratio	Measurement number	Initial SNR	Improved SNR
0.5	2164	8.02	22.21
0.4	1642	5.39	9.12
0.3	1334	4.26	6.78
0.2	814	2.88	3.72
0.1	422	1.95	2.24

Table 1. Results for different ratios.

In the proposed method, the fast convergence rate is further illustrated in Fig. 3.

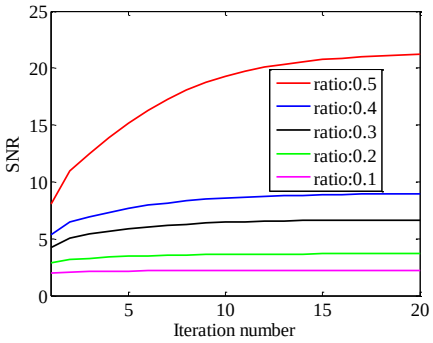

Fig. 3. The SNR value versus iteration number with different ratios.

4. Conclusions

A fast and high-quality object reconstruction method has been proposed in SPI. The method takes advantage of Fourier spectrum acquisition method and Gerchberg-Saxton-like algorithm to reduce measurement number, improve convergence rate and carry out high-quality reconstruction. Effectiveness of the proposed method is validated by simulation results.

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