Phase imaging with a coded aperture and super-resolved reconstruction

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1. Introduction

Phase imaging is a useful tool for visualizing transparent specimens, such as biological cells, without fluorescence labeling. Digital holography and diffractive imaging are established methods for phase imaging although they have a tradeoff between the measurement speed and the observable space-bandwidth product [1, 2]. We have recently reported single-shot and wide FOV phase imaging with coded modulation [3-6]. Here we enhance the throughput of this phase imaging method with a super-resolved reconstruction.

2. Method

The optical setup of single-shot phase imaging with a coded aperture is shown in Fig. 1 [3]. A coded aperture is placed between the object and the image sensor to improve the condition of phase retrieval. In the proposed method for high-throughput phase imaging, the image sensor is assumed to have a larger pixel and a lower pixel count than those on a coded aperture as shown in Fig. 1. Such an image sensor provides a high frame rate due to a low signal-to-noise ratio and a short readout time compared to an image sensor with small pixels and a large pixel count. However, the spatial resolution degrades in this case.

To solve the above tradeoff, we introduce a subpixel intensity constraint in phase retrieval [7]. In this new algorithm, the brief process of the reconstruction is the same as the phase retrieval in single-shot phase imaging with a coded aperture. The process is executed with a pixel pitch of the coded aperture, which is smaller than that of the image sensor. In each iteration, the summation of subpixel intensities on each pixel of the image sensor is replaced by a pixel intensity on the sensor pixel. Then, subpixel information is retrieved. A sparsity constraint is also employed to solve this super-resolution problem.

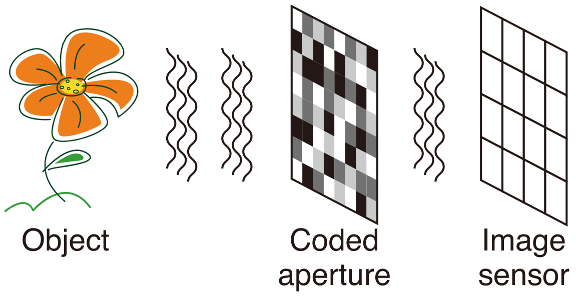

Figure 1. Phase imaging with a coded aperture and a low-resolution image sensor.

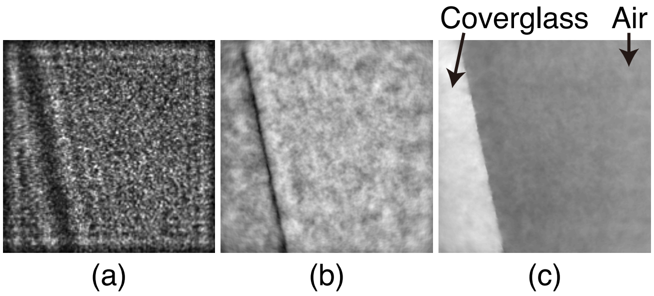

Figure 2. Experimental result. (a) Captured image with binning. Reconstructed (b) amplitude and (c) phase.

3. Experimental demonstration

The proposed method was demonstrated with binning in an image sensor (CoolSNAP MYO, manufactured by Photometrics). The coded aperture was implemented by a chrome-coated glass plate (fabricated by Kan-Dai Digital Holo-Studio in Kansai University). The object was a coverglass, which was translated by a servomotor and illuminated with a laser diode (L658P050, manufactured by Thorlabs).

The experimental result is shown in Fig. 2. The pixel count of the captured image in Fig. 2(a) is 165×165, where the downsampling ratio with binning was 3×3. The amplitude and phase of the object scene were successfully reconstructed as Figs. 2(a) and 2(b), where the pixel count is 495×495. We also confirmed the 2.1 times faster imaging speed compared to imaging without binning.

4. Conclusions

We proposed an algorithm for high-throughput phase imaging with a coded aperture. The method was experimentally demonstrated.

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