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Learning-based Classification and Imaging through Scattering Media

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1. Introduction

Sensing through scattering media is a longstanding research topic in optics and photonics, especially in the fields of biomedicine and security. Several methods have been proposed for imaging through scattering media, for example, based on the transmission matrix or the memory effect [1, 2]. We have recently demonstrated machine-learning-based methods for sensing through scattering media. Our methods simplify optical setups and alleviate assumptions in those previous methods [3, 4].

2. Classification

Object classification is an important task in sensing. In conventional approaches for classification, object images are provided to a classifier. But in some cases, such as in digital holography and computational imaging, a computational process is necessary to reconstruct the object images from the captured signals. We have shown object classification without the computational reconstruction even for imaging through scattering media [3]. In this case, the difficulties for the reconstructions are removed.

The optical setup is shown in Fig. 1. The spatial light modulator (SLM) displaying object images is located between the two scattering plates. The first scattering plate is illuminated by a collimated coherent beam. The image sensor captures speckle images through the SLM and the scattering plates. The total light transmittance and the collimated light transmittance of the scattering plates are 51.1% and 1.1%, respectively.

In the experiment, binary classification of face and non-face images was performed. 2000 training images (1000 face images and 1000 non-face images) and their speckle images were used to construct a classifier based on the support vector machine (SVM) [5]. After the training process, the SVM classifier was examined by using speckle images chosen from 200 test images (100 face images and 100 non-face images) without overlapping with the training images. The accuracy rate of the classification attained to 92.3%.

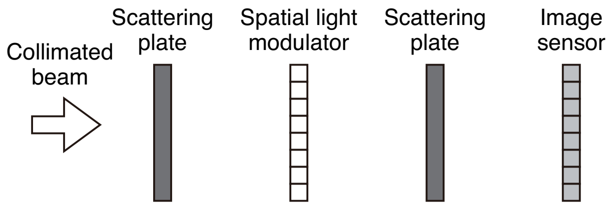

Fig. 1. Optical setup.

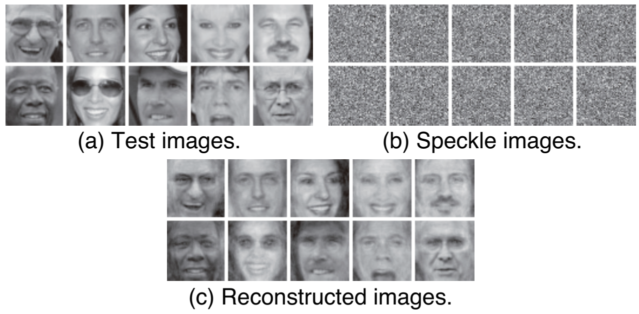

Fig. 2. Experimental result for imaging.

3. Imaging

The inverse function of the scattering process can be calculated based on a regression algorithm by using a number of object-speckle pairs [4]. Objects are reconstructed with the calculated inverse functions. This approach is applicable to a nonlinear sensing process and simplifies the optical setup, e.g. removing a reference light as shown in Fig. 1.

The experimental result is shown in Fig. 2. Here objects were face images, in which the numbers of training and test images were 4000 and 100, respectively. The support vector regression was used for the calculation of the inverse function [5]. The test images and their speckles are shown in Figs. 2(a) and 2(b), respectively. The reconstruction results are shown in Fig. 2(c). The peak signal-to-noise ratio was 21.2 dB.

4. Conclusion

We have demonstrated learning-based classification and imaging through scattering media. Our approach enables model-free sensing, in which physical processes/models are unknown.

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