Polarization imaging for 3D object recognition

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Combining the reconstructed complex amplitudes from two separate digital holograms provides a novel approach to enhanced pattern recognition.

Digital holography is a useful technique for recording all the information contained in a lightwave. The method has been used in a number of applications, including encryption and 3D object recognition. In addition, the polarization information made available by digital holography provides important clues about the surface or the interior of a material, for example, whether it has defects or is nonuniform. Reconstructing 3D objects is one of the most important functions of holography, but the technology is still in its infancy. One significant advance would be to develop a system for polarimetric imaging of 3D objects, in other words, to simultaneously obtain both polarimetric data and the shape of a 3D object from the same digital hologram. To date, however, efforts have focused on either shape or polarization.

My colleagues and I previously proposed polarimetric imaging of a 3D object by combining two different digital holograms obtained using orthogonal (i.e., perpendicular) polarized reference waves. That technique makes it possible to obtain the desired information regarding the object by recording the phase-shifted digital holograms. Here, we report preliminary experiment results using the polarimetric information to directly image a 3D object (a die). We placed two orthogonal polarizers in front of the die. The transmission axis of the right polarizer was horizontal, and that of the left one was vertical. The upper central portions of the two devices overlap. There are no polarizers in the lower central portion. A CCD camera was placed 230mm from the die. Having both the horizontal and vertical components of an object wave enables us to obtain the Stokes parameters of the object using the numerical Fresnel diffraction integral. This data in turn provides the polarimetric information about the object. Figures 1 and 2 show grayscale images based on Stokes parameters—(a) $S_0$, (b) $S_1$, (c) $S_2$, and (d) $S_3$—for a randomly polarized object without polarizers and a polarized object with polarizers. These images were obtained by combining the reconstructed complex amplitudes from the two digital holograms. They are normalized so that black and white denote minimum and maximum values, respectively.

Because the images contain both the complex amplitude and polarimetric characteristics of the object, they can then be used to improve the discriminative capability of object recognition using one or any combination of the Stokes parameters. We used conventional as well as polarimetric pattern recognition. The experimental setup was basically the same as for the polarization imaging, except that the distance from the die to the CCD was 180mm. In conventional pattern recognition, the amplitude distributions are equal to the Stokes parameter $S_0$ for both objects. Figure 3 shows the correlation signal based on this distribution. The height of the central peak gives the similarity between two objects. The difference between the autocorrelation and cross-correlation shown in the figure is small, which means that the objects are barely distinguishable.

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Polarimetric pattern recognition exploits the phase-difference distributions between the horizontal and vertical components of each object, for example, alternating polarimetric signals for both. These signals convey both the amplitude distributions and polarimetric information. Figure 4 shows a correlation signal based on this data. The height of the central peaks between the auto- and cross-correlation are quite different. This figure confirms the potential of our technique.

In summary, we have achieved polarimetric imaging of a 3D object using two kinds of digital holograms obtained by orthogonal polarized reference waves. We have also shown pattern recognition by combining the shape and the polarization information of the object obtained from the separate holograms. The combination of data provided by this technique enables higher discriminant pattern recognition than with conventional sensing. As a next step, we intend to apply this approach to recognizing and discriminating biomedical samples.

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References