INFORMATION RETRIEVAL FROM CODED IMAGES FORMED BY GENERALIZED IMAGING SYSTEMS

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Unconventional imaging systems such as e.g. arrays of pinholes get increasing importance at wavelengths where no ordinary imaging devices, i.e. lenses or mirrors, exist. However, the images formed by such systems are coded and some data processing has to be performed, in order to retrieve the original optical information.

A holographic solution of such problems has been found to be based most readily on the method of 'extended reference source' Fourier-transform holography first described by Stroke et al. [1,2] in 1965. An extension to the information retrieval for the special case of imaging with a matrix of pinholes or zone plates may be obtained by using the Stroke 'lensless Fourier-transform' point hologram [3], as first published by Einighammer [4,5], who also suggested the use of a suitable lens matrix for such applications. However, the essential 'peaked auto-correlation' function distribution, required for the pinhole camera was first suggested by Dicke [6], and the corresponding holographic solution by Stroke [7,8]. In a generalization of his methods of refs. [1-3,7-9], Stroke noted that they could form the basis of 'a new class' of optical imaging systems, and suggested, as an example, two methods capable of decoding images for such applications.

The purpose of this communication is to propose a third method which has some advantages compared with those suggested earlier. For explanation we briefly remind of the basic principle underlying this class of imaging systems.

The essential assumption is that the intensity distribution of the coded image can be described as the convolution

$$\sigma \otimes p = \iint \sigma(x,y) \cdot p(\xi-x,\ \eta-y)\ \mathrm{d}x\mathrm{d}y \qquad (1)$$

of the object $\sigma(x,y)$ with the point spread function $p(x,y)$ of the system, i.e., except for a translation $p(x,y)$ has to be shift invariant over the object field. Then the object information $\sigma(x,y)$ is retrievable, if the autocorrelation function

$$p * p^* = \iint p(x,y) \cdot p^*(\xi+x,\ \eta+y)\ \mathrm{d}x\mathrm{d}y \qquad (2)$$

of the point spread function $p(x,y)$ is a δ-function or similar to it [7-9]. According to earlier suggestions this data processing can be performed by recording the Fourier-transform hologram of the blurred object information $\sigma \otimes p$ using the point spread function p (first method) or the δ-function (second method) as a reference source. On suitable reconstruction one obtains $\sigma \otimes p * p^*$.

The disadvantage is that an *individual hologram has to be recorded from each coded image*. In order to avoid this drawback we now propose to record, once only, the Fourier-transform hologram of the point spread function p for a given imaging system, by using a δ-function (i.e. a suitable illuminated pinhole) as the reference source. The essential terms stored in the hologram are

$$|P+D|^2 = PP^* + DD^* + PD^* + P^*D, \qquad (3)$$

where P and D denote the Fourier-transforms of the point spread function p and the δ-function, respectively. Using this single hologram it is quite simple to construct a decoding apparatus for all coded images obtained by the corresponding generalized imaging system. One has just to put that hologram into the filter plane of an ordinary Fourier-transform arrangement where the Fourier-transform $f[\sigma \otimes p] = S \cdot P$ [8] of the coded image is displayed (S being the Fourier-transform of the decoded image σ). Then, according to the fourth term of eq. (3) the virtual image

$$f^{-1}[S \cdot PP^{*} \cdot D] = \sigma \otimes p * p^{*} \otimes \delta \qquad (4)$$

is reconstructed in the surrounding of the position of the reference source used in the recording process. This convolution of the object function σ and the autocorrelation function of the point spread function p is equal to the decoded image if

$$p * p^{*} \approx \delta . \qquad (5)$$

As in another holographic image synthesis method described by one of us (GWS) [10], we may note that another advantage of this method is that the *zero order* image terms of the hologram are not broadened since they correspond to δ-functions when eq. (5) is fulfilled.

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