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Extraction of difference of two images using periodic carrier modulation

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ABSTRACT

The optical method of extraction of difference between transparencies using periodic carrier modulation was first proposed and successfully demonstrated by Pennington. His method was based on the modulation of each of the image transparencies by the same grating with the difference that one modulating carrier was shifted by half-period with respect to the other. In order to ensure extraction of difference signal from unwanted sum signal, the modulating carrier frequency must be too low. This poses a serious problem because shifting a high frequency grating exactly by a half-period is not an easy task. In order to surmount this difficulty Belvaux and Lowenthal proposed that instead of using a grating, the images transparencies can be modulated by fringes obtained in a Wollaston prism. It is well-known that these fringes can be shifted by a half-period by rotating an analyzer at the output side by 90°. The optical methods of subtraction of images suffer from the disadvantage that the photographic record has to be developed and fixed by wet processes. The processed record is then Fourier transformed and suitably filtered to extract the difference signal. In the present paper we have carried out extraction of difference of two images using the principle of periodic carrier modulation by carrying out spatial frequency filtering of the total irradiance distribution numerically. Some of the results of subtraction are presented.

1. Introduction

Subtraction of two images has a number of useful applications. If two images of a certain territory, taken by a geostationary satellite, the second image being taken a fortnight after taking the first image, the extraction of their difference between these two images will show up the changes that might have occurred in the territory during the fortnight. Indeed the extraction of difference of two images is of great importance in various fields, including remote sensing, meteorology, pattern recognition, and optical communication. This is also used in astrophotography to assist with computerized search for asteroids or Kupid belt objects in which the target is moving. Ebersole [1] and Liu et al. [2] have discussed various image subtraction techniques. In the present paper we carry out numerical subtraction of two images by using modulation of each object by a periodic carrier. Pennington et al. [3] introduced a method of subtraction of two image transparencies by modulating each of the image transparencies by a grating and shifting the grating through half of its period between the two exposures taken in the same photographic film. The minimum frequency of modulating grating must be equal to twice the maximum spatial frequency present in the object in order to avoid the aliasing error. This poses an experimental difficulty because shifting a grating of high frequency by half of its period between the two exposures is not an easy task. In order to surmount this difficulty a number of workers invented ingenious methods for simulating the effect of a half-period shift of periodic carrier by optical means. The basic physics behind these techniques is to modulate the images by interference fringes instead of using a mechanical grating. Belvaux and Lowenthal [4] used the fringes produced by Wollaston prism placed between two suitable polarizers. The fringe pattern so obtained can be shifted by half-period just by rotating the polarizer at the output by 90°. Lohmann et al. [5] suggested two different techniques for subtracting two images. In the first method, he used a polarization-shifted periodic carrier for modulating the images. The shift of the fringes between the two exposures on the recording medium was achieved by polarization properties of light. In the second method they used a reflection grating to modulate images with the necessary interlacing and subtraction was done electronically.

Ghosh et al. [6] modified Lohmanns' method of subtraction using polarization-shifted periodic carrier for subtracting two images of an object formed by birefringent lens. A birefringent lens formed a

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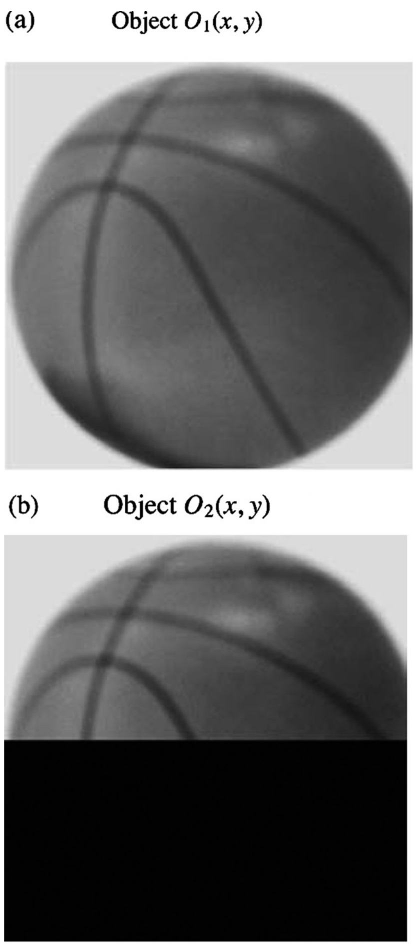

Fig. 1. (a) Image of the first object. (b) Image of the second object.

focused image and a defocused image in the same plane because the focal length of a birefringent lens is different for ordinary and extraordinary vibrations. As expected this subtraction gave high frequency enhancement of the object used.

In the present paper we have carried out the subtraction of two images numerically using periodic modulation principle mentioned above. Results presented bear out our theoretical expectation.

2. Theory

The mathematical analysis of the principle involved in the process of extraction of difference is quite simple.

Let us assume that the first and the second image transparencies are represented by irradiance distribution functions $O_1(x, y)$ and $O_2(x, y)$, respectively. For simplicity we assume that the periodic structure modulating the images to be subtracted is sinusoidal in nature. We assume that the first image is modulated by the sinusoidal grating

$$G_1(x) = \frac{1}{2}(1 + \cos 2\pi u_0 x) \tag{1}$$

And the second image is modulated by the same sinusoidal grating shifted by a half-period. Thus, the mathematical representation of this grating is

$$G_2(x) = \frac{1}{2}(1 - \cos 2\pi u_0 x) \tag{2}$$

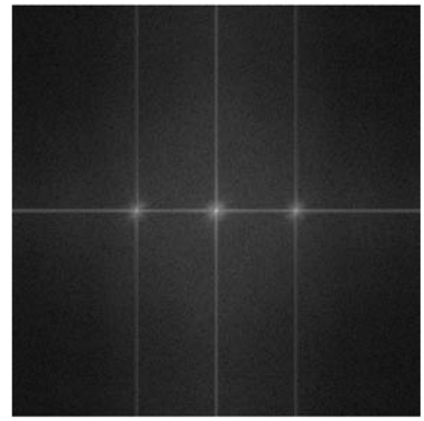

Fig. 2. Fourier spectral plane.

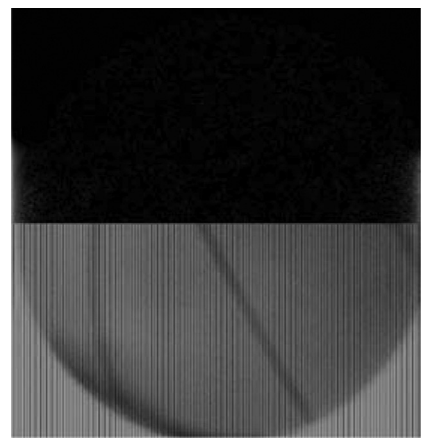

Fig. 3. Subtracted image.

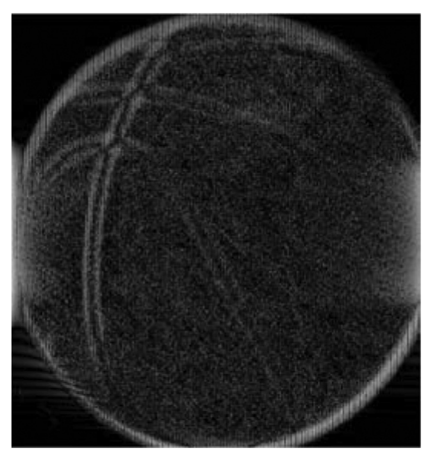

Fig. 4. Detected edge of the image.

The sum of the image irradiance distributions recorded is

$$I(x, y) = O_1(x, y)\,G_1(x) + O_2(x, y)\,G_2(x) \tag{3}$$

or,

$$I(x, y) = \frac{1}{2}\left\{O_1(x, y) + O_2(x, y)\right\} + \frac{1}{2}\left\{O_1(x, y) - O_2(x, y)\right\}\cos 2\pi u_0 x \tag{4}$$