

Pseudocoloring method using two different spatial modulations

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Pseudocoloring of gray level information is a technique for introducing false colors in a black-and-white transparency. The importance of this operation is based on the human eye's ability to distinguish different colors better than gray levels. In the last few years several pseudocoloring optical methods have been proposed.¹⁻¹⁰ Furthermore, the pseudocoloring technique has been extended to encode image spatial spectral bands¹¹⁻¹³ and holographic interferometric fringe patterns.¹⁴ In a recent paper¹⁵ we presented a further generalization of pseudocoloring for assigning false colors to depth level contours of 3-D objects.

In this Letter we propose a modification of the pseudocoloring speckle method⁹ for storing two images in a single recording material in such a way that each recorded image has a different spatial modulation. Therefore, in a decoding step, on illuminating the processed plate with a white light source, there exist two wavelength values for which the spatial spectra of both encoded images are centered at the same spatial frequency value. Thus, an additive mixture of both images is produced with a pseudocoloring effect which depends on the two mentioned wavelengths.

The scheme of the optical arrangement utilized in the encoding step is shown in Fig. 1. The image of a certain scene E_1 is recorded by using as a lens pupil a double aperture of separation d_1 . This causes a spatial spectra shift Δu_1 given by $\Delta u_1 = d_1/\lambda D$, where λ is the light wavelength, and D is the image distance. Afterward, a record of the image of another scene E_2 is done in the same plate but now using as a lens pupil a double aperture of separation d_2 . Thus, the spatial spectra shift Δu_2 is given by $\Delta u_2 = d_2/\lambda D$.

The decoding step is shown in Fig. 2. The developed plate H is illuminated with a collimated white light beam. Then, for a certain value of the viewing angle θ , there exists a superposition of the E_1 and E_2 images in the colors given by the corresponding wavelengths λ_1 and λ_2 such that, $d_2/d_1 = \lambda_1/\lambda_2$. In this way, all the common parts of the E_1 and E_2 images are pseudocolored by a color mixture which depends on λ_1 and λ_2 .

So far no relation exists between E_1 and E_2 . However, if E_1 and E_2 images are complementary (for object transparencies, the positive and negative images), the image resulting from the superposition is a pseudocolored one of either E_1 or E_2 . The corresponding contrast reversed image can be obtained employing the method of Ref. 10, that is, recording the light scattered from the silver developed grains that form the original image transparency. An alternative approach consists of employing the optical subtraction technique through Young's fringes modulated speckle.¹⁶ In this case, a first record of the image of a speckle pattern is made. Then the image of the same speckle pattern is recorded but modulated by the object transparency E_1 , introducing a π -phase delay between both exposures. Thus, a contrast reversed image of E_1 is obtained.

Another case of interest arises when the image of E_2 , instead of being the complementary one of E_1 , is a modified version of it. In this case, the third pseudocolor encodes the common

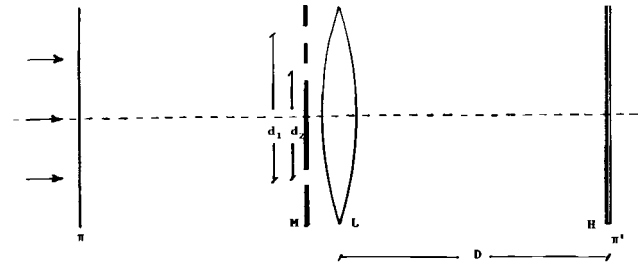


Fig. 1. Experimental setup of the encoding step: M , mask; L , lens; H , photographic plate; π and π' , conjugate planes.

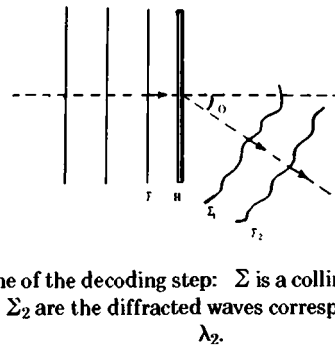


Fig. 2. Scheme of the decoding step: Σ is a collimated white light beam; Σ_1 and Σ_2 are the diffracted waves corresponding to λ_1 and λ_2 .

regions of both scenes. Some experiments have been done using as E_1 the isochromatic fringe pattern that appears in a loaded photoelastic model. The scene E_2 corresponds to the complementary fringe pattern (obtained by rotating the polarization state of the incident light by 90°) but with a different loading condition. Therefore, in the decoding step, the resulting moire pattern appears in a pseudocolor given by the mixture of λ_1 and λ_2 .

Finally, another point of interest for this pseudocolor encoding consists of studying the spatial changes in one direction of an object transparency. In this case, the E_2 image is a shifted version of the E_1 image. The amount of shifting depends on the size of the finest details to be studied. Thus, the sign of the gray level change is coded by a spectral color which corresponds to λ_1 or λ_2 .

In summary, we have presented a simple method for generalizing the speckle pseudocoloring technique to include other cases besides gray level pseudocoloring. An advantage of this method consists of employing colors, given by λ_1 and λ_2 , that are spectral. When using green and red as false colors, as usual, it is possible with this method to obtain a third color which lies in a straight line in the chromatic diagram, very close to the locus of the spectral colors. In this way, false colors of high purity are obtained.

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