Detecting small changes in process images with digital holography

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Abstract:
This paper presents a method for detecting the small changes of image, using digital holography. A hologram is constructed from a simple image using composition of spherical waves. After changing the image, a second hologram is constructed. The two holograms are subtracted and resulting hologram is observed. The results show that for small change in the image there is a great alteration in the hologram. The experiment is repeated for process images. A great change of hologram content also occurred after changing the intensity of only one pixel.

Keywords: holography, digital holography, hologram subtraction, small changes.

Introduction

In processes there is often a need for data control and it is important to act even if smallest change occurs. If a change of the measured value is very small there is a possibility that the instrumentation will not be able to register it due to finite resolution. Therefore, it is necessary to find a more accurate way to detect small changes. One of the possible ways to solve the problem is applying holography. The feature of the hologram is that the information of each part of the original object is distributed over the entire hologram. It is possible to reconstruct the original information out of any chosen part of the hologram, but providing a certain amount of noise input. In our method a hologram is constructed from input data and it is compared with the hologram constructed before the small change has occurred. Subtraction of the two holograms provides a resulting hologram which contains only the information about the change. If no change occurred the resulting hologram is equal zero.

Method

The method is based on subtraction of holograms. The hologram is constructed using composition of spherical waves [1, 2],

$$H_{x,y} = \sum_{i,j}^{M,N} A_{i,j} \sin(\frac{2\pi d}{\lambda}) . \quad (1)$$

The subtraction is done on pixel-level and it is defined as the absolute value of the subtraction of the pixel intensities of two images having equal coordinates. Intensity values are quantized in 256 levels (grayscale).

$$I(i,j) = \left| I_{H1}(i,j) - I_{H2}(i,j) \right| . \quad (2)$$

The intensity difference for a hologram quantized in two levels (monochromatic hologram) is shown in Figure 1.

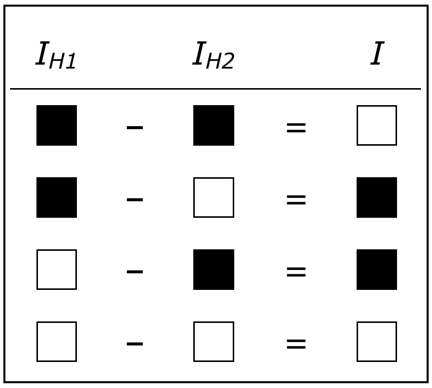

Figure 1: Monochromatic pixel subtraction

Experiment

The holograms used for the experiment were 100x100 pixels in size. The first constructed hologram was for an image of 100x100 pixels, containing a single black dot in the center of the image with a white background. Another hologram was constructed, again for the white image containing a single black dot but with the dot moved 1 pixel in direction of the x-axis. Figure 2 presents original images with the corresponding holograms and the resulting subtraction of the originals and holograms. The resulting hologram-subtract image clearly presents the difference between original images while that difference is not that evident when subtracting the originals.

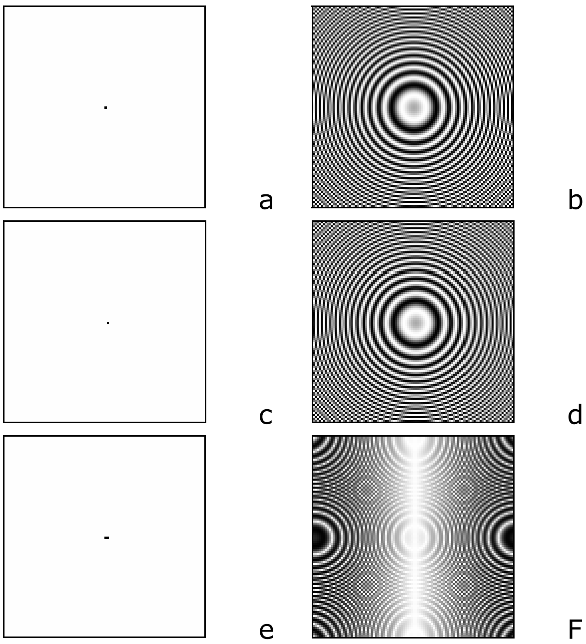

Figure 2: a – Original image; b – hologram of original image; c – changed original; d - hologram of changed original; e – original subtract; f – hologram subtract

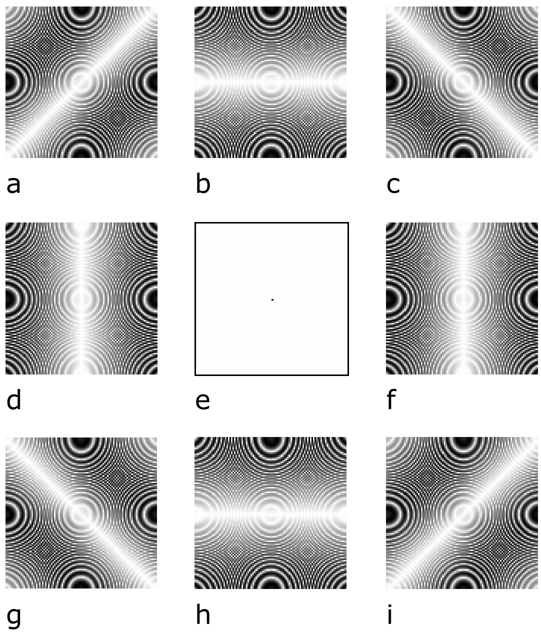

Figure 3: Hologram subtracts for the dot shift (Δx, Δy) = (-1,1), (0,1), (1,1), (-1,0), (0,0), (1,0), (-1,-1), (0,-1), (1,-1) respectively

The experiment is repeated for the cases of the black dot shift for one place in the direction of the x and y axis (positive and negative). The central image represents the original image, and the other images, present the hologram-subtract of the original image hologram (black dot in center) and the hologram where the dot is shifted for one pixel in a directions corresponding to the image position in the figure. The results show that for each dot-shift a characteristic white stripe occurs (Fig. 3). The white stripe is shifted from the center with correspondence to the shift of the dot. By analyzing the hologram subtracts the direction of the dot-shift can be determined.

In the next experiment images from the high-power laser-metal interactions in pressurized gaseous atmospheres [3] process were used (Fig. 4). Image is from the laser interaction with molybdenum in O_2 atmosphere (pressure=5.5atm, number of pulses = 30, image magnification ~ 30x). The used input image (100x100 pixels) was only a part of the original. The quantization of the input image was done in 256 levels. A hologram for that input image was constructed and subtracted from the hologram of the same image but with the intensity of the central pixel set to the maximum value (black).

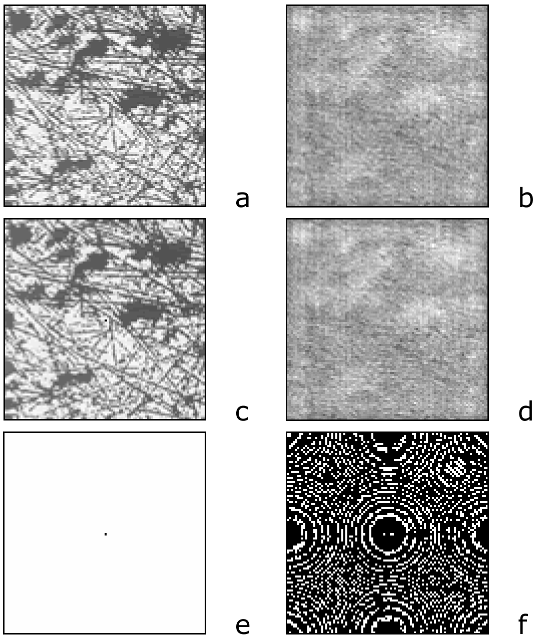

Figure 4: a – Original image; b – hologram of original image; c – changed original; d - hologram of changed original; e – original subtract; f – hologram subtract

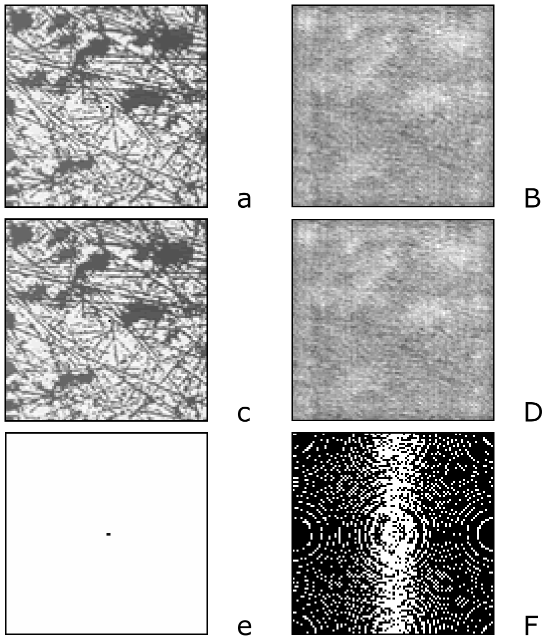

Figure 5: a – Original image; b – hologram of original image; c – changed original; d - hologram of changed original; e – original subtract; f – hologram subtract

The resulting hologram is quantized in two levels. If compared with the hologram from the first experiment it is evident that it is the hologram of the white image with a black dot in the center. If that hologram is reconstructed the dot in the center will appear (Fig. 6). With this approach information of a change was extracted and presented from the input data.

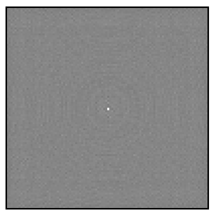

Figure 6: Reconstrustion of Figure 4f

In the last example the black pixel, in the same process image, is shifted for one place in the positive direction of x-axis as already done in the second example. The holograms are constructed and subtracted. After quantizing, a conclusion can be drawn that the central pixel has shifted towards the x-axis for a single place (Fig 5).

Conclusion

With the hologram-subtraction method it is possible to detect very small alternations in the image or very small shifts of certain textures of the image. By subtraction of the holograms, information of the change is extracted, and by reconstructing the resulting hologram that change is shown.

For the experiment holograms of 100x100 pixels were used. With usage of the bigger images, more information could be stored in the hologram and better results could be accomplished.

References

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