Improvement of the monochrome image hologram by using a random phase and increasing number of Samples

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Abstract:

This paper present a study about effect of the random phase and expansion of the scale sampling factors to improve the monochrome image hologram and compared it with previous produced others. Matlab software is used to synthesize and reconstruction hologram.

Introduction:

The hologram output is fringe pattern of intensity variations that are recorded on the holography plate. Normally these would be recorded as the constructive and destructive interference of wavefront from reference and object beam at the photography plate[1-2]. So we can simulate this process for any type of images by using computer generator hologram[3]. R. K. Jamal[4], explain the effect of a real nonnegative function to represent the transmittance of synthesized hologram:

$$H(u,v) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \sum_{k=1}^{4} F_k(u,v) \times \delta[u-(4n-k+1)/4w, v-m/w] \qquad (1)$$

The proper Fourier Transformation for the transmittance of synthesized hologram given by[5]:

$$F(k\Delta u/4,\ k'\Delta v) = \sum_{m=(N/2)}^{(N/2)-1} \sum_{n=(N/2)}^{(N/2)-1} f(m\Delta x, n\Delta y) \times \exp[-i2\pi(\frac{mk}{4} + nk')/N]. \qquad (2)$$

Where $\Delta x \times \Delta u = \Delta y \times \Delta v = 1/N$, $k = -2N, -2N+1, ...,2N-1.$, $k' = -N/2, -N/2+1, ..., N/2-1.$

The values of the amplitude transmission H(u,v) of hologram can be calculated by solved equation (1). The values of the function H(u,v) at the sampling locations are given by:

$$H\{(4m+k-1-2N)(\Delta u/4),[n-(N/2)]\Delta v\} = \begin{cases} Re((-i)^{k-1} F\{(4m+k-1-2N)(\Delta u/4),[n-(N/2)]\Delta v\}) \\ \text{if } H\{(4m+k-1-2N)(\Delta u/4),[n-(N/2)]\Delta v\} > 0 \\ 0 \text{ Otherwise} \end{cases} \qquad (3)$$

Where n, m= 0, 1, 2, …………, N-1 and k=1, 2, 3, 4.

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However, two factors added to this technique to improve the images reconstructed. The first factor is a random phase[6-10], the purpose of using this factor is the Fourier Transformation of the wavefront corresponding to most simple objects have very large dynamic ranges, because the coefficients of the dc (central spot) and low-frequency terms have much larger module than those of the high-frequency terms. This leads nonlinearity because of the limited dynamic range of the recording medium. To overcome this problem, it is convenient, where the phase of the final reconstructed image is not important, to multiply the complex amplitudes at the original sampled object points by a random phase factor before calculating the Fourier Transformation. This is optically analogous to placing a diffuser in front of the object transparency and has the effect of making the magnitudes of the Fourier coefficients much more uniform. Then, one can write.

$$F(k\Delta u/4, k'\Delta v) = \sum_{m=(N/2)}^{(N/2)-1} \sum_{n=(N/2)}^{(N/2)-1} f(m\Delta x, n\Delta y) \times \exp[-i2\pi(\frac{mk}{4} + nk')/N + i\phi]. \quad (4)$$

Where (ϕ) is a random phase having values ranged between 0 to 2π. The second factor is increasing number of sampling[11-12]. It is expanded to tow-dimensional monochrome image from N×N samples to the $n'N\times n'N$ samples where n' is a real number and large than eight and less than or equal to ten. Therefore, n' equal to (8, 9 ,10), and the (n ,m) values in equation (3) become (0, 1, 2, …………, (n' N-1)).

Experimental:

In this experiment we shall demonstrate the effects of the above two factors on images as follow:

1. Random Phase factor:-

For this factor there are two process applied to achieve this type of holograms.

a. Synthesized Hologram:

The basic algorithm for monochrome image hologram with phase random procedure is shown in figure(1). The input data to the algorithm are the amplitude of the sampled image and measured diffraction plane intensity of the picture . The amplitude are proportional to the square roots of the measured intensity. The next step is to add random phase which is ranged between 0 to 2π. Then, the results must be multiplied by the respective sampled amplitudes and by the Fourier Transformation of this synthesized complex discrete function, which is done by means of the Fast Fourier Transformation (FFT) algorithm of Cooley and Tukey according to equation (4). In this hologram a simple scheme are used to reduce the dynamic range of Fourier Transformation amplitude of the letters (MIH). Before applying the Fourier transformation into the function H(u,v), the amplitudes of the Fourier transformation samples with a predetermined threshold were compared. If the amplitude of the sample exceed the threshold, its value set to the threshold; otherwise its value remains unchanged. This schem is effective in reducing the dynamic range of Fourier transformation of objects comparing with the aperture size. Finally, the algorithm calculates the intensity value in the plane hologram by using equation (3) and prints output.

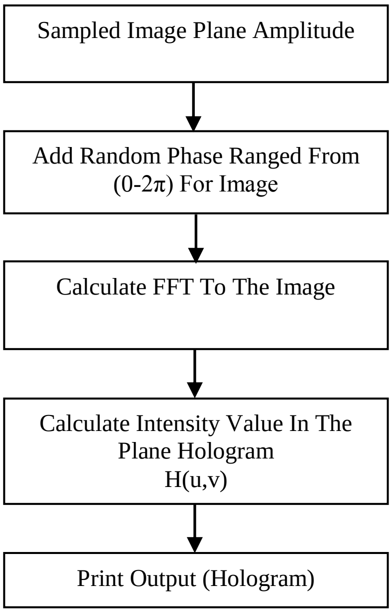
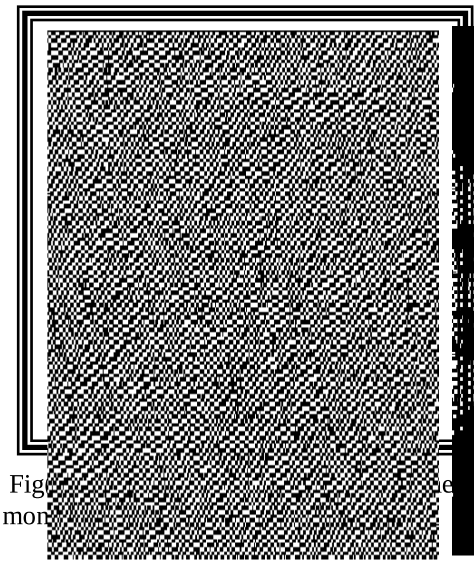
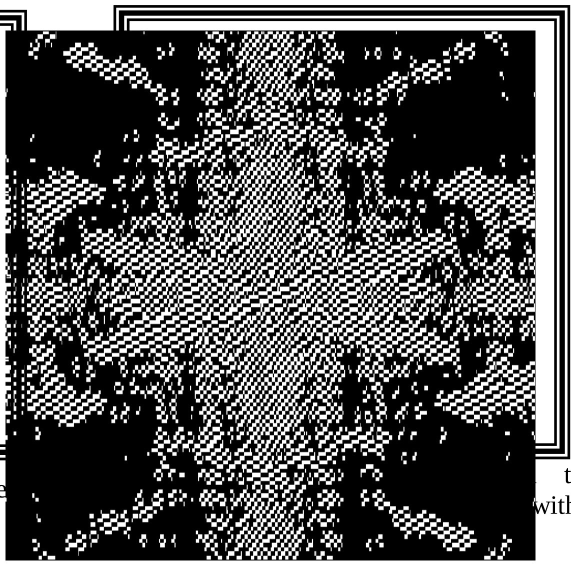


Figure (1): Algorithm to synthesized hologram with random phase.

To show the effectiveness of the above algorithm, two-dimensional monochrome image is used as shown in figure (2), This image has 128×128 samples. When applied the algorithm above on this image, the obtained synthesized hologram is shown in figure (3) and the synthesized hologram without random phase is shown in figure (4). Now if we are comparing between two those types, we will see that the edge of synthesized hologram pattern with random phase varies black-white-black etc, with almost every pixel. This means that the hologram is using maximal output bandwidth

Fig(2): Original two-dimensional monochrome image.





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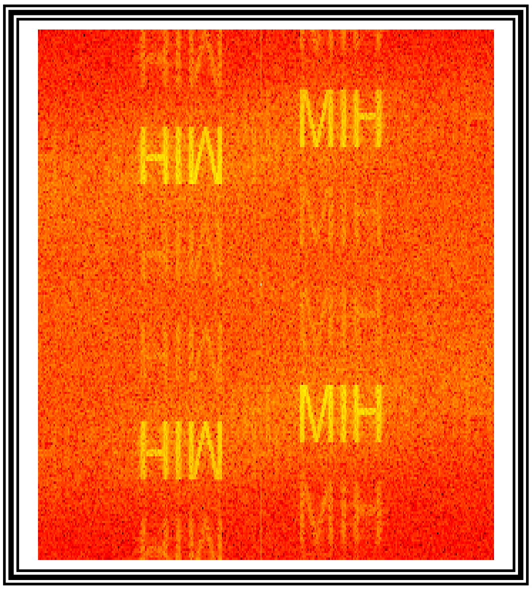
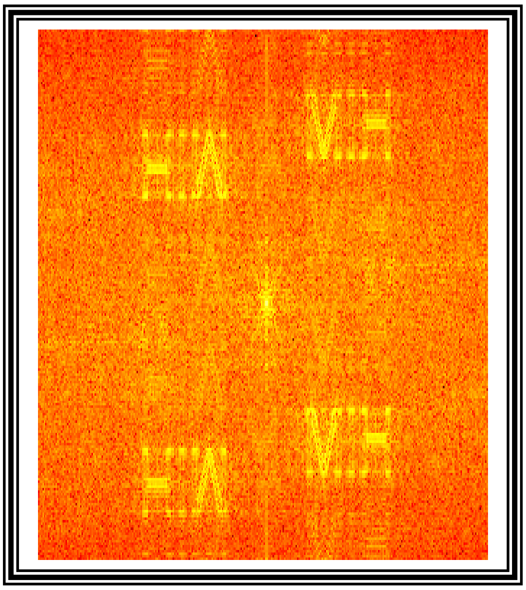
b. Reconstruction Hologram:

When the digital image reconstruction process had done on a monochrome image hologram with random phase factor, so the image reconstruction is shown in figure (5). The image reconstruction for a monochrome image hologram without random phase is shown in figure (6).

Also, If we are comparing between two those types of reconstruction images process we will see that the first order spectra for first type were very clear and have high intensity efficiency, but we still see the alteration in reconstruction images and these images were symmetrical images of the object.



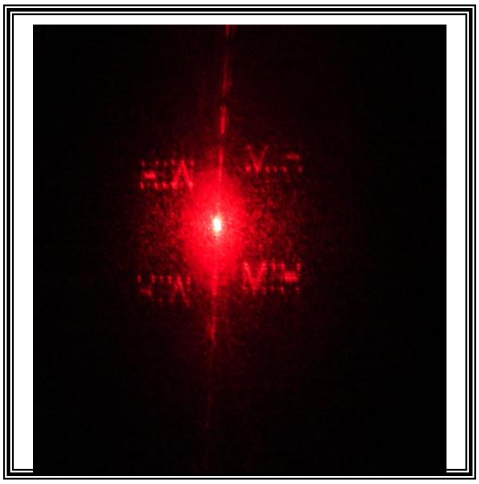
Fig(5): Digital reconstruction image of a hologram with random phase.



Fig(6): Digital reconstruction image of a hologram without random phase.

also we can see the same properties in optical reconstruction process. where, figures (7) and (8) shows optical reconstruction images of hologram with and without random phase respectively.

Fig(7): optical reconstruction image of a hologram with random phase.



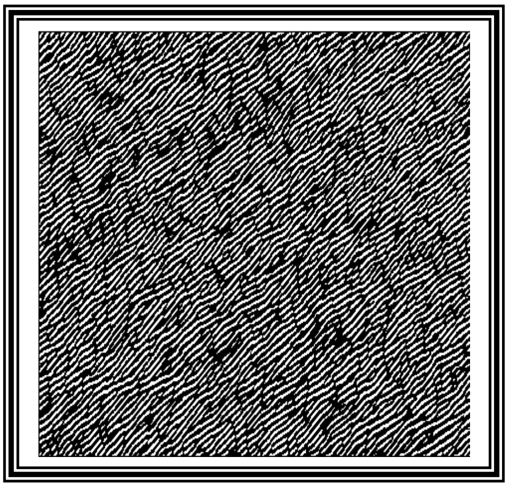
Fig(8): optical reconstruction image of a hologram without random phase.

2. Number of Sampling factor:

For this factor, there are two process applied to achieve this type of holograms.

a. Synthesized Hologram:

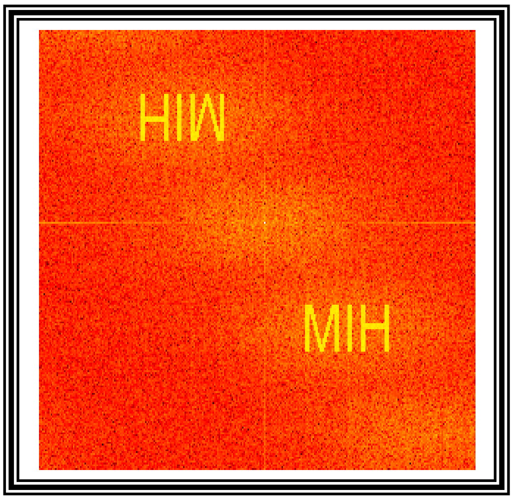
If the algorithm in figure (1) is applied on the same image in figure (2), must change the number of sampling of the corresponding Fourier Transform from (128×128) samples to (1280×1280) samples to synthesize hologram, so that means we must change values of (n,m). Synthesized hologram by adding this factor is shown in figure (9).



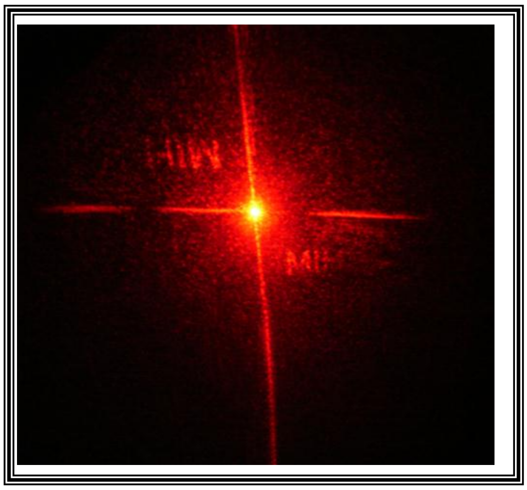
Fig(9): CGH of the synthesized two-dimensional monochrome image with random phase and expansion the scale of plane hologram.

b. Reconstruction Hologram:

When the digital image reconstruction process had done on a monochrome image hologram with random phase and increase the number of sampling, the image reconstruction is shown in figure (10). The optical reconstruction process is shown in figure (11)



Fig(10): Digital reconstruction image of a hologram with random phase and expansion the scale of sampling.



Fig(11): Optical reconstruction image of a hologram with random phase and expansion the scale of sampling.

When the comparison is applied between all reconstruction images, figure (5), figure (6) and figure(10) (digital reconstruction) or between figure (7), figure (8) and figure (11) (optical reconstruction), we can observe in figure (10) or figure (11) two images only appear in first order and disappear the others, also this two images are very clear and have high intensity efficiency.

Conclusion:

There are many conclusions we can concluded from this research:

1- The intensity efficiency increase by adding random phase of the main images.

2- The clarity image increase by using a random phase.

3- The intensity of central bright spot reduced to zero by adding random phase .

4- The number of images reduced by increasing number of sampling hologram, where produce just first order diffusion.

5- The clarity and intensity efficiency increase by increasing number of samples.

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تحسين الهولوغرامات المولدة للصور الاحادية اللون باستخدام عاملي الطور العشوائي وزيادة عدد العينات

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الملخص:

في هذا البحث قدمت دراسة جديدة حول تأثير الطور العشوائي وزيادة عدد العينات على تحسين صور الهولوغرامات الاحادية اللون ومقارنتها مع الصورة التي تم صناعتها سابقاً. تم استخدام برنامج الماتلاب لصناعة الهولوغرام واعادة بنائه.