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Image enhancement by using Hybrid methods based on Artificial Neural Networks

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Abstract **–**In this study, the elimination of zero diffraction order and twin image from three dimensional reconstructed images in digital holography and the image enhancement are desired to achieve in a short time by using hybrid methods. In addition, the brightness of the reconstructed three dimensional image is aimed to increase by using hybrid methods based on artificial neural network for the first time. To calculate the accurate phase of the hologram using in Gerchberg-Saxton algorithm (GSA), the Fourier transform algorithm and 1- dimensional continuous wavelet transform (1D-CWT) are used. These methods are expressed as hybrid methods. The usage of 1D-CWT for using in GSA is a first attempt. The intended purpose of using 1D-CWT is to reduce the twin image and zero diffraction order with performing minimum iteration numbers. The ratio of image enhancement is given by calculating the normalized root mean square values.

Keywords – image enhancement, digital holography, hybrid method, Artificial neural network, Gerchberg-Saxton algorithm, 1- dimensional continuous wavelet transform.

I. Introduction

The implementation of real time dynamic analysis in digital holography allows us to obtain three dimensional (3D) reconstructed images from hologram in a short time. [1,2]. Not only the 3D reconstructed images are desired to obtain in a short time, but also the noiseless images are demanded after reconstruction process with real time applications. Therefore the image enhancement process is required to obtain the noiseless images.

By using phase information, the noiseless images can be obtained in digital reconstruction process. To reconstruct the images by using phase information, many studies such as phase shifting technique [3], Fourier transform [4] and wavelet transform [5], [6] algorithms have been used so far. In Fourier transform algorithm (FTA), which is a classical method, twin image and zero diffraction order problems cannot be eliminated without spatial filters. On the other hand, phase shifting technique needs more than one holograms and is not suitable for real time applications. These problems are solved by using the continuous wavelet transform (CWT) algorithm [7].

Even though the reconstructed image is obtained without twin image and zero diffraction order by using above mentioned algorithm, the enhancement of 3D reconstructed images cannot be achieved noticeably. Therefore, different iterative approaches have been performed in recent years and they are used in many applications such as image processing applications, artificial neural networks (ANN) [8], [9]. Gerchberg-Saxton algorithm (GSA), is a famous iterative method used for noise elimination [10]. To find the accurate phase that is calculated by Fourier Transform algorithm (FTA), the time is wasted so much in this algorithm due to using iteration process many times.

In this study we propose a new approach by using hybrid approaches based on artificial neural network to improve the image quality. Firstly, GSA method with FTA, which is based on ANN, is used. This method is named as first hybrid method in this study. Secondly, GSA method with CWT, which is based on ANN, is used. It is expressed as second hybrid method. These proposed methods have been compared for the first time in this study.

This paper is organized in four sections. The phase extraction methods in GSA are described in section II. Moreover; the ANN method is shortly explained in section III. In addition, the results of the noiseless 3D reconstructed images obtained by using hybrid approaches are presented in section IV. Furthermore, the NRMS values of trained images with ANN according to different iteration numbers are given numerically in this section. Finally, the results are interpreted in conclusion section.

II. PHASE EXTRACTION

This work is based up on famous GSA method, where FTA is applied during phase extraction process. Due to the fact that, FTA is a classical method and known by the scientist, it is not given here.

In addition, the phase extraction process in GSA method has been performed by using CWT algorithm in this study for the first time. Therefore, CWT algorithm, whose multi-resolution characteristic is a tool to obtain noiseless image, is only explained.

A wavelet function is defined as in equation (1) by using zero average.

$$\int_{-\infty}^{\infty} \psi(z)dz = 0 \tag{1}$$

This function is normalized as $\|\psi\| = 1$. Here, by centering the wavelet function in the neighborhood, z value is taken as 0 [11].

Grossmann and Morlet are defined the CWT function as s(z) in equation (2) [12].

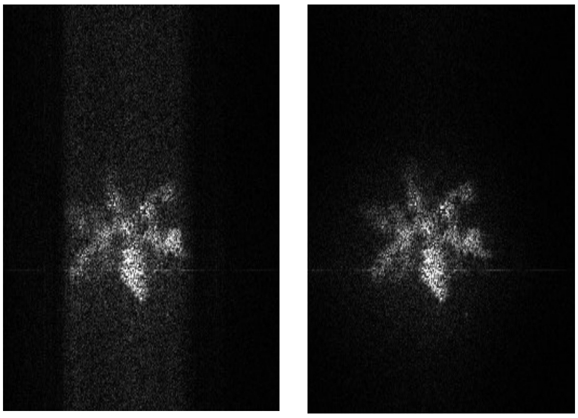
$$C_S(s,b)=\frac{1}{s}\int_{-\infty}^{\infty} s(z)\psi^*\left(\frac{z-b}{s}\right)dz \tag{2}$$

Each family function is obtained by using translation parameter that is given as $b\in\Re$ and by scaling the s(z) function with scale parameter that is defined as s. The complex conjugate mother wavelet function is also identified here as $\psi^*_{s,,b}(z)=\psi^*\left(\frac{z-b}{s}\right)$.

The phase of CWT function $(C_S(s,b))$, whose range is in $[-\pi,+\pi]$ values, is calculated by using equation (3).

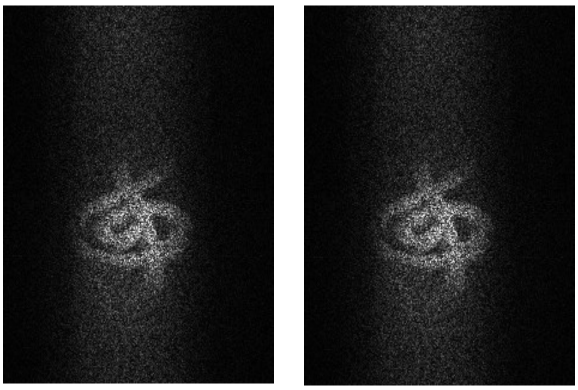
$$\phi(z)=\tan^{-1}\left(\frac{\mathrm{Im}(C_S(s,b))}{\mathrm{Re}(C_S(s,b))}\right) \tag{3}$$

After calculating the phase in each iterations for GSA by using FTA and CWT algorithms, the 3D images are reconstructed. These images are shown in Fig. 1 and Fig. 2 for star and clef images respectively.



a b

Fig. 1 3D reconstructed star images a) obtained with GSA by using FTA b) obtained with GSA by using CWT



a b

Fig. 2 3D reconstructed treble clef images a) obtained with GSA by using FTA b) obtained with GSA by using CWT

To improve the image quality of 3D reconstructed image, the hybrid methods based on ANN are proposed to use.

III. THE USAGE OF ARTIFICIAL NEURAL NETWORK

Artificial Neural Network (ANN) applications have been used in many studies so far. These applications are generally named as connection-oriented networks based on artificial intelligence [13], [14]. To determine this network parameters, many algorithms are performed. The learning and teaching algorithms are an example of these algorithms. In addition, the parameter estimation algorithms are also used for system identification. Levenberg-Marquardt algorithms (LMA) is a well- known algorithm that is used to estimate the parameters.

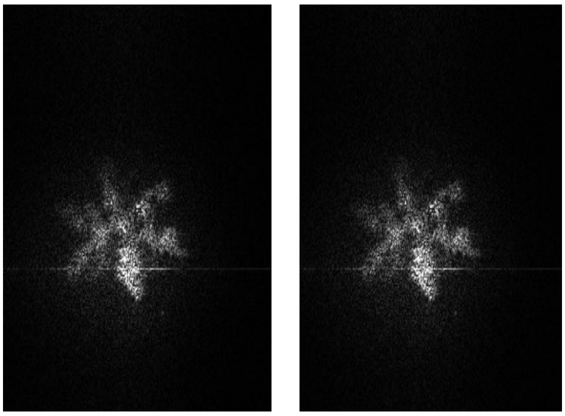
In this study, it is aimed to improve the reconstructed image quality by using hybrid methods based on ANN. In this context, LMA is used via MATLAB Neural Network Fitting Toolbox (nftool) for the implementation in this work. To show the achievement performance of the image enhancement obtained by using hybrid method based on ANN, the error ratio between the input image obtained by GSA and output image obtained by ANN is calculated. Actually, the errors of the difference between trained input and output in ANN are aimed to be minimized by using back propagation algorithm [15]. But this implementation is different for digital holographic images. Due to the fact that the noise of the 3D reconstructed image in digital holography is aimed to eliminate with training process in ANN, the obtained output image after training process is desired to be different from input image, which is trained in the system. Therefore the error is desired to obtain with maximum value. In this study this error is accepted to equal as the normalized root mean square (NRMS) value.

In this work, ANN is applied to GSA method with FTA (first hybrid method) in the first stage and GSA method with CWT (second hybrid method) in the second stage of this study. In addition, the ratio of noise reduction by using both methods based on ANN is given with the NRMS values for different iteration numbers.

IV. RESULTS AND DISCUSSION

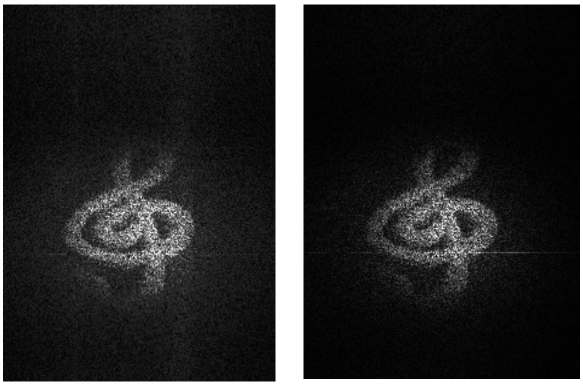
In this section, the 3D reconstructed images obtained by using both methods are presented. The image enhancement of 3D reconstructed images are achieved with training process in ANN.

The reconstructed images are trained with 15 iterations by using first hybrid method. The trained reconstructed images are given in Fig.3 (a) and Fig. 4(a) for star and treble clef images respectively. To improve the image quality with minimum iteration number in training process, the second hybrid method is proposed. Therefore, in the second hybrid method the star and treble clef images are trained with 3 iterations. The output images of ANN trained with 3 iterations are also shown in Fig. 3(b) and Fig. 4(b) respectively.



a b

Fig. 3 3D reconstructed star images obtained by using first and second hybrid methods respectively a) trained with 15 iterations b) trained with 3 iterations



a b

Fig. 4 3D reconstructed treble clef images obtained by using first and second hybrid methods respectively a) trained with 15 iterations b) trained with 3 iterations

To demonstrate the achievement results of image enhancement, the ratio of noise elimination by using proposed both hybrid methods is given with the NRMS values for different iteration numbers. In table 1, the obtained NRMS values are presented for star and treble clef images.

Table 1. The NRMS values for both methods based on ANN according to different iteration numbers

Iteration Numbers	NRMS Values for reconstructed star image		NRMS Values for reconstructed treble clef image	
	Second Hybrid Method	First Hybrid Method	Second Hybrid Method	First Hybrid Method
3	0.2000	0.1707	0.9295	0.7295
5	0.1978	0.1880	0.9169	0.7498
8	0.1713	0.1905	0.9117	0.7636
10	0.1632	0.1980	0.9150	0.7716
12	0.1601	0.2006	0.9096	0.7858
15	0.1595	0.2028	0.9048	0.7941

As it is seen in table 1, the maximum error is obtained with 15 iterations by using first hybrid method. Whereas the second hybrid method gives the maximum error with 3 iterations. This means that second hybrid method provides a better result. In addition the 3D reconstructed images obtained by proposed hybrid methods are brighter than the images trained without ANN method. Namely, the training process increases the brightness of the reconstructed images.

V. CONCLUSION

In this study, the image quality of 3D reconstructed images in digital holography is desired to improve by using hybrid methods. Moreover, the brightness of these images is aimed to increase. In this context, GSA methods with FTA and CWT, which are trained with ANN, are proposed to use.

It should be noted here that, if first hybrid method is used, the iteration numbers in GSA will increase. It is seen in table 1 that, the maximum error is achieved with 15 iterations by using first hybrid method and 3 iterations by using second hybrid method. Namely, the noiseless image is obtained with minimum iterations by second hybrid method. Therefore, the time loss is prevented by this method.

REFERENCES

[1] J. Zhong and J. Weng, *Reconstruction of digital hologram by use of the wavelet transform*, in Holography, Research and Technologies, J. Rosen, Ed. InTech, 2011.

[2] K. Khare, P.T.Samsheer Ali and J. Joseph, "Single shot high resolution digital holography," *Optics Express,* vol. 21, pp. 2581-2591, 2013.

[3] K. Creath, " Phase-measurement interferometry techniques," *Progress in Optics,* vol. 26, pp.349–393, 1988.

[4] M. Takeda and K. Mutoh, "Fourier transform profilometry for the automatic measurement of 3-D objects shapes," *Applied Optics,* vol. 22, pp. 3977-3982, 1983.

[5] Jaideva C. Goswami and Andrew K. Chan, *Fundamentals of Wavelets: Theory, algorithms, and applications*,2nd ed., Wiley, 2011.

[6] M. Bahich,, M. Afifi and E. Barj, "Optical phase extraction algorithm based on the continuous wavelet and the hilbert transforms," *Journal of Computing,* vol. 2, pp. 1-5, 2010.

[7] D. Onal Tayyar, Z. Saraç and N. F. Ecevit, "Real-time optical recontruction of the diffused 3D object using phase information calculated by continuous wavelet transform," *Optics Communications,* vol. 284, pp. 5460-5465, 2011.

[8] T. Nakamura, K. Nitta and O. Matoba, "Iterative algorithm of phase determination in digital holography for real-time recording of real objects," *Applied Optics,* vol. 46, pp. 6849-6853, 2007.

[9] F. Latifoglu, "A novel approach to speckle noise filtering based on Artificial Bee Colony algorithm: an ultrasound image application," *Journal Computer Methods and Programs in Biomedicine,* vol. 111, pp. 561-569, 2013.

[10] R. W. Gerchberg and W. O. Saxton, "A Practical algorithm for the determination of phase from image and diffraction plane pictures," *Optik*, vol. 35, pp. 237-246, 1972.

[11] M. Liebling, T.F. Bernhard, A. H. Bachman, L. Froehly, T. Lasser, and M. Unser, "Continuous wavelet transform ridge extraction for spectral interferometry imaging,“ in Proc. SPIE 5690, Coherence Domain Optical Methods and Optical Coherence Tomography in Biomedicine IX. 2005.

[12] A. Grossman and J. Morlet, *Decomposition of functions into wavelets of constant shape and related transforms*, Mathematics and physics, lectures on recent results, Ed.: L. Streit, World Scientific Publishing, Singapore. 1985, vol. 1.

[13] F. S. Gharehchopogh, M. Molany and F. D. Mokri, "Using artificial neural network in diagnosis of thyroid disease: a case study," *International Journal on Computational Sciences & Applications (IJCSA),* vol. 3, pp. 49-61, 2013.

[14] V. Sarasvathi and Dr. A. Santhakumaran, "Towards artificial neural network model to diagnose thyroid problems, " *Global Journal of Computing Science & Technology*, vol. 11, pp. 52-55, 2011.

[15] L. L. Guan, R. O. Duda, P. E. Hart and D. G. Stork, *Pattern Classification*, New York: John Wiley& amp; Sons, 2007.