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Digital Image Watermarking using Digital Holographic Interferometry (DHI) Technique

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ABSTRACT

An image watermarking technique, with digital holographic interferometry (DHI) is presented and tested here. The unique property of DHI allowed precise measurement of the object displacement without physical content. In DHI, a double exposure technique is used to capture a 3D object with two different states (disturbed and undisturbed) as hologram. Then the respective holograms are numerically interfered to form the interference fringes. When DHI is applied into watermarking field, either one of the holograms can be used as watermark or as a key. Hence this method created an extra layer of security as both holograms and some experimental parameters are required to recover the watermark information. For watermarking purposes, the undisturbed hologram is embedded into the host image via Singular Value Decomposition (SVD), while the disturbed hologram is kept as key. Experiment results show that the DHI method is more robust than conventional holographic watermark method against most image processing attacks.

1. INTRODUCTION

Today's technology is rapidly evolving. Digital contents such as image, audio and video are easily downloadable and duplicated. As a result, it is difficult to differentiate a pirated copy from its original. These cause a concern over ownership and copyright protection of digital content. To prevent such information theft, Cox et.al in 2000, they introduced digital watermarking techniques to protect the owner copyright by embedding hidden information into the digital contents. In 2002, Takai and Mifune further extended the watermarking capability by introduced optical image watermarking by digital holography technique, or also known as holographic watermark. The unique characteristic of the hologram has an advantage over traditional watermark image in term of robustness towards cropping attacks. In 2012, Yong et,al, shown that watermark hologram information has higher resistant toward cropping attacks compare to traditional watermark. Besides that every part of a hologram contains the information (amplitude and phase) about the entire object data, where as traditional watermark contains only the amplitude of an object. As a results, the performances of holographic watermark techniques has been extensively studied and expanded by (Chen et.al, 2014, De et.al., 2009; Tan et.al., 2012 and Okman et.al., 2007). However, these watermarking schemes offers little security as the experimental parameters including the wavelength and diffraction distance can be easily deducted through research. To further enhance the holographic security, data encryption method by (Jianzhong Li, 2014; Khisk and Javidi, 2003; Meng et.al.,2007; Giuseppe and Michele,2011 and Nishchal et.al, 2010) have been proposed for holographic watermark. Each of the methods mentioned above have reported a high security watermarking as they require a number of correct keys to recover the watermark hologram information. However the data quantity of the keys is very large. Furthermore the sizes of the resultant encrypted data increase proportionally since the holograms are complex signal. Moreover, the encrypted data requires a set of transformation to recover the watermark information.

Meanwhile, the other unique characteristic of holographic techniques allows precise measurement of the object displacement without any physical contact. In Digital Holographic Interferometry (DHI), two different states of the object are made to interfere to form the interference fringes. The fringes pattern shows the phase different between the interfering waves. In this experiment, a cantilever beam is used as an object. Using the double exposure, the object undisturbed state is firstly captured as a hologram before a second hologram is capture for the now disturbed object. The object used in this experiment is a cantilever. Both holograms are then numerical simulated to reconstruct the fringes pattern.

In this paper, a watermarking scheme based on digital holographic interferometry (DHI) is proposed here and is shown in Figure 1. There are a few advantages of using the DHI method. Firstly either one of the hologram (undisturbed or disturbed) can be used as a watermark or as a key. For watermarking purposes, we embedded the undisturbed hologram as hologram watermark using Singular Value Decomposition (SVD) algorithmic into the host image as watermarked image. While the disturbed hologram is keep as a key. Secondly, by using the correct experimental parameters and without the knowledge of the key, an authorized user can only recover the holographic watermark (cantilever hologram). However, together with the experimental parameters and the key, the user can recover the DHI watermark (fringes pattern). Hence the DHI method created an extra layer of security. Lastly, the DHI method is less complex as data does not require a set transformation to recover the watermark information. To test both watermark robustness, the watermarked image undergo some common image processing attacks including salt and pepper noise, JPEG compression, Gaussian filter, Mean & Median filter, rotation and image cropping. The robustness of this method is evaluated by comparing the 2-D correlation coefficient (CC) of the extracted watermark hologram with its original.

2. DIGITAL HOLOGRAPHY INTERFOMETRY

The experimental set-up for the implementation of DHI based on off-axis configuration is shown in Figure 2. The object is a cantilever beam, which is firmly secured at one end and loaded at the free end. The load is applied with a micrometer screw toward the direction of the CCD camera. Two holograms are captured. First the undisturbed object is recorded. The complex amplitude of the object wave in undisturbed state is given as:

$$O_1(x, y) = o(x, y) \exp[i\varphi(x, y)] \tag{1}$$

where $o(x, y)$ and $\varphi(x, y)$ are the real amplitude and phase of the object wave, respectively.A second hologram is recorded after the cantilever is bent a few

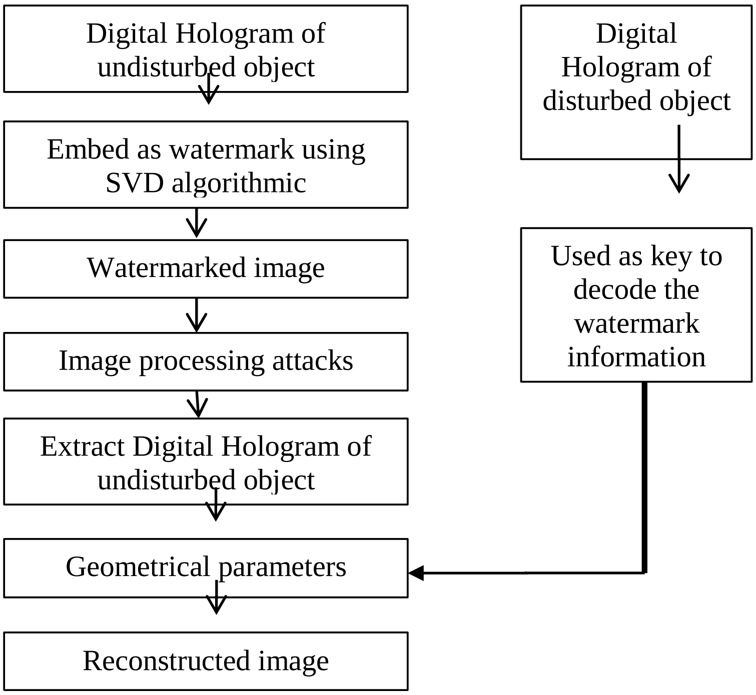


Figure 1: Proposed watermarking scheme using fusion of DHI and Singular Values Decomposition

microns to produce the disturbed state. The complex amplitude of the disturbed object wave is given as:

$$O_2(x,y) = o(x,y)exp\big[i\big(\varphi + \Delta\varphi(x,y)\big)\big] \tag{2}$$

where $\Delta\varphi(x,y)$ is the interference phase between the undisturbed and disturbed state of the object.

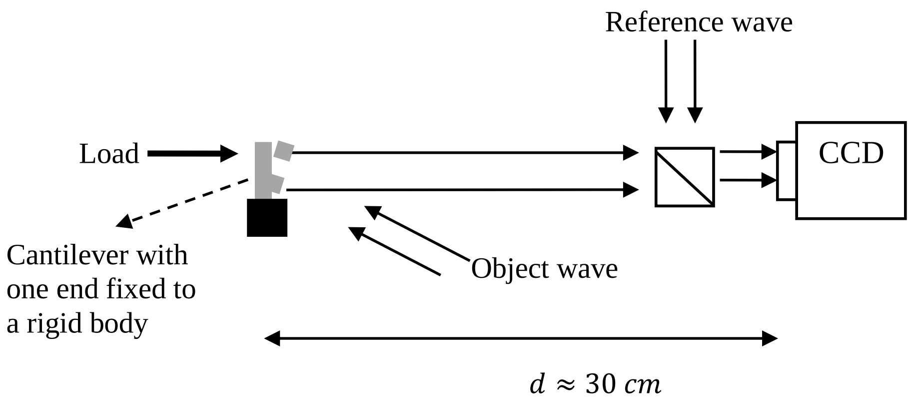


Figure 2: Experiment setup for digital holographic interferometry based on off-axis configuration.

3. PROPOSED WATERMARKING SCHEME

A. Embedding of watermark

Figure 3 shows the procedure to embed and extract the watermark using the SVD algorithmic. A host image, I is SVD transformed into three (U, S, V) components matrices by

$$I = \quad USV^T \tag{3}$$

where U and V are the orthogonal matrices and S is a diagonal matrix. The hologram H is embedded into the S matrix by

$$Sw = \mathrm{S} + \alpha H \tag{4}$$

where S and H are host image and watermark respectively, α is the weighting factor and its value is set to 0.2 in this experiment. An inverse SVD transform is applied to obtain the final watermarked image.

$$G = \mathrm{USw}V^T \tag{5}$$

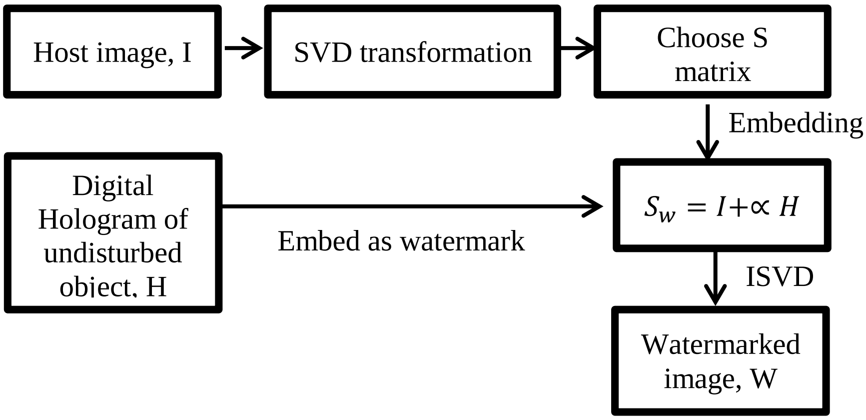


Figure 3: Flowchart of the procedure to embed and extract the watermark using the SVD algorithmic.

B. Watermark image extraction and reconstruction

Figure 4 shows the procedure to extract and reconstruct the watermark. The watermark image is recovered by using a reverse watermark embedding process. To reconstruct the watermark information, firstly the complex amplitude of two holograms is calculated. Secondly the phase of each hologram is calculated by using the 2-dimensional Discrete Fourier Transform [2]. Lastly, the interference phase the hologram is determined and displays in grayscale image.

4. RESULTS AND DISCUSSION

The light source used in this experiment is a 30-mW DPPS with wavelength of 532.8 nm and recording distance of 30 cm. Figure 5(a)-(b) shows the undisturbed hologram and disturbed hologram. Figure 5(c) shows the reconstructed DHI method using right key. Figure 5(d) shows the reconstructed holographic watermark (cantilever hologram) without using the key.

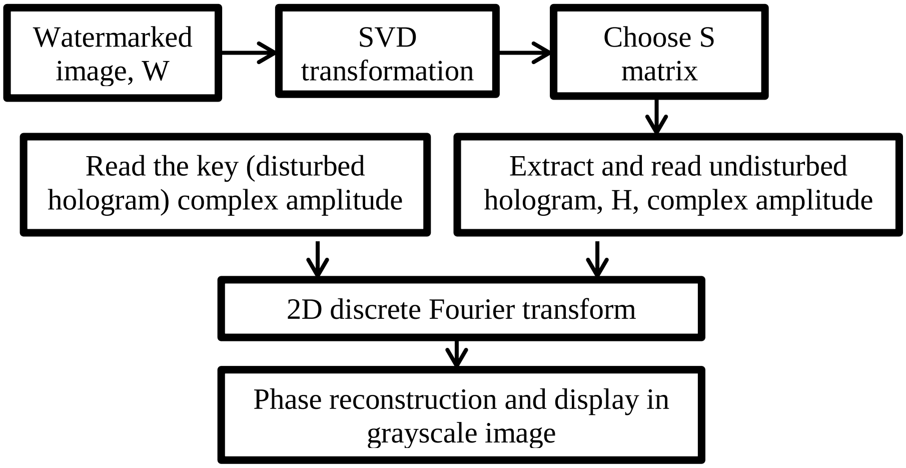
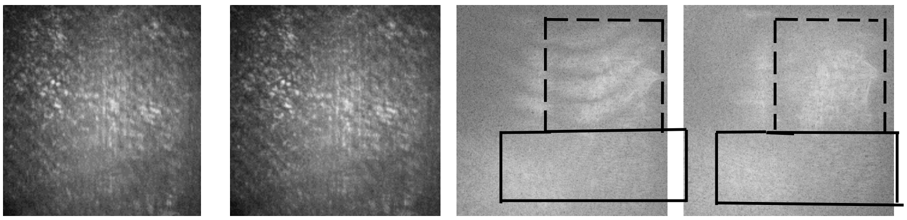


Figure 4: Flowchart of the extraction and reconstruction of the watermark.



(a) (b) (c) (d)

Figure 5: Digital hologram (a) before disturbed (b) after disturbed. The results of numerical reconstruction (c) DHI method (d) holographic watermark (cantilever hologram).

Figure 6 shows the reconstructed amplitude contrast image using wrong key. Figure 7 shows the 1024x1024 grayscale host images including Baboon Lena, Cameraman and House. In order to test the robustness, the watermarked image will undergo some common image processing attacks including salt and pepper noise, JPEG compression, Gaussian filter, Mean & Median filter, rotation and image cropping. The quality of the retrieved is tested by 2-D correlation coefficient (CC). It should be noted that the higher NCC values, it is more robust.

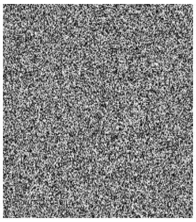
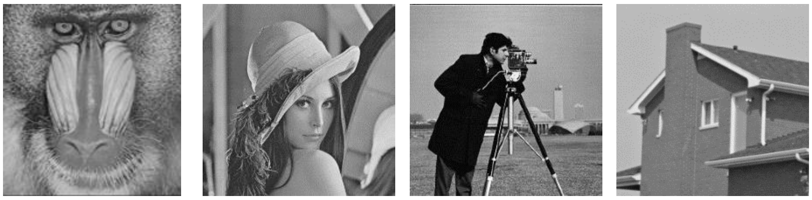


Figure 6: Reconstructed amplitude contrast image using wrong key.



(a) (b) (c) (d)

Figure 7: The host images. (a) Baboon (b) Lena (c) Cameraman (d) House.

Table 1 shows the 2-D correlation coefficient (CC) of the extracted watermark hologram from each host images. Table 2 shows the 2-D correlation coefficient (CC) after each image processing attacks for baboon host image only. The DHI method shows better robustness especially against JPEG compression and filters. However, the DHI method is slightly vulnerable to noise attacks. Both the watermark of DHI method and the holographic watermark are detected after 75% of the total watermarked image is chopped.

Perceptual Quality	**Method**	**Host images**			
		Baboon	Lena	Cameraman	House
Correlated Coefficient of Extracted Watermark Hologram	DHI method	0.996	0.995	0.995	0.996
	Holographic watermark (Cantilever hologram)	0.995	0.995	0.995	0.994
	Percentage difference (%)	-0.1	0	0	-0.1

Table 1: 2-D correlation coefficient values after each attack.

	Normalized Correlation Coefficient (NCC)		
	DHI method	**Holographic watermark (Cantilever hologram)**	**Percentage difference (%)**
Salt and pepper Noise			
100%	0.610	0.642	-4.98
200%	0.600	0.632	-5.06
300%	0.590	0.618	-4.53
400%	0.587	0.613	-4.24
Gaussian Noise			
σ = 5	0.651	0.681	-4.60
σ = 10	0.621	0.634	-2.09
σ = 15	0.580	0.598	-3.10
σ = 20	0.571	0.573	-0.35
JPEG Compression			
Q = 25	0.784	0.715	9.65
Q = 50	0.737	0.703	4.84
Q = 75	0.684	0.681	0.44
Q = 95	0.600	0.600	0.00
3x3 Gaussian filter			
σ = 0.2	0.987	0.735	34.29
σ = 0.3	0.980	0.730	34.25
σ = 0.4	0.947	0.719	31.71
σ = 0.5	0.849	0.704	20.60
3x3 Mean filter			

	0.825	0.667	19.15
3x3 Median filter			
	0.813	0.553	31.98
Rotation (^{o})			
5	0.827	0.366	55.7
-5	0.826	0.365	55.8
Image cropping			
25%	0.785	0.658	19.30
50%	0.730	0.641	11.64
60%	0.673	0.628	7.17
75%	0.530	0.520	2.78

Table 2: 2-D correlation coefficient values after each attack for baboon host image.

5. CONCLUSION

In this paper, we proposed a watermarking scheme using holographic interferometry. Experiment results from different image processing attacks demonstrated that the DHI method is more robust compared to holographic watermark. Another advantage of this method is that, to recover the hologram watermark information, it requires a key (hologram of disturbed object) besides the geometrical parameters. Therefore the DHI method offers higher level of higher security in overall. For future work, we are planning to compare results of the DHI method with other recent methods.

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