

**LETTER**

**Fusion on the Wavelet Coefficients Scale-Related for Double Encryption Holographic Halftone Watermark Hidden Technology**

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**SUMMARY** We present a new framework for embedding holographic halftone watermarking data into images by fusion of scale-related wavelet coefficients. The halftone watermarking image is obtained by using error-diffusion method and converted into Fresnel hologram, which is considered to be the initial password. After encryption, a scrambled watermarking image through Arnold transform is embedded into the host image during the halftoning process. We characterize the multi-scale representation of the original image using the discrete wavelet transform. The boundary information of the target image is fused by correlation of wavelet coefficients across wavelet transform layers to increase the pixel resolution scale. We apply the inter-scale fusion method to gain fusion coefficient of the fine-scale, which takes into account both the detail of the image and approximate information. Using the proposed method, the watermarking information can be embedded into the host image with recovery against the halftoning operation. The experimental results show that the proposed approach provides security and robustness against JPEG compression and different attacks compared to previous alternatives.

**key words:** double encryption, halftone, fusion, scale-related, holographic watermarking hidden

1. Introduction

Data hiding in halftone images approaches are useful in a wide variety of applications. The print security documents such as ID card, meta-data embedding, document authentication and tracking control are examples of applications for which data embedding is currently employed. A digital watermarking is a kind of marker covertly embedded in a noise-tolerant signal such as image data. Watermarking is the process of hiding digital information in a carrier signal [1]. Digital watermarking may be used to verify the authenticity or integrity of the carrier signal to show the identity of its owners.

It is prominently used for tracing copyright infringements and for bank note authentication. Like traditional watermarks, digital watermarking are only perceptible under certain conditions and imperceptible anytime else [2]. A signal may carry several different watermarks at the same time. Unlike meta-data that are added to the carrier signal, the digital watermarking does not change the size of the carrier signal.

Several different halftoning algorithms are utilized in practice and choices among these are made based upon the characteristics of the physical printing process employed in the printer [3], [4]. The hidden information, which is embedded into halftone images can be retrieved by scanning and applying some extraction algorithms. In Most studies, various examples of data hiding techniques have also been proposed [5]–[7]. The key factor of the printing process is a bit-depth reduction step called digital halftoning which produces an illusion of continuous tone by trading off amplitude resolution for spatial resolution [8], [9]. Those methods include adopting intensity selection concepts to put the embedded data in a suitable location [10], using modified data hiding techniques to embed watermark into ED images [11] and coordinating the BCH error correcting code with data hiding techniques [12]. J.M.Guo presented a high payload watermarking in multiple halftone images using the OMES [13]. For the data hiding problem, the channel distortions are intimately tied to the nature of the halftoning algorithm [14].

In this paper, we proposed a method for digital watermarking in halftone image using fusion on the scale-related wavelet coefficients through double encryption of holographic halftone watermarking, which is a new halftoning technique employed in printing systems. This algorithm is easy to realize and has strong robustness to cropping and paint attack, thus generates clearer watermark. We describe the individual system elements in detail in the following sections.

2. Fresnel Hologram Halftoning Watermarking Scheme

In order to clearly take on the original watermark and conjugate image, we use the watermark image of sizes $64 \times 64$ pixels to transform symmetric extension, which the size is $128 \times 128$ pixels watermark image.

There is closely combine the digital hologram watermark with halftone image, namely, the hologram is calculated as a digital watermark, which will be embedded the image to be printed. This method ensures the high fidelity of holographic watermark image.

In the section of this article, we address the aspect of halftoning that have to do with the original watermark. Then it is embedded in the host image, so that the watermark information will be lost greatly reduction for the host image halftone process when printing.

During the halftone processing of the original watermark image, we are using Bayer dithering, error diffusion,
Table 1  Three kinds of halftone hologram reproducing watermark image quality parameter.

<table>
<thead>
<tr>
<th>parameter</th>
<th>watermark</th>
<th>original</th>
<th>Bayer dithering</th>
<th>ED</th>
<th>Green noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>1.0000</td>
<td>0.8617</td>
<td>0.8856</td>
<td>0.8342</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1  Fresnel hologram watermarking generation. (a) original watermark (b) symmetric extension (c) Fresnel halftone holographic watermark.

green noise three kinds of algorithms, respectively. The three halftone watermark images were Fresnel holography transform and the test results are evaluated using normalized correlation coefficient NC. The experimental data are demonstrated in Table 1.

Table 1 illustrates the best visual effects that reproducing watermark is error diffusion halftone hologram watermark. In this article, we select the ED halftoning Fresnel hologram watermark as digital watermarking information in the system. The procession of Fresnel holographic watermark generation is shown as Fig. 1.

3. Fusion of the Scale-Related Wavelet Coefficients for Double Encryption of Holographic Halftone Watermarking

3.1 Arnold Transformation Processing

The image is encrypted by scrambling transformation that enhanced the security of information. At the same time, scrambling transformation has a strong resistance to cropping and paint attack. Images matrix are transformed using Arnold transform. In this paper, it used Arnold transform to encrypt the halftone watermarking image, then insert the watermark image into the important coefficients at different orientations of the wavelet transformation.

The watermark image is seen as a dual function on the flat area $G = F(x, y)$, for arbitrary point $(x, y) \in R$, then $F(x, y)$ is on behalf of image information, (such as the gray value, etc.).

The result of iterative process is expressed as:

$$P_{xy}^{n+1} = AP_{xy}^{n} \pmod{N}$$  \hspace{1cm} (1)

where $P_{xy}^{n} = (x, y)^T$, $n = 0, 1, 2, \ldots$ is the number of iterations, the iteration process is cyclical.

The Fresnel halftone holographic watermark image is transformed by Arnold scrambling, after encryption, whose iteration cycle equals to 96. After 19 iterations, we get a secondary encryption Fresnel halftone holographic watermark image of $w(i, j)$. The result is shown in Fig. 2.

3.2 Data Hiding via Halftone Fusion on the Scale-Related Wavelet Coefficients

Halftoning is widely used in most constitutes the primary distortion for watermark data hiding. In this section, we give an overview of the proposed scheme. Figure 3 illustrates a halftone watermark hiding and recovery process where the continuous-tone image $C(x, y)$ and the watermark $w$ constitute the inputs to the encoder. The halftoning and embedding processes produce a halftoned image $H(x, y)$ that visually approximates the original image and carries the watermark information. In practice, watermark embedding can be performed prior to, after or concurrently with halftoning. In this article, the proposed method enables joint halftoning and embedding.

The original image is first decomposed using discrete wavelet transformation (DWT). The transformation from spatial domain to wavelet domain provides a compact representation of the original image. The multiscale information is shown in Fig. 4.

We can see that most of image energy compacted onto a few wavelet coefficients with large magnitudes while most wavelet coefficients are very small. This compact property allows us to capture the key characteristics of an image from a few large wavelet coefficients. Since most wavelet coeffi-
The wavelet coefficients have small values while only a few ones have large values. It is reasonable to assume that the wavelet coefficients are mutually independent. The boundary information of the image target is fused by the wavelet coefficients of the correlation between wavelet transform layer, which increases the pixel resolution scale. We apply the inter-scale fusion method to gain fusion coefficient of the fine-scale and take into account both the detail of the image and approximate information. The fusion information of wavelet coefficients inter-scale are shown in Fig. 5.

The human eye is equivalent to a low pass filter according to the characteristics of the human visual system, which is the most sensitive of low frequency and less sensitive of high frequency. However, the part of high frequency is liable to suffer from the attack of compression and filtering. Moreover, the energy is concentrated on the part of low frequency, which can resist strong outside attack and damage. The intermediate frequency falls in between high and low frequency. In this article, we select low, intermediate and high frequency as the position of embedding watermark information in the light of scale integration-related multi-resolution wavelet coefficients characteristic. The position of the embedded watermark information is preferably.

4. Experiments

In this section, we give the experimental settings, measure the watermarked image in terms of PSNR and UIQI. We also evaluate the performance of the proposed algorithm by comparing the performance among the proposed algorithm, Fu-Au [10]–[12] and J.M. Guo [13].

4.1 Holographic Halftone Watermark Embedding

In order to improve the reliability of results, we select the flower image (512 × 512) as a host image whose different scales fusion are embedded location in the halftoning process. The best embedding region is selected by comparison and analysis. The results are shown in Fig. 6 and the processing of halftone image embedding digital watermark is completed.

To further examine the performance of the proposed algorithm, we compare the proposed algorithm with the Fu-Au’s works [10]–[12] and J.M.Guo’s [13] method. The results are organized in Figs. 7 (a) and (b).

By combining different frequency domain, the performance of the proposed algorithm achieves 33dB and above 0.6 in terms of UIQI. Notably, the PSNR and UIQI by fusing scales 0, 1 and scales 0, 1, 2 are lower than Fu-Au [10]–[12] and J.M.Guo [13], whereas the fusion of scales 0, 1, 2, 3 and scales 0, 1, 2, 3, 4 results higher performance than alternative methods. After the original host image embedded watermark, note that the visual quality does not change and affect its use value. The best image quality is the scales 0, 1, 2, 3 and 4 fusion region and the worst is scales 0 and 1.

4.2 Extraction Method

Holographic halftone watermark extraction process is the inverse of watermark embedding. The extraction formula is
given as

\[ w(i, j) = [W'(i, j) - W(i, j)] / \alpha \] (2)

The wavelet coefficients of high, intermediate and low frequency where the target image is extracted, which is gained the cryptographic holographic watermark \( w(i, j) \). The decryption holographic watermark image is obtained after Arnold transform, where the number of iterations is equal to 77.

4.3 Holographic Halftone Watermark Robust Detection

Computer simulation watermark image may be subject to a variety of external attack during processing of pre-press and transmission, which contain noise, cut, scaling, filtering and JPEG compression attack. The results and robustness of the system are evaluated in Figs. 8 and 9.

Moreover, the performance of Fu-Au [10]–[12] and J.M.Guo [13] with NC is shown in Fig. 9 for comparison. The numerical data is also marked on the curves of Fig. 9. The experimental results suggest that NC is inferior to Fu-Au [10]–[12] and J.M.Guo [13] by fusing scales 0, 1 and scales 0, 1, 2. The proposed method is superior to these competing algorithms by fusing scales 0, 1, 2, 3 and scales 0, 1, 2, 3 and 4.

4.4 Influence of Watermarked System with Different Embedded Intensity

The process of the image halftone is a kind of watermark attack, which can be unable to extract the clear and effective watermarking information when security certification.

In order to achieve an appropriate trade-off between robustness and imperceptibility, the watermark image must have ability to resist halftone and need to choose the watermark embedding strength.

The different embedding intensity is organized in Tables 2 and 3 in terms of PSNR and UIQI of watermarked and halftone image. Figures 10 (a) and (b) show the PSNR and UIQI result from Tables 2 and 3. The PSNR of host image values decreases when the embedding strength increases before halftone attacks, but the watermark halftone image PSNR and UIQI values with different embedding strength are very similar. They are within the range of halftone image quality standards.

The results show that the effect of embedding intensity relative to halftoning changes can be ignored within a certain range. A comparison of the two watermarked indicates that the holographic watermarked has good concealment and large information capacity.

Table 4 shows NC value changes of watermark infor-

![Fig. 8 Various attacks experimental comparison image (a) Gaussian (b) Salt&pepper (c) Cut (d) Enlarge (e) Shrink (f) Filtering (g) JPEG compression.](image)

![Fig. 9 NC of watermark information after attract with different frequency domain.](image)

![Fig. 10 Quality evaluation parameters changes of watermarked and halftone image with different embedding intensity (a) PSNR (b) UIQI.](image)
The NC value changes of watermark information by halftone image with different embedding intensity. Figure 11 shows the NC result from Table 4. The NC increases when the embedding strength increases. The larger watermark embedding strength, the better robustness of watermarking system.

5. Conclusion

This article provides a technique for holographic halftone watermark embedding into halftone image when halftoning process, which provides high invisible watermark and low distortion. Our method for embedding via determining embedding regions and factor during the halftoning process enables low distortion. Experimental results show that the proposed scheme is robust against several attacks. During the processing of halftoning, the holographic halftone image watermark has good invisibility.

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