A Rapid Watermarking Strategy for Multi-Tone Images

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Abstract— Digital multitoning is an enhanced version of the halftone printing technique which can render multiple tones at each pixel of an image. This superior strategy offers a better printing quality in terms of smooth texture, homogeneity and less artifacts. Considering the potential scope of multitoning, an effective strategy to embed a binary watermark image is proposed. The proposed approach is based on multiple look up table (MLUT) which can alter multitone pattern in correspondence to the watermark tone. The MLUT table consist of adjacent multitone screens which are statistically differentiable and cannot be visually distinguishable. From experimental simulations, it is validated that the proposed technique yields consistent decoding rate, payload capacity and computationally less intensive in comparison with various halftone watermarking strategies.

I. INTRODUCTION

Digital halftoning is a technique for converting a gray or color scale image into its approximate binary image. The converted image is useful for paper printing using the standard black-andwhite printers [1], [2]. With the latest advents in printing technology, the printers can render more tones offering high quality printing output. Relevantly, the digital multitoning [3] is trending prevalent as it can offer enhanced visual output in terms of homogeneity, contrast and stable patterns. Standard halftoning techniques such as ordered dithering, error diffusion, dot diffusion and direct binary search can also be extended to the multitoning cases. As multitone method is computationally more intensive than the standard halftoning, the simplest approach of ordered dithering is highly favorable. Ordered dithering involves thresholding the gray scale images in a block wise manner using the halftone screens, and the output is assigned with either 0 or 1.

Formerly, the conventional halftone algorithms utilize ordered dithering techniques using the standard clustered- and dispersed-dot dither arrays. Though it is a straight forward and simple approach, the output image suffers from visible non-

homogeneous artifacts. Subsequently, the error- and dotdiffusion [4] were introduced to distribute the quantization error to the neighborhood pixels to improvise the rendered image quality. Finally, direct binary search (DBS) technique gained prominence as it can incorporate human visual system based filter [5]. But DBS is an iterative approach, hence it takes

more processing time. In the past few years, a major breakthrough has been achieved, with the introduction of blueand green-noise arrays, a comparable quality can be achieved even with an ordered dithering approach. With these extensive research in optimization of halftone patterns, the quality of the two-tone printing is nearly saturated and very difficult for further improvisations. In subsequent developments, digital multitoning is introduced to overcome the limitations of conventional halftones, and it can offer excellent image quality. The digital multitoning is broadly classified based on the spectral properties such as blue- and green-noise to support various printers [6]. Blue-noise pattern is preferable for inkjet printers which can deliver consistent rendering of various shades and stable dot patterns. Conversely, laser printers favor green-noise property that suits its nature of unstable dot printing. This paper deals with watermarking scheme for clustered dot (green-noise) multitones.

On the other hand, printed document watermarking is very essential to secure them against illegal copyrights, duplication and forgeries. The confidential printing papers range from legal documents, currencies, passports and other copyrighted works. For instance, in currency notes, various patterns are hided or made partly visible, makes it very difficult to reproduce without the knowledge of adopted printing technique. The watermarking usually involves embedding data that may be an audio, image, web link or other multimedia content. This papers deals with embedding binary image into multitone image, and can be extracted with high accuracy. The main objectives of the watermarking strategy are to achieve an imperceptibility and robustness. From literature review, it can be seen that majority of watermarking strategies are proposed for error diffusion halftones. Initially, vector quantization techniques [7] are used to embed watermark in the least- or most-significant bit and then modified error diffusion technique is used to embed the secret watermark. Subsequent strategies are proposed based on adaptive error diffusion kernels [8], a noise balanced error diffusion technique [9], [10] and a parity-matched strategy with minimum error searching [11] [12]. All these methods mainly exploit the difference in error diffusion kernels to embed the watermarks and as multitone has no such features, it is not applicable to them. A similar scenario exists for iterative-based halftones such as oriented modulation [13], block spread spectrum [14] and minimal error bit searching techniques [15].





Basically multitoning is an upgradation to ordered dither halftones, but there are very limited watermarking works exits in this category. Some of the successful works are based on dither matrices pairs [16] [19] [20], bit and sub-image interleaving [17] and hiding in high frequency regions [18]. All these methods are based on toggling between two dither array pairs which can deliver similar patterns. This approach is quite simple in halftones, as a dither array and its simple conjugate would satisfy this requirement. But in order to implement in multitone, which have multiple screens, it becomes more complex and cannot be implemented. Hence, a feasible watermarking approach for clustered dot multitone images is proposed in this work.

The contribution of this papers are as follows,

a) The multitone screen generation is analyzed in detail and an approach to generate similar multitone pattern is identified.

b) The watermarking approach does not require additional computation as the process is inherited in the multitoning scheme. This makes its rapid and simplistic than the other halftone watermarking strategies.

c) An effective way to decode the watermarked image is proposed using the maximum of inner product sum and is consistent with other methods.

The paper proceed as follows: Section II elaborates on digital multitoning implementation. Section III & IV details the proposed watermarking technique and its performance evaluations.

II. DIGITAL MULTITONING

Digital multitoning is usually performed using the ordered dithering technique of halftoning. In ordered dithering, host

image is divided in a block wise manner and then thresholding is carried out using a specific screen.

$$I_{out} = \begin{cases} 1 & if \ im(x,y) > S(x,y) \\ 0 & otherwise \end{cases}$$
(1)

where im(x, y) and S(x, y) corresponds to the image pixel and its corresponding dithering screen; $x \in \{1, 2, ..., M1\}$ and $y \in \{1, 2, ..., M2\}$, where M1x M2 refers to the image size.

The above stated ordered dithering is applicable to obtain binary patterns, and it is extended to multitoning as defined,

Three tone multitoning

$$I_{3} = \begin{cases} 1 & if \ im[m,n] > S^{1}; \\ 0.5 & if \ S^{1} \ge im[m,n] > S^{2}; \\ 0 & otherwise. \end{cases}$$
(2)

where S^1 and S^2 refers to the different level of multitone screens and I_3 refers to the 3-tone multitone output. In general, the number of screens required to perform multitoning is NT-1 (NT refers to the number of tones).

The construction of multitone screen relies on the direct binary search approach, which basically optimize the screens based on the perceived error between the original and multitone image. As human vision system (HVS) is a low pass filter (LPF), in order to compute the perceived error, a gaussian based filter is adopted. Among the various specification, a mixed gaussian model proposed by Kim, et. al [21], is found to generate superior pattern.

$$g[u, v] = k_1 \exp\left(-\frac{\gamma}{2\sigma_1^2}\right) + k_2 \exp\left(-\frac{\gamma}{2\sigma_2^2}\right), \quad (3)$$

where $\gamma = u^2 + v^2$ and $k_1 = 43.2$; $k_2 = 38.7$; $\sigma_1 = 0.02$; $\sigma_2 = 0.06$;

In general, the clustered dot multitone screen generation involves two filters for initial and update stages [22]. The proposed watermarking scheme exploits this filter specification to generate a visually similar but statistically differentiable patterns. As indicated in Fig. 1, {Screen 1, Screen 2... Screen N} represents the multitone screen which possess statistically proximal relation and their corresponding patterns are visually indistinguishable as shown in Fig. 2. (based on Liu. et. al [23]).



(a) Screen 1 output ($\sigma_{update} = 1.79$) (b) Screen 2 output ($\sigma_{update} = 1.80$) Fig. 2. Multitone output for different screens

It is important to mention that; the proposed watermark embedding does not require any additional computation with reference to standard multitoning procedure.

III. PROPOSED WATERMARKING STRATEGY

Fig. 1, illustrates the flowchart of the proposed watermarking strategy.

A. Image-watermark embedding strategy

i) The host image is processed in a block wise manner of size of B1xB2. Let us assume that the actual image size is M1xM2, then the size of the watermark is provided by

$$W1 = M1/B1; W2 = M2/B2$$
 (4)

As block size reduces, the watermark embedding capacity increases. Typically, 8x8 block size is used in default, and further reduction usually results in minor artifacts.

ii) Under this scheme, for each block of a host image, onebit data (single pixel) of a watermark information is embedded. Before embedding the watermark information, it is scrambled in a random manner using the pseudo random generator. This also serves as an additional key during the decoding strategy.

iii) The appropriate dither array is selected from the multiple look up table (MLUT) based on the watermark tone and processing block size. For binary watermark, two screens are randomly picked and their locations remains as the another secret key. For instance, screen 1 corresponds to bit '0' and some screen 'P' is picked randomly to indicate the watermark bit '1'.

B.Decoding strategy

In order to decode the embedded image pattern, the secret key corresponding to the pseudo random key and multitone screen location are required. The watermarked multitone image is divided in a block wise manner, and mean of each block undergoes with the inner product of MLUT.

$$IP_x = \sum_{x=1}^p \langle B_{wm}, S_x \rangle \tag{5}$$

where B_{wm} , S_x corresponds to the watermarked multitone image and multitone screens. The watermark is decoded with reference to the x which corresponds to maximum inner product.

$$ST = \max\{IP_1, IP_x\},\tag{6}$$

Once the secret tone (ST) is retrieved, the decoded pixels are re-arranged based on the pseudo random key used at the embedding end.

IV. RESULTS AND DISCUSSION

For performance evaluation and validation, 3-tone images are embedded with binary secret patterns. As printed images may undergo some damages such as tampering and cropping, their results are also added to ensure the robustness. To compute the retrieved image quality, the structural similarity index (SSIM) is adopted and is defined as [22],

$$SSIM = \left(\frac{2\mu_{x}\mu_{y}+C1}{\mu_{x}^{2}+\mu_{y}^{2}+C1}\right) \left(\frac{2\sigma_{xy}+C2}{\sigma_{x}^{2}+\sigma_{y}^{2}+C2}\right)$$
(7)

where μ_x , σ_x and μ_y , σ_y refers to the mean and; variance of test and reference image respectively. σ_{xy} corresponds to correlation coefficient between the test and reference image, and C1 and C2 are constants.

TABLEI

S. No	Block Size=8	Block Size=16	Block Size=32	Block Size=64
Actual Case	0.91	0.99	1	1
Tampered	0.85	0.93	0.94	0.98
JPEG(50%	0.79	0.86	0.92	0.97
compression)				

The image quality of the decoded watermark for actual, tampered and JPEG case is provided in Table I. The test result shows the average decoding accuracy performed on 100 host images with 10 different binary pattern embedded randomly. It can be inferred that, as block size increase the decoding quality also increases, as the inner product value is more differentiable. From Table II, it can be observed that the decoded image quality is consistent and the size of the watermark with respect to block size reduces with reference to Eq. 4.

TABLE II

DECODED SECRET IMAGE FOR 3-TONE IMAGE FOR DIFFERENT BLOCK SIZES





TABLE III TAMPERED IMAGE AND ITS DECODED WATERMARK.



2-Tone Watermark	Extracted Image
·· <u> </u>	SSIM_0.96 (BS_9)
	5511VI-0.00 (DS-0)

In Table III, an example of the tampered image and its result is shown, and from the decoded result the robustness of the proposed method is found to be valid.

TABLE IV WATERMARKING METHODS FOR HALFTONE IMAGES.

	Avg. Decoded	Avg Image	Maximum
Method	PSNR value	Quality	Bit
		(SSIM)	Depth
[8]	40.7 dB	0.98	1
[9] [15]	41.2 dB	0.99	1
[13]	43dB	0.996	3
[17] [18]	42 dB	0.98	1
Proposed	40.6 dB	0.99	1

As multitones are different from halftoning methods, the direct comparison in terms of payload or decoding rate won't be a good evaluation. Instead the average decoding rate, watermark image quality and bit depth are compared to ensure consistency. From Table IV, it can be validated that the proposed method exists similar performance with the other halftoning strategies.

V. CONCLUSION

A foremost and simple approach to embed a secret image pattern in the multitone image is proposed. The proposed strategy utilizes the properties of multitone screens to generate a visually similar patterns. In order to authenticate the secure image, the knowledge of multitone screen and pseudo random key are required. In compared with the existing methods, the strategy does not require any extra computation and has a consistent decoding rate. To summarize, the proposed strategy would be feasible for future printing applications and is proven to exist an effective and robust performance.

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