Watermarking for Multimedia *e*-Comics Copyright Protection

Paul Bao, *Senior Member IEEE* and Xiaohu Ma
Nanyang Technological University

Abstract — In this paper, we propose a novel watermarking scheme for resolving rightful ownership for the halftone images converted from drawing using a halftone-to-grayscale transform and the wavelet based watermarking. The scheme is comprised of three steps. Firstly the grayscale image is constructed from the binary image by a simple pattern-based transform, Secondly the grayscale image is watermarked using a general wavelet-based watermarking scheme. Finally the watermarked binary image is obtained through the inverse pattern-based transform of the watermarked grayscale image. Experimental results show that proposed approach is very simple yet yields an excellent performance in the quality of the watermarked image and the robustness of watermark.

1. Introduction

The rapid progression and widespread of handheld electronic devices capable of storing and displaying multimedia media such as eBooks, PDAs, Tablet PCs, etc. and the advancement of digital imagery in the past decade have enabled numerous applications in the areas of the multimedia entertainment and communications on electronic displays. One of the applications is the digital comic strips and cartoons stored, displayed and transmitted on eBooks, PDAs and Tablet PCs. The explosion of Internet furthermore enables the massive transmission of the digital comic strips over Internet but at the same time exposes their vulnerability to illegal copying and malicious tampering. Digital watermarking [1] for identifying the rightful owner and the authenticity of the digital data thus becomes an essential issue for the development of the digital comics.

An effective watermarking scheme for resolving the rightful ownership should possess the following characteristics: transparency, robustness to compressions and malicious tampering and blind detection of watermarking signatures. Digital comic strips and cartoons are generated typically from binary drawing, thus possess rather different characteristics than the traditional halftone images converted from the grayscale images. Digital comics tend to have non-smooth and discontinuous regions due to the hand-drawing whereas halftoned images are naturally smooth similar to their original grayscale images. Thus applying watermarking schemes directly for the comics may fail to preserve the fidelity and transparency of the images since the watermark embedding may alter the perceptions of the discontinuous regions. Unfortunately, very few works on watermarking for halftone and binary images have appeared in literature.

In this paper, we introduce a simple yet very effective watermarking scheme for the rightful ownership identification and authentication of digital comic strips. In this scheme, a digital comic (binary image) is first transformed into a grayscale image with the intensity resolution ranged in [0,7]. Then the grayscale image is wavelet transformed, watermarked by embedding the watermarking bits into the 1000 largest high-pass wavelet coefficients and inverse wavelet transformed to form the watermarked grayscale image. Finally, the watermarked grayscale image is inverse transformed to a halftone image using a pattern-based halftoning transform.

2. Watermarking For Binary Image

The proposed watermarking scheme for binary images is comprised of three steps in watermark embedding process, detailed as follows.

Firstly, the original binary image B is transformed to a 2^3 grayscale image G using 2×2 pattern-based transform, shown as in Figure 1.

$$\textit{Case}\,0\quad \begin{bmatrix}\circ & \circ\\ \circ & \circ\end{bmatrix}\to 0$$

$$\textit{Case}\,1\quad \begin{bmatrix}\bullet & \circ\\ \circ & \circ\end{bmatrix}\to 1,\quad \begin{bmatrix}\circ & \circ\\ \bullet & \circ\end{bmatrix}\to 1,\quad \begin{bmatrix}\circ & \circ\\ \circ & \bullet\end{bmatrix}\to 1,\quad \begin{bmatrix}\circ & \bullet\\ \circ & \circ\end{bmatrix}\to 1$$

$$\textit{Case}\,2\quad \begin{bmatrix}\bullet & \circ\\ \circ & \bullet\end{bmatrix}\to 2,\quad \begin{bmatrix}\circ & \bullet\\ \bullet & \circ\end{bmatrix}\to 2,\quad \begin{bmatrix}\bullet & \circ\\ \bullet & \circ\end{bmatrix}\to 3,\quad \begin{bmatrix}\circ & \circ\\ \bullet & \bullet\end{bmatrix}\to 3,\quad \begin{bmatrix}\circ & \bullet\\ \circ & \bullet\end{bmatrix}\to 4,\quad \begin{bmatrix}\bullet & \bullet\\ \circ & \circ\end{bmatrix}\to 4$$

$$\textit{Case}\,3\quad \begin{bmatrix}\bullet & \bullet\\ \bullet & \circ\end{bmatrix}\to 5,\quad \begin{bmatrix}\bullet & \circ\\ \bullet & \bullet\end{bmatrix}\to 5,\quad \begin{bmatrix}\circ & \bullet\\ \bullet & \bullet\end{bmatrix}\to 6,\quad \begin{bmatrix}\bullet & \bullet\\ \circ & \bullet\end{bmatrix}\to 6$$

$$\textit{Case}\,4\quad \begin{bmatrix}\bullet & \bullet\\ \bullet & \bullet\end{bmatrix}\to 7$$

Figure 1. Pattern-based Transform

where $\bullet$ or $\circ$ indicates the black or white pixel, respectively. Using this pattern-based transform, all the 16 2×2 patterns can be converted to resolution range [0,7] and a binary image can be transformed into a grayscale image of range [0,7]. Of course, this is a many-to-one transform. Figure 2 show the resulted grayscale image transformed from the original binary images shown in Figure 4.

Secondly, we first perform wavelet transform on the grayscale image *G*, and embed the watermark bits on the N ($N = 1000$ in our experiment) largest high-pass wavelet coefficients. Finally the watermarked grayscale image G_w is formed through the inverse wavelet transform of the watermarked coefficients. The embedding process can be described as follows.

Form the 1000 largest high-pass wavelet coefficients to be a vector V and insert watermark X into V to obtain $V^{'}$ according to the following formula [22]

$$v_i^{'} = v_i(1 + \alpha_i x_i) \quad (1)$$

where α_i is a weighting parameter. For simplicity, we set $\alpha_i = 0.1$ for all the elements x_i.

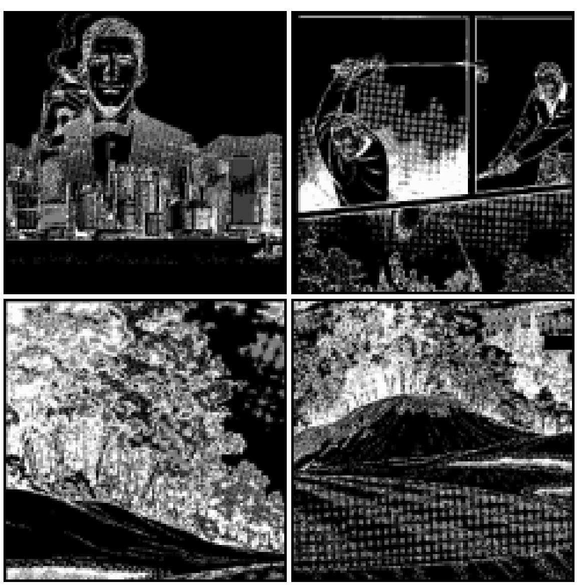

Figure 2 .The resulted grayscale image converted from the tested original binary images shown as in Figure 4.

Finally, an inverse pattern-based transform is performed on the watermarked grayscale image G_w, resulting in the watermarked binary image B_w. Experiment shows that the watermarked image B_w achieves an excellent performance in both the visual perception (Figure 5) and the similarity measurement (Table 1). The inverse pattern-value transform can be detailed as follows.

(1) For each pixel in G_w, if its value is same as that of the corresponding pixel in *G*, then the corresponding 2×2 block in *B* is copied to the corresponding block of the output watermarked binary image B_w.

(2) For each pixel in G_w, if its value is different from that of the corresponding pixel in *G*, then perform the following:

a) If the pixel value is out of the range [0,7], it is forced to the block [0 0;0 0] in *Matlab* notation.

b) If the pixel value is 0 or 7, the it is converted to the block [0 0;0 0] or [1 1;1 1] respectively, where 1 stands for black dot, and 0 stands for white dot.

c) If the pixel value is in the range [1], then the corresponding pattern in case 1, case 2 or case 3 shown in figure 1 is selected, respectively, and copied to the corresponding block of the watermarked binary image B_w.

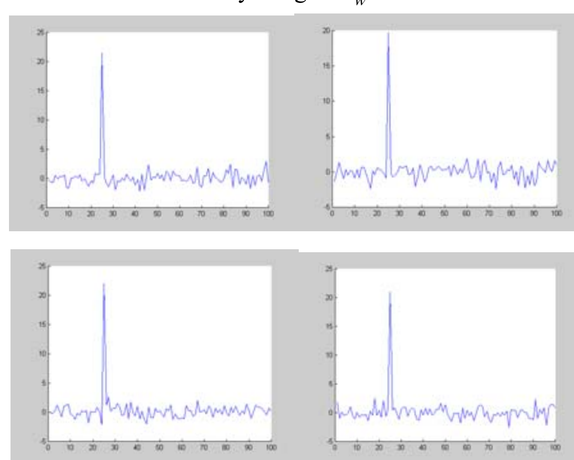

Figure 3. Detector response to the randomly generated 100 watermarks, only one peak exceeds the threshold *T*=6, corresponding to the test image 1, image 2, image 3 and image 4 respectively, shown in Figure 4.

In the watermark detection procedure, the grayscale image G_w is first obtained by performing the pattern-based transform to the watermarked binary image B_w. Denoted by X' the watermark extracted from the coefficient vector $V^{'*}$ corresponding the vector $V^{'}$ ($V^{'*}$ and $V^{'}$ may be slightly different duo to the non-uniqueness of the inverse pattern-based transform), we adopt the following formula [22] to evaluate the detector response (or similarity between X and X') and then compare it with a threshold ($T = 6$) to determine if the watermarks match.

$$sim(X, X') = X^T . X / \|X'\|_2 \qquad (2)$$

3. Experiment

In our experiments, 2×2 pattern and 3×3 pattern are adopted to transform the binary image into grayscale image for wavelet based watermarking. The watermarked binary image is obtained through the inverse pattern-based transform from the grayscale image. Experimental results show that the watermarking scheme based on 2×2 pattern outperforms that of 3×3 pattern based, as shown in Table 1, where the correlation coefficient r=corr2(B, B_w) between the original binary image *B* and the watermarked binary image B_w, defined by

$$r = \frac{\sum_i \sum (B_{ij} - \overline{B})((B_w)_{ij} - \overline{B}_w)}{\sqrt{\left(\sum_i \sum_j (B_{ij} - \overline{B})^2\right)\left(\sum_i \sum_j ((B_w)_{ij} - \overline{B}_w)^2\right)}}$$

where $\overline{B}$ is the mean of B, is larger in 2×2 pattern than in 3×3 pattern. Compared with the direct wavelet-based watermarking scheme, 2×2 pattern transform based scheme possesses the higher response of the detector, also shown in Table 1. In our experiments, 100 *Gaussian* random vectors are used to test our scheme, where the 25^{th} random vector is watermark embedded into all the test images of resolution 400×400. Figure 4 shows the four original images. The corresponding watermarked images obtained by 2×2 pattern transform scheme are shown in Figure 5.

Table 1. Similarity of *X* and *X'*, Correlation coefficient r between the original binary image *B* and the watermarked binary image B_w

Method / Image	2×2 Pattern	3×3 Pattern	Directly DWT
Image 1	21.4715 0.9480	21.4974 0.8841	17.5565 0.9761
Image 2	19.6954 0.9618	20.8096 0.9078	17.5565 0.9787
Image 3	21.9857 0.9709	23.2502 0.9223	17.5565 0.9871
Image 4	20.9792 0.9705	22.3806 0.9224	17.5565 0.9853

4. Conclusion

In this paper, a simple yet effective watermarking scheme for digital comic strips and cartoon images is presented for resolving the rightful ownership and authentication. Experiment shows that the proposed scheme possesses an excellent transparency in visual perception and the high response values of the detector.

References

[1] G.L. Friedman, "The trustworthy digital camera: Restoring credibility to the photographic image," *IEEE Trans. Consumer Electron.*, vol. 39, pp. 905–910, Nov. 1993.

[2] I. J. Cox, J. Kilian, F. T. Leighton and T. Shamoon, Secure spread spectrum watermarking for multimedia, *IEEE Trans. Image Processing*, vol. 6, no. 12, pp. 1673-1687, 1997.

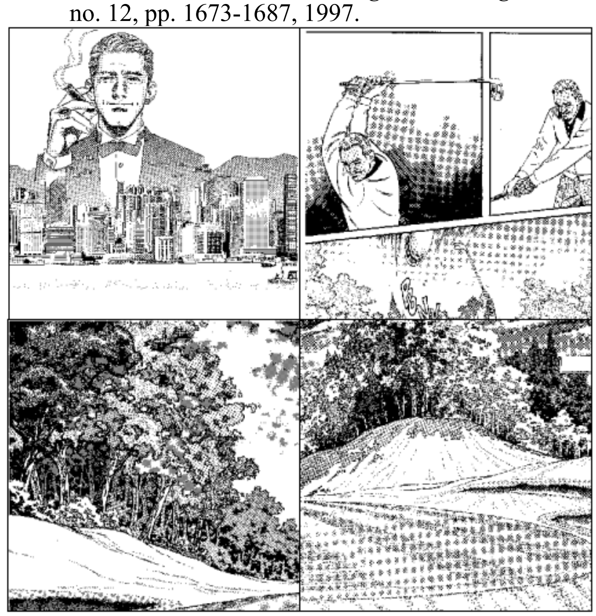

Figure 4. Original digital comic images 1,2,3,and 4.

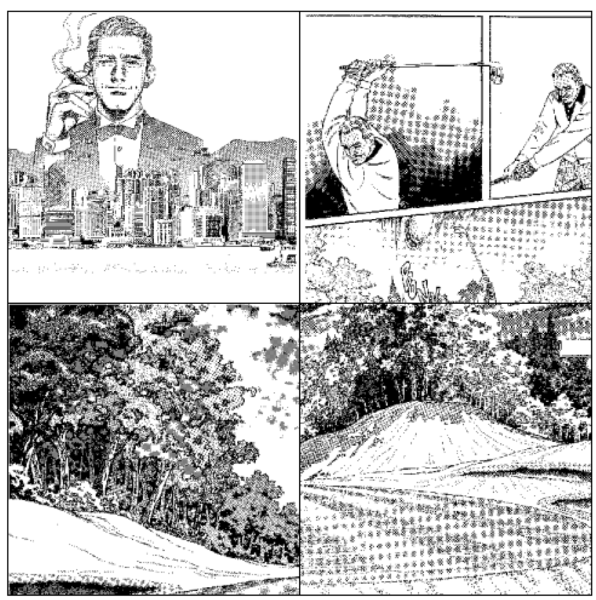

Figure 5. The corresponding watermarked images.