Self-Synchronization Object Watermarking Scheme Based on shape Subdivision

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Abstract-*This study proposes a new object-based watermarking scheme based on efficient segmentation using parallel and perpendicular lines of two principal axes in the spatial domain. The lengths and orientation of two principal axes of the object were employed to achieve synchronizing detection problem. Experimental results reveal that the proposed method is robust to geometrical and boundary pixel cropped attacks*

Keywords: Object-based watermarking, Shape subdivision, Principal axis, Geometrical attacks. Synchronization Recovery

1. Introduction

The current rapid development of IT technologies on the Internet for fast provision of commercial multimedia services has derived an urgent demand for reliable and secure copyright protection for digital multimedia. Watermarking is the technology used for copy control and media identification and tracing. Most proposed watermarking methods are designed for the protection of digital images. Theses methods embed *a* short message (a watermark) in the image without affecting the usability but that can be detected using dedicated analysis software. There are many robust watermarking techniques such as statistics [1], signal transformation [2], spread spectrum [3], Discrete Cosine Transform (DCT)[4], Discrete Fourier Transform (DFT)[5], wavlets[6], fractals[7], Fourier-Mellin transform[8],and content based method[9] which can be efficiently applied in doing watermarking into digital images. The stego-images generated by these methods own the ability to survive common image processing operations, such as lossy compression, filtering, noise adding, geometrical transformations, etc. For a comprehensive description about watermarking technique, see [10].

Owing to the development of MPEG4 and its object-based nature, video objects (VOs) become more important in multimedia applications. However, video objects are very easily manipulated or copied without suffering too much efforts and any noticeable distortion. Another important demand about copyright protection comes from Internet. Auction on web has become an important commodity exchange at the present time. Provos and Honeyman [16] ran a project automatically examined over two million JPEG images on e-Bay to discover the secrete message embedded in them after the September 11 attacks. Besides, images on auction web are easy to be copied, segmented and poached with handy image processing tools like PhotoShop or PhotoImpact. For non-object-based watermarking scheme, segmenting object from an image could cause a fatally result in watermark detection. Therefore, to develop a robust object-based watermarking technique becomes a very important issue. In the previous works about object-based watermarking schemes[11][12], few of them considered the synchronization detection problem. Recently, Guo[13] and Lu[14] apply inertia ellipse and eigenvectors to rectify the object distortions derived from geometrical attacks such as rotation and scaling, respectively. However, those works used frequency based watermarking schemes and DCT based methods, which work well to survive from signal process attacks but are very sensitive to geometrical attacks like scaling and warping[14], that might cause fatal result for slightly “miss-position” by using inaccurate segmentation procedure.

This work presents a new object-based watermarking scheme to improve the tolerance against geometrical attacks. Proposed scheme is based on the invariance of spatial relationships between a set of sub-regions in an image object. Combined with the computation of orientation and lengths of principle axes to make the proposed scheme rotation and translation invariant. The procedure of proposed scheme is illustrated in Fig.1

The remainder of this paper is organized as follows. The following section briefly describes the proposed method of segmenting an object image into numerous small sub-regions based on MPEG-4 BIFS. Section 3 then details the procedures of watermark embedding and extraction. Section 4 describes the experimental results related to some attacks, including mean filter, JPEG compression, rotation, rotation and scaling, and boundary pixel cropping. We also implemented Lu's[14] method for comparison. Section 5 gives a detailed discussion. The final section summarizes our work.

2. Shape Sub-division for Synchronization

Let f be an object image segmented from gray level or color images and let its corresponding shape S be simply obtained in binary image form by converting all pixel's illumination of f by all pixels into the same gray value. To ensure the success of embedding /extracting watermarks on specified locations of f, shape subdivision corresponding to the principal axes is performed. This procedure is described as follows:

Step 1: Calculate the second-ordered central moments of S, including μ_{02}, μ_{20}, and μ_{11}.

Step 2: Calculate the principle angle ϕ of S from the central moments with:

$$\theta = \frac{1}{2}\tan^{-1}\left(\frac{2\mu_{11}}{\mu_{20}-\mu_{02}}\right) \quad (1)$$

Step 3: Determine the minimum bounding rectangle of the rotated object S with rotated around its mass center c at an angle of ϕ. The length and width of rectangle are equal to the lengths of computed principal axes, respectively.

Step 4: Divide the object image by segment the bounded rectangles into m by n small similar rectangles. Figure 2(b) shows an example of a doll shape subdivision.

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3. Watermark embedding and extraction

Supposed that an object image f is first transformed into f' by applying an affine transformation T described as a geometrical attack. The transformed image f' is then divided into disjoint m x n gray level image blocks $,B'_1,B'_2,\ldots,B'_{mxn}$, by using the above segmentation method. The parameters m and n can be regarded as secret keys to embed and protect data. Then, all the pixels in object f are classified into one of the blocks $B_1,B_2,\ldots,B_{mxn}$ by performing the following test: if the pixel with coordinates (x, y) mapped by T located in the block B_i' then p will be assigned into block B_i. We partition all blocks B_i into k groups, $G_1, G_2, \ldots, G_k$, when k-bit secret bits required to be embedded as a watermark. Each group G_i can be denoted as

$$G_i = \{B_j : (i-1)\times\left\lfloor\frac{m\times n}{k}\right\rfloor + 1 \le j \le i\times\left\lfloor\frac{m\times n}{k}\right\rfloor, j\in N\} \quad (2)$$

Besides, we divided G_i into a pair of subsets C_i and D_i where C_i contains all the blocks B_j in G_i with odd indices and D_i with the even indices, respectively.

Finally, the following rule is kept to embed watermark bit w_i:

$$\left|\overline{C_i} - \overline{D_i}\right| \ge ¢_u \quad \text{if } w_i = 1$$
$$\left|\overline{C_i} - \overline{D_i}\right| \le ¢_l \quad \text{if } w_i = 0 \quad (3)$$

where $\overline{C_i}$ and $\overline{D_i}$ are the mean gray values of pixel intensities on their corresponding blocks, respectively. $¢_u$ and $¢_l$ are the upper and lower threshold to control the out watermarked image quality. We can adaptively modify the values of $\overline{C_i}$ and $\overline{D_i}$ by adding or subtracting a fix value to each pixel of relative blocks to fit the requirement of the rule. Besides, to improve the quality of watermarked image, adjusting the pixel intensities according to the gradient of each pixel is also helpful for reducing the effect of blockness.

The gradient of each pixel computed here is defined as

$$g_p = \max(|p-q|), q\in D, \quad (4)$$

where D is an area centered by pixel p.

To avoid from blockness effect , we adjust the intensity of each pixel by keeping the following constraint .The modified capacity of each pixel is defined as

$$C_p = \lfloor \log_2(g_p) \rfloor + 1 \quad (5)$$

To extract watermarks from a test object, the same normalization and segmentation procedures in watermark embedding are performed with the specified used secret keys. We can then compute the corresponding blocks and extract watermarks easily by comparing $\overline{C_i}$ and $\overline{D_i}$, if $\left|\overline{C_i}-\overline{D_i}\right| \geq (¢_u + ¢_l)/2$ then watermark bit "1" is extracted, otherwise bit "0" is extracted.

4. Experimental results

An object image "Russian Doll" is used for our watermarking experiments. Fig. 2(a) shows the original object image and its principle angle is obtained as Φ =1.29 , and Fig. 2(b) is its corresponding normalized object by transformed. Fig. 2(c) illustrates the shape segmentation result of Fig. 2(a) on where there are totally 24 × 24 small blocks. We embed 32 watermark bits into the object image in Fig. 2(a).

To evaluate the proposed scheme, two similarity measurements *PSNR* and *NC* are used. The *PSNR* is used to measure the gray image quality and the *NC* is used to measure the similarity between two bi-level watermarks. The *NC*(Normalized Correlation)[15] is defined as follows:

$$NC = \frac{\sum_i w_i \cdot w'_i}{\sum_i w_i^2} \frac{\sum_i (1-w_i)\cdot(1-w'_i)}{\sum_i (1-w_i)^2} \qquad (5)$$

Different attacks in our experiments including mean filtering, JPEG compression, noises, scaling and boundary pixel cropping. Fig. (3) shows another experiment using the image "Vase". To evaluate the proposed method under different attacks, Lu's method[14] which is based on DCT and side information is implemented and compared. Experimental results are shown in Table 1.

5. Discussion

Digital watermarking algorithms in the frequency domain are well known to have better characteristics on resisting general image processing attacks. The experimental results show that the method of Lu performed slightly better than the proposed method in some image processing attacks, such as mean filtering and uniform noise adding. However, the proposed method performs much better than that of Lu in resisting general geometrical attacks such as row/column removal and boundary pixel cropping. Attack of removing two continuous lines from watermarked object causes a fatal detection error using the method of Lu. Moreover, certain commercial software such as PhotoImpact and PhotoShop provide a boundary pixel cropping function to erode the boundary pixels of object images.

Row/Column removal and boundary pixel cropping attacks refer to that the removal of some pixels of the watermarked object image will reduce the accuracy of synchronization in the watermark detection, thus disabling the ability of the detector to retrieve the watermark blindly. The visual quality of the image that has been applied the attacks mentioned above is usually quite acceptable to the human perception even with a poor watermark detection result. Notably, the watermarking method of Lu tends to be more vulnerable than the proposed method to this type of attack. This difference may exist because each pixel on the removed one row/column of watermarked images contains contributions from all DCT transform. Furthermore, the position translation between the watermarked and the original object images will cause the DCT-based method to fail in watermark detection. Table 1 reveals that the JPEG compression attacks on object images generate new pixels around the boundary regions. This phenomenon significantly reduces the correlation detector.

For non-object-based watermarking scheme, segmenting object from an image could cause a fatally result in watermark detection [16]. The proposed object based watermarking scheme is possible to select relevant objects separately and embed watermarks into the selected objects. Those objects should be the most important parts of the image. When a certain region contained one of these objects is cut from the image and poached, we could still detect the watermarks with the proposed method correctly. Figure 4 gives an example to embed watermarks into a selected object, the face of Lenna. Experimental result shows that even after the attacks of rotation, scaling and boundary pixel cropping, a high NC value of 0.82 is obtained.

Besides, adopting simple operations in shape subdivision, the proposed scheme can efficiently achieve the synchronization recovery which is required for recovering from some geometrical attacks such as "skew". Skew operation will change the locations of the principal axes of image objects. Figure 5 shows an example of synchronization recovery from skewing the image "Vase". The x and y axes in Figure 5(c) stand for the orientation adjustment of the two principal axes, respectively. The output value on z axis stands for *NC* values of watermark detection.

6. Conclusions

This study presented a new object-based watermarking scheme, based on principal axes and self-similarity segmentation. This proposed scheme also was compared with the DCT-based method developed by Lu. Three object images taken from product images on the Ebay auction site were used for model testing. Experimental results show that the proposed scheme is preferable to that of Lu for resisting geometrical attacks, particularly under the row/column and boundary pixel cropping attacks.

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Table 1: Experimental results against attacks

Target object image		Russian Doll		Vase	
attacks		NC proposed	NC-Lu's	NC proposed	NC-Lu's
PSNR		40.91	41.39	38.89	39.55
Watermarked (no attack)		1.00	0.80	1.00	0.64
mean filter	3×3	0.94	0.80	1.00	0.66
	5×5	0.88	0.80	0.76	0.68
jpeg	20%	0.94	0.58	1.00	0.16*
Uniform noises	ó=10	1.00	0.80	1.00	0.64
	ó=15	0.94	0.80	0.41*	0.64
	ó=20	0.25*	0.80	0.18*	0.64
rotation 20°		0.94	0.72	0.92	0.62
scaling	0.8 × 0.8	0.94	0.72	1.0	0.64
	1.25 × 1.0	0.94	0.72	1.0	0.62
	1.0 ×	0.94	0.72	1.0	0.62
one row/column removal		1.00	0.20*	1.0	0.45
two rows/columns removal		0.92	0.05*	1.0	0.21*
Boundry cropping(3 pixels)		0.68	0.01*	0.81	0.10*

* Undetectable

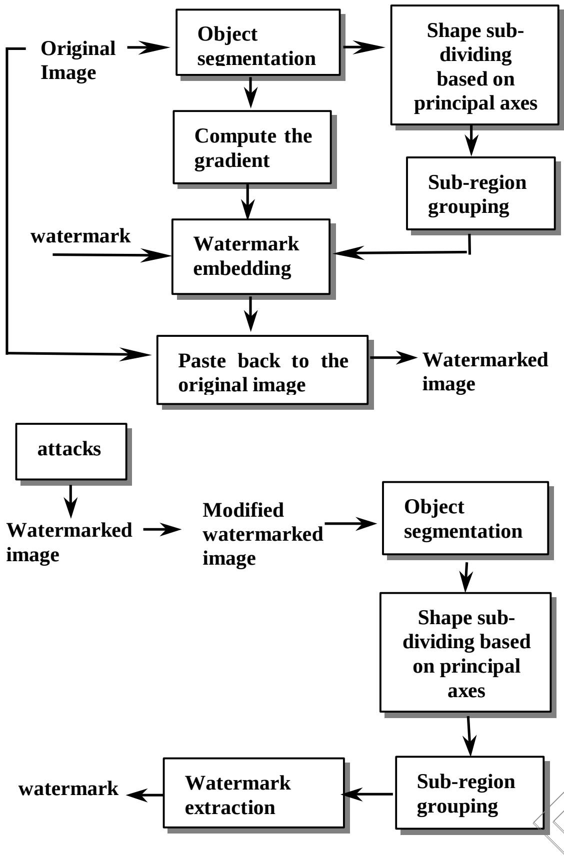

Figure 1: Block diagram of the proposed watermarking scheme


Fig.2(a)


Fig.2(b)

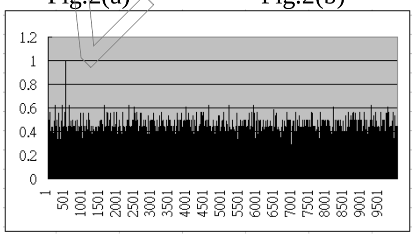
Fig.2(c)

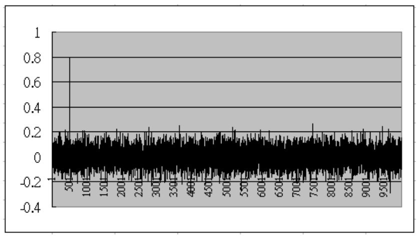
Fig.2(d)

Figure 2: Proposed scheme on a “Russia Doll” object
Fig.2(a): The test object image “Russia Doll”.
Fig.2(b): The shape subdivision of image in Fig.2(a).
Fig.2(c): The corresponding detector response using the proposed method.
Fig.2(d): The corresponding detector response using Lu’s method.


Fig.3(a)


Fig.3(b)

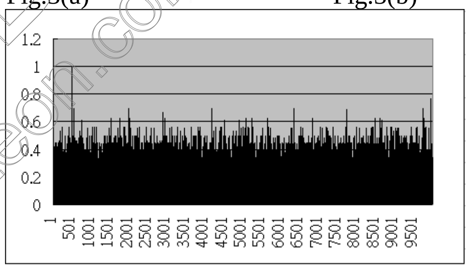
Fig.3(c)

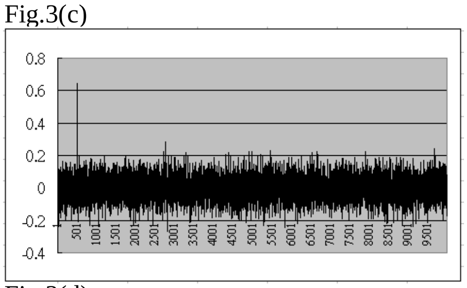
Fig.3(d)

Figure 3: Proposed scheme on a “Vase” object
Fig.3(a): The test object image “Vase”.
Fig.3(b): The shape subdivision of image in Fig.2(a).
Fig.3(c): The corresponding detector response using the proposed method.
Fig.3(d): The corresponding detector response using Lu’s method.

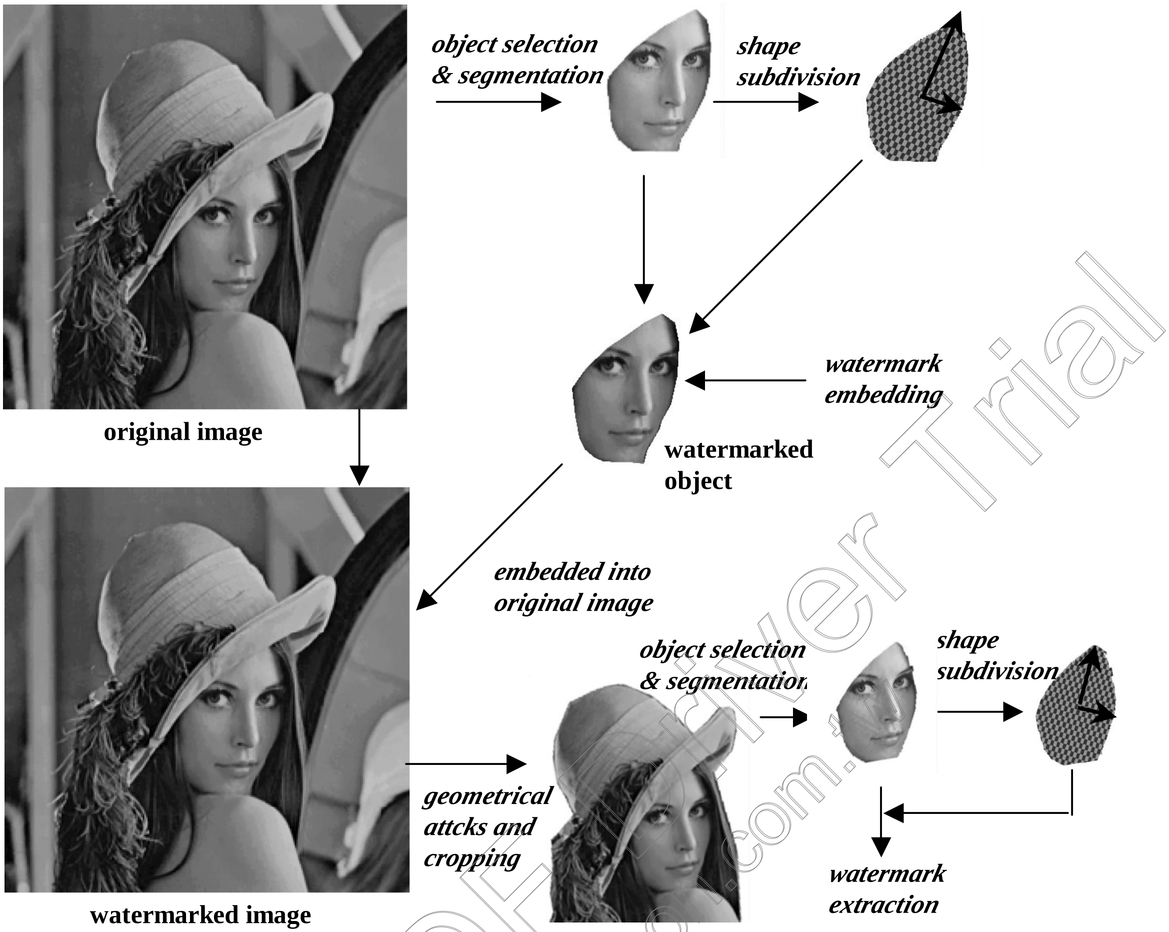

Figure 4: An interactive object watermarking application using the proposed scheme

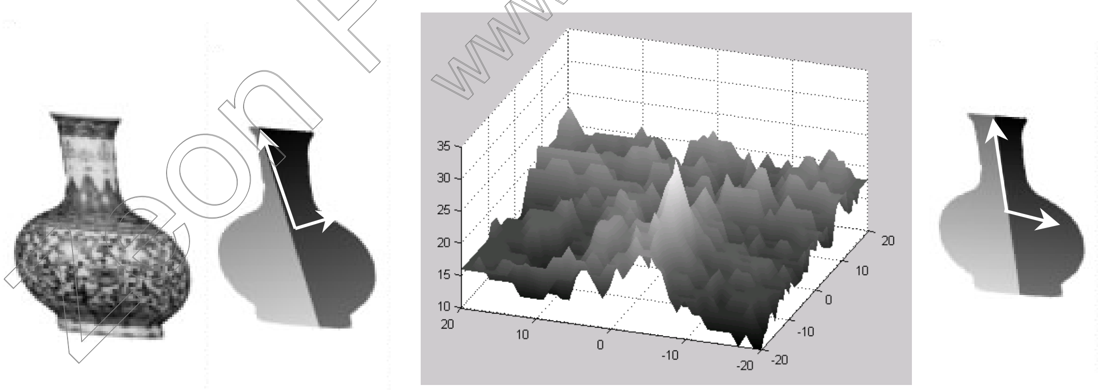

Fig.(a) Fig.(b) Fig.(c) Fig.(d)

Figure 5: The experiment of skew calibration by searching the nearly angles of computed principal axes orientations.

Fig.5(a): The skew “Vase” image.

Fig. 5(b): The principal axes detection of object in Fig. 5(a)

Fig. 5(c): Synchronization recovery by searching correct orientations of the two principal axes.

Fig. 5(d): The principal axes after recovery.