

An Improved DCT Based Color Image Watermarking Scheme

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Abstract. In this paper, an improved blind color image watermarking algorithm based on relationship embedding strategy is proposed. Firstly, the original RGB color image is transformed into YCbCr color space. Secondly, the *Y* channel of YCbCr color space is divided blocks sized 8×8, and then perform two dimensional discrete cosine transform on each block. Finally, embed binary watermarking signal by changing one pair selected middle-frequency sub-band coefficient's relationship. Experimental results show that the proposed algorithm has very good transparency and robustness against the common image processing. Compared with other similar algorithms, it has better performance.

Introduction

In recent years, with the rapid development of digital multimedia technology, the multimedia data can be produced and restored easily without distortion. However, many new issues such as security of multimedia communication and copyright protection of multimedia products have emerged. For copyright protection problem of digital multimedia, copyright owner usually embeds a watermarking signal into original cover multimedia to certify its copyright. Generally, traditional watermarking technologies can be classified into three categories according to cover multimedia type, namely audio watermarking [1], video watermarking [2] and image watermarking [3-18], respectively.

For image watermarking technology, most schemes use grayscale image as cover signal. If the host image is RGB color image, on the one hand, the watermarking algorithms can embed directly watermarking signal into each component or selected component [3-5]. On the other hand, the embedding schemes perform color model transformation from RGB color space to YCbCr or YUV color space firstly and then usually embed watermarking information into *Y* component [6-16]. Since transform domain schemes have better performances in terms of transparency and robustness than spatial domain methods, researchers usually embed watermarking signal into transform domain coefficients at present. For transform domain image watermarking algorithms, first the cover image or image block is performed by DCT [3, 5, 8-17] or discrete wavelet transform (DWT) [2, 6] or singular value decomposition (SVD) [1, 18]. And then, the watermarking signal bits are embedded in the frequency domain coefficients by designed watermarking embedding method.

Currently, many digital image watermarking algorithms based on DCT have proposed in the literature. In 2013, Yesilyurt et al. [10] proposed a novel blind DCT based on watermarking algorithm using neighbour DCT coefficients, but we have found that this algorithm cannot extract correctly watermarking bits in some un-attacked watermarked image blocks. In [11], an adaptive blind watermarking algorithm in DCT domain is proposed. This scheme also embeds binary watermarking bits in selected middle frequency coefficient by using neighbour DCT coefficients. It has a good transparency. However, its robustness performance has the same drawback with [10]. Therefore, in this paper an improved blind robust watermarking scheme based on DCT is proposed for RGB color image. The proposed algorithm first converts the RGB color space to YCbCr model and then embeds the binary watermarking signal into the *Y* channel of the YCbCr model. This scheme can not only achieve good transparency but also resist common image processing attacks. Compared with similar

watermarking schemes based on DCT, it has a better robustness performance under the same conditions.

Proposed Watermarking Scheme

Embedding Scheme. Step 1. Convert original RGB color image to YCbCr color space. The transformation is defined as Eq. (1).

$$\begin{cases} Y = 0.299R + 0.587G + 0.114B \\ Cb = -0.169R - 0.331G + 0.500B \\ Cr = 0.500R - 0.419G - 0.081B \end{cases} \quad (1)$$

Step 2. Select Y component of YCbCr color space and it is divided blocks sized 8×8 . For each image block, 2D-DCT transform is applied on it.

Step 3. Assume the watermarking embedding strength is K . Modify $DCT(5, 2)$ and $DCT(4, 3)$ coefficients to embed binary watermarking signal bits.

If $DCT(5, 2) \geq DCT(4, 3)$

$F = 1$

End

If $DCT(5, 2) < DCT(4, 3)$

$F = 0$

End

$Dif = |DCT(5, 2) - DCT(4, 3)|$

If $F = 0 \ \&\& \ w = 0$

If $Dif < K$

$DCT(4, 3) = DCT(4, 3) + (Dif + K) / 2$

$DCT(5, 2) = DCT(5, 2) - (Dif + K) / 2$

End

End

If $F = 1 \ \&\& \ w = 1$

If $Dif < K$

$DCT(4, 3) = DCT(4, 3) - (Dif + K) / 2$

$DCT(5, 2) = DCT(5, 2) + (Dif + K) / 2$

End

End

If $F = 1 \ \&\& \ w = 0$

$DCT(4, 3) = DCT(4, 3) + (Dif + K) / 2$

$DCT(5, 2) = DCT(5, 2) - (Dif + K) / 2$

End

If $F = 0 \ \&\& \ w = 1$

$DCT(4, 3) = DCT(4, 3) - (Dif + K) / 2$

$DCT(5, 2) = DCT(5, 2) + (Dif + K) / 2$

End

Step 4. Perform inverse 2D-DCT transform on new DCT coefficients to obtain an embedded image block. When all blocks are embedded watermarking signal, the RGB watermarked image is obtained after inverse color transformation. The inverse color space transformation is defined as equation (2).

$$\begin{cases} R = 1.000Y - 0.001Cb + 1.402Cr \\ G = 1.000Y - 0.344Cb - 0.714Cr \\ B = 1.000Y + 1.772Cb + 0.001Cr \end{cases} \quad (2)$$

Extraction Scheme. Step 1. Convert RGB watermarked color image to YCbCr color space using Eq. (1).

Step 2. Select Y component of YCbCr color space and it is divided blocks sized 8×8 . For each image block, 2D-DCT transform is performed.

Step 3. The binary watermarking bits are extracted as below.

If $DCT(5, 2) > DCT(4, 3)$

$w = 1$

End

If $DCT(5, 2) < DCT(4, 3)$

$w = 0$

End

Experimental Results

In this section, in order to evaluate the performance of proposed algorithm, a 64×64 binary image is used as original watermarking signal and is shown in Fig. 1. Four standard RGB color images sized $512 \times 512 \times 3$ are selected as original cover image, namely Airplane, Sailboat, Peppers and Lena, as shown in Fig. 2. In the experiment, for Yesilyurt's algorithm, the constant C is set to be 8. The embedding strength β in [11] is 2.5. The threshold K of the proposed scheme defined in Section 2 is set to be 16.

Imperceptibility Test. In this paper, the peak signal to noise ratio (PSNR) is used to measure the distortion between the original image and the watermarked image, which is defined as follows.

$$PSNR = 10 \times \log_{10} \left(\frac{255^2}{MSE} \right) \quad (3)$$

The mean square error (MSE) between the original image x and the watermarked image x' is defined as:

$$MSE = \frac{1}{M \times M} \times \sum_{i=1}^M \sum_{j=1}^M (x_{i,j} - x'_{i,j})^2 \quad (4)$$

where, M is width or height of cover image and is set to be 512 in this paper. Generally speaking, if the watermarking algorithm has high $PSNR$ value, the visual quality of watermarked image is very good.



Fig.1 Original binary watermarking image.

The $PSNR$ comparison results between each component of original RGB image and watermarked image are shown in Table 1. From Table 1, these results indicate that the proposed algorithm and other two schemes in [10] and [11] have good visual quality of watermarked image and satisfy the basic requirements of the invisible watermarking technology. The average $PSNR$ are about 40 dB.



Fig. 2 Original images and watermarked images.

Robustness Against Various Attacks. For watermarking technology, the normalized cross-correlation (NC) is usually used to evaluate the similarity between the original watermarking image w and the extracted watermarking image w' in the literature, which is defined as Eq. (5).

$$NC = \frac{1}{N \times N} \times \sum_{i=1}^N \sum_{j=1}^N (w_{i,j} \oplus w'_{i,j}) \quad (5)$$

where, N is width or height of binary watermarking image and is set to be 64 in this paper, \oplus symbol represents XOR operation. Generally speaking, if it has high NC , the algorithm has better robustness against attacks.

Table 1. *PSNR* comparisons between proposed algorithm and other algorithms in [10] and [11].

Images	Proposed algorithm's <i>PSNR</i> (dB)			Ref.[10]'s <i>PSNR</i> (dB)			Ref.[11]'s <i>PSNR</i> (dB)		
	R	G	B	R	G	B	R	G	B
Airplane	40.6580	40.8078	41.2068	40.1391	40.2889	40.6879	41.5967	41.7464	42.1455
Lena	42.0335	41.7917	41.4706	42.7574	42.5156	42.1945	41.6830	41.4412	41.1201
Peppers	41.1149	41.3376	41.0394	41.4141	41.6369	41.3386	43.3305	43.5533	43.2550
Sailboat	39.6963	40.3106	40.4146	37.9864	38.6006	38.7047	39.7202	40.3345	40.4385

Robustness Comparisons with Similar Algorithms. In order to further evaluate the robustness performance of the proposed algorithm against different attacks such as common image processing, we compared our algorithm with similar color image watermarking algorithms based on DCT in [10] and [11]. The comparison results between visual quality (*PSNR*) and robustness performance (*NC*) after various common image processing attacks under the same conditions are shown in Table 2. It can be easily seen that three algorithms have almost same *PSNR* values after various attack due to the *PSNR* values of watermarked image without attack are also almost same, but the proposed scheme has better robustness performance than other two algorithms in [10] and [11] against most image processing attacks in Table 2.

In conclusion, the proposed algorithm has obtained a better trade-off between the imperceptibility of watermarked image and the robustness of extracted watermarking image. Compared with similar embedding algorithms based on DCT in [10] and [11], the proposed algorithm has better robustness performance under the same conditions.

Conclusions

An improved blind watermarking algorithm for color image based on discrete cosine transform is proposed in this paper. The algorithm embeds only one bit watermarking signal in each block by changing one pair selected middle-frequency sub-band coefficient's relationship. Experimental results show that this algorithm is simple and has good transparency and robustness against common image processing attacks, such as added noise, filtering, JPEG compression and so on. The comparison of proposed algorithm with similar algorithms based on DCT in [10] and [11] show that this algorithm has better performance. To further enhance proposed algorithm's security, one simple and feasible solution is that the watermarking signal is encrypted by chaos signal and Arnold scrambling or the embedding position is selected randomly based on secret key.

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Table 2. PSNR and NC comparisons between proposed scheme and other schemes in [10] and [11].

Images	Attacks	Proposed algorithm		M. Yesilyurt [10]		B. Xie [11]	
		PSNR (dB)	NC	PSNR (dB)	NC	PSNR (dB)	NC
Airplane	Gaussian noise (0.0001)	19.5041	0.7869	19.5079	0.6797	19.5075	0.6030
	Salt & peppers noise (0.01)	24.0761	0.9211	24.1003	0.8496	24.2816	0.7329
	Speckle noise (0.01)	21.9728	0.8613	21.9661	0.7429	21.9857	0.6460
	Median filter (3×3)	33.3195	0.9280	33.2551	0.8813	33.3594	0.6445
	Wiener filter (3×3)	36.1187	0.9402	35.9015	0.8931	36.1318	0.6604
	JPEG quality = 50	30.0722	0.8000	30.0465	0.5974	30.1346	0.5220
	JPEG quality = 60	30.4322	0.9187	30.4366	0.6892	30.5637	0.5632
	JPEG quality = 70	31.0294	1.0000	31.0381	0.8848	31.2308	0.5967
	JPEG quality = 80	31.7654	1.0000	31.7154	0.9441	31.8816	0.6521
Lena	Gaussian noise (0.0001)	19.9188	0.7903	19.9169	0.6824	19.9188	0.6174
	Salt & peppers noise (0.01)	24.8510	0.9336	24.8214	0.8335	24.7789	0.7542
	Speckle noise (0.01)	24.9619	0.9304	24.9792	0.8196	24.9469	0.7034
	Median filter (3×3)	33.3099	0.9365	33.2933	0.8767	33.2411	0.6621
	Wiener filter (3×3)	35.3262	0.9707	35.2589	0.9119	35.1429	0.6880
	JPEG quality = 50	31.3173	0.7864	31.4540	0.6040	31.3416	0.5684
	JPEG quality = 60	31.5997	0.9207	31.7594	0.7136	31.6835	0.5969
	JPEG quality = 70	32.0343	1.0000	32.1602	0.8962	32.1259	0.6191
	JPEG quality = 80	32.7328	1.0000	32.8395	0.9551	32.7325	0.6794
Peppers	Gaussian noise (0.0001)	19.4781	0.7988	19.4572	0.6833	19.4921	0.5950
	Salt & peppers noise (0.01)	24.0940	0.9302	23.9500	0.8503	24.0095	0.7559
	Speckle noise (0.01)	25.0089	0.9226	25.0315	0.8047	25.0526	0.6924
	Median filter (3×3)	31.0158	0.9429	30.9878	0.8745	31.0391	0.6382
	Wiener filter (3×3)	33.4169	0.9624	33.3499	0.8999	33.4406	0.6755
	JPEG quality = 50	28.2122	0.7788	28.2590	0.6316	28.3310	0.5554
	JPEG quality = 60	28.5711	0.9143	28.6268	0.7329	28.7180	0.5869
	JPEG quality = 70	28.9464	0.9919	29.0015	0.8875	29.1089	0.6218
	JPEG quality = 80	29.4273	0.9985	29.4663	0.9504	29.5558	0.6707
Sailboat	Gaussian noise (0.0001)	19.8710	0.7952	19.8475	0.7021	19.8668	0.6516
	Salt & peppers noise (0.01)	24.4540	0.9287	24.3915	0.8386	24.4810	0.7903
	Speckle noise (0.01)	24.7083	0.9165	24.6456	0.8169	24.7080	0.7546
	Median filter (3×3)	28.0875	0.8701	28.0248	0.8113	28.0992	0.6523
	Wiener filter (3×3)	31.1443	0.9148	30.9842	0.8506	31.1399	0.7136
	JPEG quality = 50	27.0625	0.8428	26.9784	0.7280	27.0781	0.6123
	JPEG quality = 60	27.3784	0.9419	27.2904	0.7764	27.4094	0.6555
	JPEG quality = 70	27.7571	0.9995	27.6541	0.8870	27.7811	0.6978
	JPEG quality = 80	28.2893	1.0000	28.1689	0.9216	28.2978	0.7576

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