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LETTER

An Efficient Compression of Amplitude-Only Images for the Image Trading System

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SUMMARY This letter proposes an efficient compression scheme for the copyright- and privacy-protected image trading system. The proposed scheme multiplies pseudo random signs to amplitude components of discrete cosine transformed coefficients before the inverse transformation is applied. The proposed scheme efficiently compresses amplitude-only image which is the inversely transformed amplitude components, and the scheme simultaneously improves the compression efficiency of phase-only image which is the inversely transformed phase components, in comparison with the conventional systems.

key words: *digital fingerprinting, trusted third party, random phase flipping, quantization, JPEG 2000*

1. Introduction

In order to protect the copyright held by content providers (CPs) and the privacy of consumers in trading images, a new framework has been proposed [1]; an image is divided into two pieces by a CP where one is directly sent to a consumer from the CP and the other is fingerprinted by a trusted third party (TTP) before the consumer receives it. The consumer obtains the fingerprinted image by combining two received pieces. By doing so, the TTP knows only a part of the content. However, in conventional systems dividing images in the spatial domain [1], [2], an adversary has a possibility to estimate the original image from the piece which is leaked from a TTP, and a fingerprint for copyright protection can only cover a half of the image. The latest system separates an image into an unintelligible amplitude-only image (AOI) and a visible phase-only image (POI) to solve these problems [3], where the AOI and POI are inversely transformed amplitude and phase components of discrete Fourier transformed (DFTed) coefficients of the image, respectively. However, this system does not take compression into account, and it is quite difficult to efficiently compress AOIs.

2. Conventional Schemes

In conventional scheme [3], an image purchased by a consumer is divided into an AOI and a POI by using the DFT. The AOI is fingerprinted by a TTP and the POI is directly sent to a consumer; This system reduces the potential information leakage at TTPs by introducing AOIs which are unintelligible. The POI is too distorted to be of commercial value, but the POI reveals the original image and it is useful for consumers to confirm the received image.

Images may be compressed for transmission between a CP and a TTP and between the TTP and a consumer in practical scenarios, conventional system [3] has never taken compression into account.

3. Proposed Scheme

Figure 1 shows a block diagram of the proposed scheme.

Step 1 A CP applies two-dimensional discrete cosine transformation (2D-DCT) to $N_1 \times N_2$-sized image $\mathbf{f}$ to get $N_1 \times N_2$-sized 2D-DCTed coefficients $\mathbf{F} = \{F(k_1, k_2)\}$, where $k_1 = 0, 1, \cdots, N_1 - 1$ and $k_2 = 0, 1, \cdots, N_2 - 1$.

Step 2 Separate real numbered DCT coefficients $\mathbf{F}$ into amplitude components $\mathbf{F}_a = \{F_a(k_1, k_2)\}$ and phase components $\mathbf{F}_p = \left\{F_p(k_1, k_2)\right\}$ as $F_a(k_1, k_2) = |F(k_1, k_2)|$, $F_p(k_1, k_2) = \mathrm{sgn}\,(F(k_1, k_2))$, where $\mathrm{sgn}(\cdot)$ returns the positive and negative sign of the input.

Step 3 $N_1 \times N_2$-sized random matrix $\mathbf{R} = \{R(k_1, k_2)\}$ which consists of ± 1 is multiplied to $\mathbf{F}_a$ as $\mathbf{F}'_a = \mathbf{F}_a \circ \mathbf{R}$, where $\circ$ represents Hadamard product.

Step 4 Applying the inverse 2D-DCT (2D-IDCT) to $\mathbf{F}'_a$ generates AOI $\mathbf{f}'_a$.

Step 5 Quantize AOI $\mathbf{f}'_a$ to an image with K-bit integers.

Step 6 Compress quantized AOI.

Step 7 The CP sends quantized and compressed AOI to a TTP, whereas the CP sends phase components $\mathbf{F}_p$ to a consumer.

The steps to reconstruct the fingerprinted image and those to extract consumer's ID are shown in Fig. 1. It is noted that any arbitrary quantization and image compression techniques can be employed here in the proposed scheme.

4. Experimental Results

Figures 2 (a), (b), and (c) show original image $\mathbf{f}$, AOI $\mathbf{f}_a$, and POI $\mathbf{f}_p$ of the proposed scheme, respectively. It is noted that $\mathbf{f}_p$ is easily obtained by applying 2D-IDCT to phase component $\mathbf{F}_p$ shown in Fig. 2 (d). As shown in Fig. 2 (b), it is

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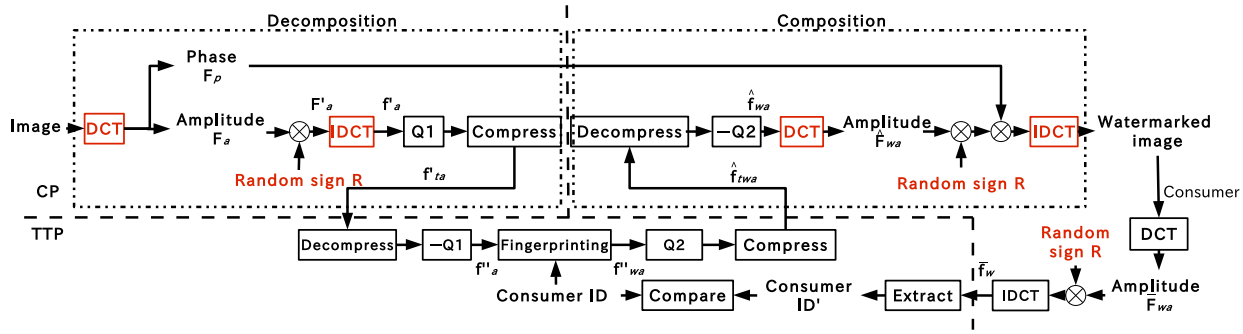
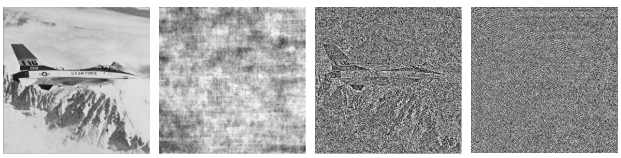


Fig. 1 Block diagram of the proposed scheme. Q1: quantization between a CP and a TTP, −Q1: inverse quantization for Q1, Q2: quantization between the TTP and a consumer, −Q2: inverse quantization for Q2. Note that three random sign R in the proposed scheme use the same seed.



(a) Original image **f**. (b) AOI $\mathbf{f}_a$. (c) POI $\mathbf{f}_p$. (d) Phase components $\mathbf{F}_p$.

Fig. 2 Images in the proposed scheme based on 2D-DCT.

Table 1 Fingerprinting performance of the proposed scheme using the technique [5] used in [3].

Image		Total compression rate c [bpp]					
		2.5	3.0	3.5	4.0	4.5	5.0
Airplane	PSNR [dB]	38.42	40.33	42.23	42.98	43.74	44.34
	BER [%]	41.3	19.6	12.1	0.0	0.0	0.0
Baboon	PSNR [dB]	30.00	32.14	34.30	36.64	38.57	40.24
	BER [%]	46.9	46.4	30.4	25.9	5.8	0.0
Lena	PSNR [dB]	39.17	40.76	42.37	43.18	44.32	44.44
	BER [%]	32.9	12.7	11.9	1.8	0.0	0.0
Peppers	PSNR [dB]	37.37	39.17	40.64	42.36	44.13	45.08
	BER [%]	43.7	21.7	14.3	4.7	0.0	0.0
Sailboat	PSNR [dB]	35.08	37.18	38.87	40.39	41.66	42.90
	BER [%]	47.2	33.4	20.8	20.3	2.3	0.0

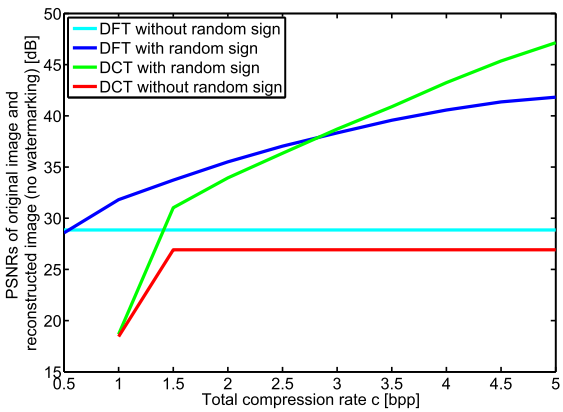


Fig. 3 PSNR's comparison between the proposed scheme and conventional system 2 [3]. The quantizer is used.

quite hard to estimate original image **f** from AOI $\mathbf{f}_a$.

Table 1 shows the fingerprinting performance of the proposed scheme, and Fig. 3 shows averaged PSNR of five test images, where the total compression rate is c and JPEG 2000 is used for compression. In the proposed scheme, $\mathbf{F}_p$ is always represented in 1 bpp, so the AOI is compressed as $(c-1)$ bpp, whereas POI and AOI are compressed with $c/2$ bpp, respectively, in the conventional scheme [3]. The proposed scheme suppresses the error in fingerprint extraction to 20% for images with the PSNR over 40 dB, c.f., Table 1, even it embeds about 2000 bits data. It is confirmed the proposed scheme (DCT with random signs) is superior to the conventional scheme (DFT without random signs). As random sign reduces the dynamic range of AOIs, compression becomes more efficient.

5. Conclusions

This letter has proposed an efficient compression scheme of AOIs for the copyright- and privacy-protected image trading system. The proposed scheme makes the image trading system practical.

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