AN INTEGRATED PROGRESSIVE IMAGE CODING AND WATERMARK SYSTEM

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ABSTRACT

The design of an integrated image coding and watermark system with the wavelet transform is examined in this work. First, the multi-threshold wavelet codec (MTWC) is used to achieve the image compression purpose. Unlike other embedded wavelet coders which use a single initial threshold in their successive approximate quantization (SAQ), MTWC adopts different initial thresholds in different subbands. A superior rate-distortion tradeoff is achieved by MTWC with a low computational complexity. Then, a non-invertible progressive watermark scheme is incorporated in MTWC for copyright protection. This watermark scheme uses the user input data to produce a Gaussian distribution pseduorandom watermark in the wavelet domain. The performance of the proposed watermark technology is supported by experimental results.

1. INTRODUCTION

The increased use of multimedia data through the Internet makes information exchange fast and convenient. Many large image files are being sent through the network daily. The arise of embedded image codecs, which compress and transmit images in a progressive fashion, is crucial to this development. Besides, due to the open environment of Internet downloading, copyright protection has been widely studied to prevent illegal distribution of privately owned images. This need requires a mature digital watermark technology. Our motivation for this research is to integrate these two technologies into a single system so that image compression and watermark protection can be performed at the same time to achieve secure and efficient image transmission.

Digital watermark algorithms have been widely investigated. Many software companies start to insert the watermark in their products such as Photoshop and Digimarc. In the international standard activities such as JPEG 2000 and MPEG 4, the watermark technology is also considered as an integral part of the standard contributions. A good digital watermark algorithm should be invisible and robust to different attacks, especially on the attack from compression. Moreover, retrieval of the digital watermark can be used to identify the ownership and copyright unambiguously. Several digital watermark algorithms have been proposed with different contributions. Roughly speaking, these contributions can be categorized according to their inserting/processing domain, hiding position and signal type of the watermark.

In the proposed integrated system, the multi-threshold wavelet codec (MTWC) is used in the compression stage. This new codec was motivated by a careful analysis of the rate-distortion performance and the coding efficiency of existing embedded wavelet coders. Unlike other embedded wavelet coders which use a single initial threshold in their successive approximate quantization (SAQ), MTWC uses different initial thresholds in different subbands and applies a subband decision scheme to decide which subband should be coded in the successive subband quantization (SSQ). Then, a non-invertible and progressive watermark scheme is incorporated into MTWC for copyright protection. This watermark scheme uses the user input data to produce a Gaussian distribution pseduorandom watermark which cannot be simulated easily. The subband decision scheme and SSQ in MTWC help to determine significant coefficients for watermark insertion to reduce the distortion created by the watermark while keeping the maximum protection in watermark retrieval. The spectral spectrum technology is applied to hide the watermark so that the watermark can survive under different types of attack.

The paper is organized as follows. The compres-

sion algorithm MTWC and the watermark algorithm are described in Sections 2 and 3, respectively. The blockdiagram of the entire system and the function of each module are presented in Section 4. Preliminary experimental results are shown in Section 5. Finally, concluding remarks are given in Section 6.

2. REVIEW OF EMBEDDED WAVELET CODEC

The new embedded wavelet image codec, known as the multi-threshold wavelet codec (MTWC), was described in detail in [4]. This algorithm will be repeated here due to the space constraint. Instead, we will highlight several unique features of MTWC in comparison with other existing embedded wavelet coders below.

Its first distinct feature lies in the use of multiple quantization thresholds. In all current embedded wavelet codecs such as EZW, LZC, modified LZC and SPIHT, a single initial quantization threshold is applied to wavelet coefficients for all subbands and refined successively. However, the maximum magnitude of wavelet coefficients varies significantly from bands to bands in most typical images. For example, coefficients in lower frequency bands tend to have a higher magnitude while coefficients in higher frequency bands have a smaller magnitude in natural images. With a single initial quantization threshold, it is common to generate a lot of zeros in high frequency bands at first several quantization steps. However, these zero bits can be avoided, if these coefficients are quantized only at a later stage with a smaller initial quantization threshold. In MTWC, different initial threshold values are chosen with respect to different subbands. The coding of multiple initial threshold values creates negligible overhead information. We developed a simple subband decision rule, which selects the subband with the current maximum threshold for quantization. With this decision rule, the encoder and the decoder can work in a coordinated way in determining the proper quantization order with respect to these subbands.

The second feature is the rearrangement of significant and refinement maps at different quantization levels. In traditional embedded wavelet coders, the significant map, which consists of significance identification bits, is sent first followed by the refinement map, which consists of refinement bits of the same quantization level. By studying the coding efficiency of significant and refine maps in SAQ, we found that it is advantageous not to send the refinement map immediately after its significant map. Instead, we may want to send the significant map of other subbands to achieve a better performance. The subband quantization/coding

sequence is actually determined by a new rule. That is, once we return to the same subband visited before, we should send the refinement map and followed by its significant map of the next level. This is called the R-S (Refinement-Significant) map coding.

3. DIGITAL WATERMARK

Our goal in this research is to provide an integrated system with applications for image transmission over the network. Thus, it is important to have the progressive property both in compression and watermark. We choose the spectral domain to be the processing domain for watermark insertion. Moreover, it is important to use the same transform as used in compression. Previous work considers watermark insertion either in the spatial domain or in the DCT domain. We propose a watermark technology in the wavelet domain so that it can conveniently incorporated in our MTWC compression algorithm. Under this principle, we preserve the perceptual significant bit selection scheme, subband decision and SSQ from MTWC and insert the watermark in the significant coefficient. The basic idea is to keep the progressive property of MTWC, and the retrieved watermark strength increases with more coded bitstreams received.

The proposed embedded digital watermark can hide user's special key (ID) in the image to give the authority and copyright protection. However, a good watermark should not only be invisible to human eyes but also robust under different attacks. They include low bit rate compression, filtering and geometric transformation etc. Moreover, it should be unambiguous on the identification of watermark retrieval. Cox et al. [6] proposed a spectral spectrum digital watermark technology in the DCT domain, which can survive under the JPEG compression with quality factor equal 0.05 (or around equal to 50:1 compression ratio). Our watermark technology is a generalization of Cox's work, which is can be applied in association with different transforms e.g. Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) and Wavelet Packet (WP) etc. It is a non-invertible watermark scheme that can prevent the attack by creating a faked original image.

The watermark is generated as follows. Any entropy coder can be used to compress user input data (i.e. the user key) to a uniformly distributed coded bitstream. The bitstream are then converted to a pseudorandom sequence of the Gaussian density via Box-Muller's transform. The user input data can be dependent or independent of the image to be protected. For example, it can be text, image or audio data. One ad-

vantage of using user input data is to create the random inserting skipping sequence and form a non-invertible watermark scheme. Consequently, the attacker cannot create a faked original without the user key even though the proposed watermark algorithm is known to the public. The insertion of the digital watermark into MTWC is described in the blockdiagram given in the next section.

4. BLOCKDIAGRAM OF INTEGRATED SYSTEM

The block diagram of MTWC is shown in Figure 1. The precise description of each module of the proposed MTWC is detailed below.

RGB to YUV conversion. Use the CCIR 601 standard to convert RGB component to YUV component. For low bit rate compression, we perform Y:U:V=4:1:1 conversion.

YUV resource arrangement. The bit resource is allocated according to the YUV component size. For example, for a low bit rate compression with Y:U:V=4:1:1 conversion, we assign 4B/6 output bytes to Y component and B/6 bytes to U and V components, where B is the desired total output bytes.

Image transform. The discrete wavelet transform (DWT) is chosen in our current implementation. However, the above block diagram allows the use of other transforms such as the discrete cosine transform (DCT) and the wavelet packet transform (WP) as well.

Subband grouping. Coefficients with the same spectral indices are grouped together to form a subband. For DWT and WP, coefficients are already grouped into different subbands so that there is no extra work needed. For 8-by-8 block DCT, all DC terms are grouped to form the DC subband, AC terms from different spatial blocks but with the same frequency indices are grouped to form an AC band. As a result, we obtain 64 subbands with the same size.

Subband decision scheme. The maximum magnitude of coefficients in each subband is used as the initial quantization threshold for coefficients in that subband. Once coefficients in the subband are quantized, the corresponding threshold value is halved. The subband decision scheme always chooses the subband with the maximum threshold value for quantization.

Successive subband quantization (SSQ). Successive approximation quantization (SAQ) and R-S map coding are applied to coefficients of one subband one time.

R-S map coding. Bits are classified to significant and refinement bits. The transmission of kth refinement map of subband i is followed immediately by the
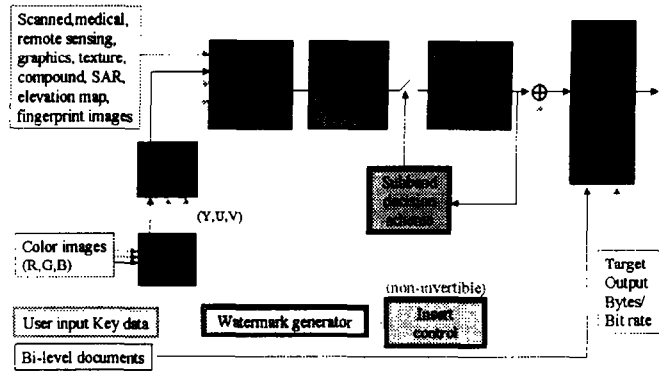

Figure 1: The blockdiagram of proposed integrated system of compression and watermarking.

transmission of $(k+1)^{th}$ significant map of subband i.

Entropy coder stage. Any efficient binary entropy coder can be applied, e.g. JBIG, binary Arithmetic coder and even the JBIG-2 under development. The context-based QM coder is adopted in our implementation.

User input key data. The user input data is a set of dummy data which is used to created the digital watermark key. These input data may or may not have any relationship with the protected media. For example, it could be the image to be compressed itself, author information, one document or a complete random dummy data.

Watermark generator. Watermark generator uses entropy coder to compress the user input key data to uniform distribution symbol and then apply the Box-Muller's transform to generate the broadband watermark.

$$K_i = \sqrt{-2lnE_i}cos(2\pi E_{i+N})$$

where K_i is the Gaussian distribution sequence, E_i is the uniform distribution sequence and N is the number of watermark.

Watermark insert controller. The watermark insert controller adds the watermark into the significant pixel selected by subband decision scheme and SSQ. Moreover, the controller uses the N bits data in the generated uniform symbol as the significant pixel skipping interval between two watermarks to form a non-invertible watermark scheme.

5. EXPERIMENTAL RESULTS

The PSNR performance comparison between MTWC, EZW and SPIHT at several bit rates are given in Tables 1 and 2 for the Lena and Barbara images, respectively. MTWC out-performs EZW and SPIHT in most

bpp	1.0	0.5	0.25	0.125	0.0625
SPIHT	40.40	37.21	34.11	31.09	28.36
EZW	39.61	36.43	33.55	30.70	28.36
MTWC	40.39	37.23	34.22	31.18	28.43

Table 1: The PSNR performance comparison of the Lena image.

bpp	1.0	0.5	0.25	0.125	0.0625
SPIHT	36.42	31.39	27.58	24.85	23.35
EZW	34.80	29.88	26.96	24.74	23.32
MTWC	36.54	31.51	27.59	25.14	23.37

Table 2: The PSNR performance comparison of the Barbara image.

cases. In addition to the superior rate- distortion performance, MTWC has two additional advantages [4]. First, it has a lower computational complexity. Second, its coding performance is more robust with respect to the choice of different wavelet bases. It is well known that the 9-7 biorthogonal wavelet transform provides the best compression result for almost every known wavelet coder. The compression performance degrades significantly if other bases (say, the Haar or the orthogonal Daubechies bases) were used in these coders. It was observed from experiments that the performance degradation of MTWC is much smaller by choosing other wavelet bases. In other words, MTWC is more robust with the choice of different transforms.

The second experiment is used to show the robustness of the digital watermark under various attacks. Consider the test Lena image inserted with 1000 broadband watermarks. The peak signal noise ratio (PSNR) of the protected image is around 50 dB. The protected image still survives under a wavelet-based compression with 160:1 compression ratio as shown in Figure 2 (a). We also demonstrate watermark retrieval results after edge enhancement, noise adding and crop attacks as shown in Figures 2 (b)-(d).

6. CONCLUSION

An integrated image coding and watermark system based on the wavelet transform was proposed. The multithreshold wavelet codec (MTWC) is used for compression while a non-invertible progressive watermark scheme is incorporated in MTWC for copyright protection. The performance of the proposed watermark technology was demonstrated with experimental results.
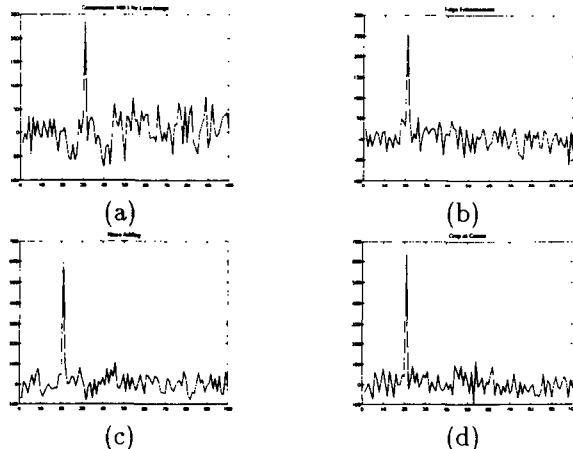

Figure 2: Watermark retrieval of the 512x512 graylevel Lena image with attacks: (a) 160:1 compression (b) edge enhancement (c) noise adding and (d) crop in the center

7. REFERENCES

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