Improved Performance of Zerotrees Based Digital Watermarking

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Abstract: Nowadays, zerotrees based digital watermarking techniques are considered to be an efficient watermarking technique used for multimedia data in a compressed form. This paper presents a technique for watermarking an image, by employing zerotrees derived from the wavelet packet coefficients of the transformed image to carry the watermark signal. By setting a proper threshold in zerotrees determining process, the watermark signal can be recovered without the need of original image. With our proposed technique, more amount of watermark signal can be embedded within the image, compared to ordinary wavelet transform based techniques. The experimental results show the improved performance in both qualities of the resultant watermarked image and robustness of the embedded watermark signal against common signal processing such as brightness/contrast enhancement, high-pass filtering, Gaussian noise adding and JPEG compression scheme.

1. Introduction

Since one characteristic of the digital data is that the digital data can be reproduced again and again without suffering from fidelity loss, the pirated materials cannot be therefore easily addressed. However, there are many approaches available for preventing such circumstance not to occur, and digital watermarking technique is one among several efficient approaches. By watermarking the digital material before distributing it to the public is a way to show the possession of the copyright work, and to discourage someone to misuse the copy he owns.

Generally, digital watermarking is a technique used to embed small amount of information such as text or image that usually does not have any perceptible effect on the image's appearance. The main requirements that any watermarking technique should satisfy can be briefly described as follows: invisible, undetectable, unalterable and unambiguous [1]. Moreover, a digital watermark should survive many kinds of image processing techniques such as blurring, rotating, cropping, and data compression.

In this paper, the zerotrees based digital watermarking techniques are considered. We propose a new watermarking technique by using the zerotrees derived from the wavelet packet coefficients of the transformed image. By making new arrangement and dividing those coefficients properly, with a pre-defined threshold value, we can determine some zerotrees used to carry the watermark signal. Since by using our technique more numbers of zerotrees can be obtained, compared to ordinary wavelet based techniques, more amount of watermark signal can then be embedded, and still be robust to various common signal processing. Moreover, since the wavelet packet transform provides more energy compaction than ordinary wavelet transform, better quality of the resultant watermarked image will be obtained. In the next section, a survey of several existing watermarking techniques is given. Section 3 describes the related background of zerotrees of wavelet packet coefficients, and the details of the proposed watermarking technique. The experimental results are shown and discussed in section 4. Finally, in Section 5, we draw the main conclusions.

2. Related Work

In [2], the authors described a new multi-solution watermarking method, based on the discrete wavelet transform, for a digital image. The watermark signal is first transformed into independent identical distribute (i.i.d.) Gaussian distribution and then embedded into the significant components in the high and mid frequency bands of discrete wavelet coefficients of the transformed image. Later, Tsai *et al.* [3] proposed a new watermarking scheme which incorporates wavelet and spatial transformations. The method used in the scheme utilizes the wavelet multi-resolutional structure to construct the image in frequency components, and the spatial transform to select the locations of watermark bits in the embedding process. This method required very few parameters as the side information to extract the watermark signal.

An efficient watermarking technique based on zerotrees of the Discrete Cosine Transform (DCT) was proposed in [4]. The technique embedded the watermark signal by changing the value of coefficients derived from the DCT of the image. The watermark bit is assigned in the zerotrees by changing the number of zerotrees contained in a transformed block. This technique does not need the original image in the extraction process, but instead needs to carefully consider the suitable reference threshold. A similar technique that uses the zerotrees derived from the DCT in the watermark embedding process was also proposed in [5]. However, the watermark signal was coded by an error correction code i.e. Hamming code in order to enhance its robustness against various attacks.

To gain more advantages on new wavelet-based compression algorithm, the same principle was applied by using the zerotrees derived from the wavelet transform of the image [6]. In this technique, the positions of zerotrees defined in the embedded zerotree wavelet (EZW) and threshold value were used to detect the embedded data. One of the interesting techniques based on wavelet packet transform was proposed by [7]. Since the wavelet packet transform provides more energy compaction than ordinary wavelet transform, the watermark scheme applying this approach can then provide an impressive robustness against compression. To embed the watermark signal, the original image was first decomposed into small subbands by the wavelet packet transform. Then the watermark signal as a sequence of 0 and 1 was added to the coefficients in the chosen subbands. However, this technique still needs the original image in the extraction process. To overcome the problem of requiring the original image for recovering the watermark signal, the direct sequence spread spectrum technique was applied to the watermark signal before being added to the coefficients in the chosen subbands [8]. Furthermore the watermark signal created by this approach was proved to be robust against many types of attacks.

3. Background and Proposed Technique

The related background of determining the zerotrees of wavelet packet coefficients from the transformed image can be summarized [9] as follows: Wavelets are mathematical functions that divide data into different frequency components, and then study each component with a resolution matched to its scale, while wavelet packets are particular linear combinations of wavelets. They form bases, which maintain many of the orthogonality, smoothness, and localization properties of their parent wavelets. The coefficients in the linear combinations are computed by a recursive algorithm. The wavelet packets offer considerably more flexible than the wavelet transforms for dealing with classes of unknown time-frequency characteristics. The arrangement of coefficients in the ordinary wavelet and wavelet packet transforms is showed in Figure 1 (a) and (b), respectively.

1	2	5	6	17	18	21	22
3	4	7	8	19	20	23	24
9	10	13	14	25	26	29	30
11	12	15	16	27	28	31	32
33	34	37	38	49	50	53	54
35	36	39	40	51	52	55	56
41	42	45	46	57	58	61	62
43	44	47	48	59	60	63	64

(a)

1	2	5	6	17	18	21	22
3	4	7	8	19	20	23	24
9	10	13	14	25	26	29	30
11	12	15	16	27	28	31	32
33	34	37	38	49	50	53	54
35	36	39	40	51	52	55	56
41	42	45	46	57	58	61	62
43	44	47	48	59	60	63	64

(b)

Figure 1: Arrangement of coefficients in 8×8 pixels block after taking (a) ordinary wavelet transform 3 times (b) wavelet packet transform twice

3.1 Zerotree in wavelet packet coefficients

The spatial coefficient tree structure defined for the wavelet case was designed to capture the spatial relationships of coefficients in different frequency bands. Parent-child relationship is the relation between coefficient at the coarse scale that is called the parent and all coefficients corresponding to the same spatial location at the next finer scale of similar orientation are called children. For the generalized wavelet packet, we can still define a spatial coefficient tree as the set of coefficients in different bands. Figure 2 illustrates the parent-child relationships of spatial coefficient trees between wavelet transform and wavelet packet transform.

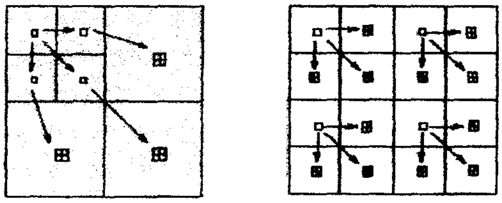


Figure 2: Parent-child relationships of spatial coefficient trees in (a) ordinary wavelet transform (b) wavelet packet transform

3.2 Watermark embedding and extraction process

The watermark embedding process is shown in Figure 3, where the original image is segmented into 8×8 non-overlapping blocks, and each block is then transformed by using wavelet packet transform twice. In order to determine the zerotree in each transformed block, we use default quantization table provided by many compression standards i.e. JPEG as a pre-defined threshold value, and modify it until we obtain the proper zerotree. The process of finding the zerotree is shown in Figure 4.

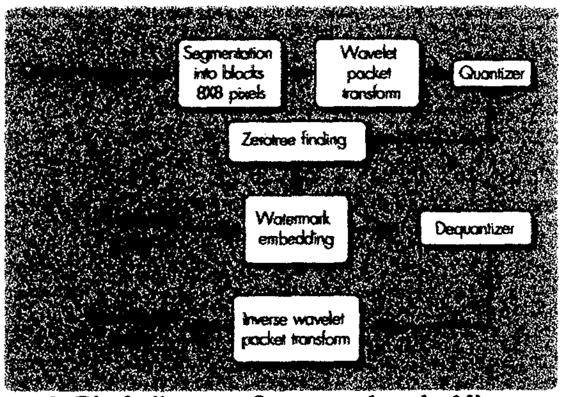


Figure 3: Block diagram of watermark embedding process

538	542	0.25	1.5	-2.2	-1.5	0.25	1
530	529	0.7	10.2	4.7	2.2	1.3	-4.7
-0.7	1	-1.4	5.5	-1.8	0.5	0.75	2
3.7	2.3	0.2	2.2	0.25	0.25	4.7	-4.7
2.7	0.5	-1.7	1	2.7	1	-4.7	-9.5
5.7	3.2	-3.7	5.2	0.25	-3.7	-1	-2.8
3.25	5.5	-1.3	-1	-1	1	-2.3	1.5
-1.7	-1.7	0.75	-4.7	0.75	-3.7	1.25	0.25

(a)

16	11	10	16	24	65	181	191
12	12	14	19	56	100	210	205
14	13	16	24	140	187	99	186
14	17	22	29	181	117	110	92
18	72	177	196	68	129	123	97
84	110	195	184	101	124	133	112
189	210	181	171	123	141	140	121
182	199	185	198	132	120	123	119

(b)

34	49	0	0	0	0	0	0
44	44	0	1	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

(c)

0	0	0	0	0	1	1	1
0	0	0	0	1	1	1	1
0	0	0	0	1	1	1	1
0	0	0	0	1	1	1	1
0	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1

(d)

Figure 4: Process of finding the zerotrees (a) the coefficients obtained from each wavelet packet transformed block (b) the modified quantization table block (c) the quantized coefficient block (d) the resultant zerotrees contained in each block

It can be seen that there are up to *nine* zerotrees contained in each quantized transformed block. For example, at the coordinate (2,6), (3,7), (3,8), (4,7), (4,8), where (2,6) is considered as a parent, and (3,7), (3,8), (4,7) and (4,8) are considered as a child. It can also be noticed that the number of zerotrees derived from the wavelet packet transform is three times larger than the ones derived from the ordinary wavelet transform. Therefore three times higher of watermark signal can be embedded within the same image frame.

To embed the watermark, the number of zerotrees is changed according to the watermark bit. For instance, assuming the number of zerotrees contained in the block is odd; if the watermark bit is zero, we will modify the coefficient value in that block until the resultant number of zerotrees is even. In the same way, if the watermark bit is one, the zerotrees remain untouched. Note that the value of selected coefficient to be changed should result in slight perceptual degradation of the image, but still be robust against compression process, e.g. in the mid frequency range. To extract the watermark signal, the same steps as used in the watermark embedding process are performed in reverse. After the zerotrees in each quantized transformed block are obtained, we count for the number of zerotrees contained within each block. If the result is odd, the embedded bit is one, and vice versa.

4. Results and Discussions

The first experiment was performed with the aim of comparing the performances between ordinary wavelet and wavelet packet transform based techniques, by measuring the Peak Signal to Noise Ratio (PSNR) of watermarked images obtained from both techniques. In the experiment, the gray-scale image "*boat* " with the size of 512×512 pixels was used as the original image, while the black & white image "*MCL*" with the size of 64x64 pixels was used as the watermark signal, as shown in Figure 5 (a) and (b), respectively. The resultant watermarked images using ordinary wavelet and wavelet packet transforms are illustrated in Figure 5 (c) and (d), respectively.

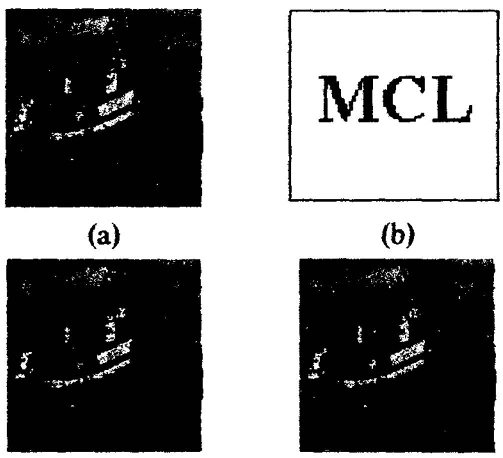


Figure 5: (a) the original image "*boat*" (b) the watermark image (c) the resultant watermarked image using ordinary wavelet transform and (d) wavelet packet transform

The PSNR obtained from the watermarked image using wavelet packet transform was 38.57 dB, which is approximately 3.6 dB higher that of the one using ordinary wavelet transform i.e. 34.99 dB. However, note that in this experiment we embedded the same amount of watermark signal into the same image. The reason of doing this is to demonstrate that applying the wavelet packet transform instead of ordinary wavelet transform gains better performance. Furthermore, the results after applying the JPEG compression at various compression ratios to the watermarked image are compared as shown in Table 1.

Table 1. Comparison of PSNR between the compressed watermarked image by using ordinary wavelet and wavelet packet transforms at different compression ratios

Compression Ratio (%)	PSNR of Ordinary Wavelet Transform	PSNR of Wavelet Packet Transform
10 %	34.26 dB	35.50 dB
15 %	33.90 dB	35.28 dB
20 %	33.59 dB	34.69 dB

According the PSNR shown in Table 1, the quality of the watermarked images was improved by approximately 1.1-2.5 dB, when applying the wavelet packet transform in the watermark embedding process.

In the next experiments, we focused on the watermark embedding technique based on zerotrees of wavelet packet coefficients, and the gray-scale image "*harbour*" with the size of 256x256 pixels was used as the original image, while the black & white image "*KMUTT*" with the size of 32x96 pixels was used as the watermark signal. Note that this time the original image contains 1024 8x8 pixel block, and each block will carry three bits of watermark signal, at the top-right, bottom-left and bottom-right regions. The resultant watermarked image with PSNR of 30.7130 dB and the extracted watermark images without being attacked are shown in Figure 6 (a) and (b) respectively.

Figure 6: (a) the watermarked image "*harbour* "
(b) the extracted watermark image

When the watermark signal was embedded into the original image, a number of attacks was then applied to the watermarked image e.g. brightness/contrast enhancement, high-pass filtering, Gaussian noise adding and JPEG compression scheme at various levels of strength, and the experimental results are shown as follows:

The extracted watermark images after applying high-pass filtering at 20x20, 10x10 and 1x1 window pixels are illustrated in Figure 7, while the values of PSNR of watermarked image were 20.1955, 19.3756 and 17.5101 dB respectively.

(a) (b) (c)

Figure 7: The extracted watermark image after applying high-pass filtering at (a) *20x20* (b) *10x10* and (c) *1x1* window pixels

The extracted watermark images after applying brightness enhancement at 60, 80 and 100 % are illustrated in Figure 8, while the values of PSNR of watermarked image were 12.5227, 10.0990 and 8.3784 dB respectively.

(a) (b) (c)

Figure 8: The extracted watermark image after applying brightness enhancement at (a) 60 (b) 80 and (c) 100 %

The extracted watermark images after applying contrast enhancement at 30, 40 and 50 % are illustrated in Figure 9, while the values of PSNR of watermarked image were 23.1207, 20.4341 and 17.9526 dB respectively.

(a) (b) (c)

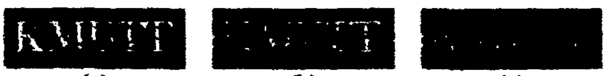
Figure 9: The extracted watermark image after applying contrast enhancement at (a) 30 (b) 40 and (c) 50 %

The extracted watermark images after adding Gaussian noise at 5, 10 and 20 % are illustrated in Figure 10, while the values of PSNR of watermarked image were 28.9449, 26.1889 and 21.6305 dB respectively.

(a) (b) (c)

Figure 10: The extracted watermark image after adding Gaussian noise at (a) 5 (b) 10 and (c) 20 %

The extracted watermark images after applying JPEG compression scheme at 80, 60 and 50 % qualities are illustrated in Figure 11, while the values of PSNR of watermarked image were 29.3987, 28.8038 and 28.0686 dB respectively.



(a) (b) (c)

Figure 11: The extracted watermark image after applying JPEG compression scheme at (a) 80 (b) 60 and (c) 50 %

It is obvious that the contents contained within the watermark image could still be recognized after applying various types of attack. However, if the watermarked images were badly attacked until the contents inside could not be recognized, the quality of the watermarked image would also be destroyed to an unacceptable level. Note that even if there were some errors occurred in the extracted watermark images, we were still able to understand their contents i.e. the characters "*KMUTT*". Also, note that the PSNR values mentioned in each experiment were obtained by comparing the original image and the watermarked image after being attacked at various levels.

5. Conclusions

A digital watermarking technique based on the zerotrees of wavelet packet coefficients has been presented in this paper. The experimental results showed the improved performances obtained from the proposed technique, compared to ordinary wavelet based techniques, in both the qualities of the resultant watermarked image and the robustness against various common signal processing. Moreover, in the extraction process, the embedded watermark signal can be extracted without the need of original image. Finally, since the number of zerotrees provided by the wavelet packet transform is three time higher than that of ordinary wavelet's, more bits of watermark signal can be embedded into an image.

6. Acknowledgement

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