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COMMUNICATIONS

DCT VERSUS WHT FOR FRAGILE IMAGE WATERMARKING

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Digital watermarking is nowadays defined to be part of digital signal processing. This paper concerns with a special case of digital watermark, fragile watermark. The presented algorithm uses the DCT or WHT spectral domain for watermark embedding. Comparisons of the advantages of both spectral domains for errors detection are the part of this paper.

K e y w o r d s: DCT spectrum, WHT spectrum, JPEG quantization, fragile watermark

1 INTRODUCTION

In the signal transmission process one has to take into account also potential errors that can appear. So on the receiver's side we want to be able to detect these errors. Digital watermarking seems to be a possible solution of this problem [1]. It means that on the transmitter's side we add some redundant information - a fragile watermark. The receiver tries to extract this watermark. Since we embed a fragile watermark, an error in the data stock causes watermark's destruction and this fact uncovers the data transmission error. The algorithm described in the rest of this paper was originally proposed for video applications [2] and the watermark was embedded into the quantized DCT coefficients. We test not only DCT spectral coefficients but also WHT spectral coefficients for fragile watermarking of still images.

In the analysis we concern with two types of errors: (1) The pixel's value was set to zero (it may represent the loss of the pixels) and (2) Removing the rows or columns from the image. The loss of the column or of the row corrupts synchronization between the transmitter and the receiver. So the output of the detector should be wrong blocks after deleting a row or column. On the receiver a demand should appear for retransmission of these blocks of the image.

Also in this case, like for every kind of the watermarking algorithm, we have to make a compromise between the probability of errors in the communication channel and visual quality of the watermarked image.

The following part includes a description of the principles of embedding the fragile watermark and of the detection of errors. Finally, we show some experimental results.

2 WATERMARK EMBEDDING PROCESS

On the coder side the watermark is embedded in the quantized spectral coefficients of all coded blocks 8×8 and then watermark integrity is tested on the decoder side. If the watermark is corrupted, then we consider that the appropriate block 8×8 is detected as wrong, otherwise we consider that the block is errorless. In the embedding process we used the discrete cosine transform and discrete Walsh-Hadamard transform.

All quantized spectral coefficients in the block, after predefined position *pos* in zig-zag scanning, are modified to the nearest smaller even value. (Predefined value of the position should vary according to the probability of error rate and the allowed watermarked image distortion.) Modification of spectral coefficients is represented by (1)

$$AC_i^* = AC_i - sgn\,(AC_i) \times W\,(AC_i) \tag{1}$$

where $i = pos,\ pos+1, \dots, 63$, AC_i are original Q-DOT coefficients, AC_I^* are modified Q-DOT coefficients, $sgn()$ is the signum function and W represents the watermark for which holds the following statement:

$$W(x) = \begin{cases} 0 \text{ if } |x| \text{ is even} \\ 1 \text{ if } |x| \text{ is even} \end{cases} \tag{2}$$

According to (2) the detector also decides.

The standard JPEG quantization matrix is defined as, [3]

$$Q = \begin{bmatrix} 16 & 12 & 10 & 16 & 24 & 40 & 51 & 61 \\ 11 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 129 & 103 \\ 72 & 92 & 95 & 98 & 112 & 100 & 101 & 91 \end{bmatrix} \tag{3}$$

The image marking process can be split into the following steps:

- image division into non-overlapping 8×8 blocks

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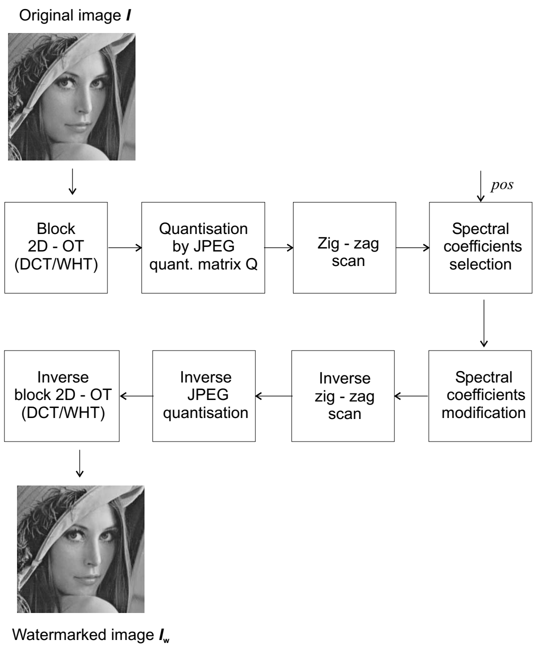

Fig. 1. Embedding of the fragile watermark onto still image.

- calculation of discrete orthogonal transform (DOT = DCT or DWHT) for each block
- quantization of spectral coefficients by the standard JPEG matrix defined in (3) (JPEG quality factor is equal to 50)
- zig-zag scanning of quantized spectral coefficients, see Fig.2
- modification of spectral coefficients according to (1)
- inverse zig-zag scanning of quantized spectral coefficients to the matrix
- re-quantization of the spectral coefficients by standard JPEG matrix
- calculation of inverse DOT for each block. The embedding process is shown in Fig. 1.

3 ERROR DETECTION PROCESS

Detection process of the wrong blocks is based on the enumeration of the EAF function value for each block 8×8. So we calculate the value of the error assessment function EAF to evaluate the measure of block distortion. An error is reported to the decoder if the EAF value is greater than a specified decision value T. Otherwise it is reported that data with an embedded watermark are errorless. (In experiments we concentrated on the case when T was equal to zero).

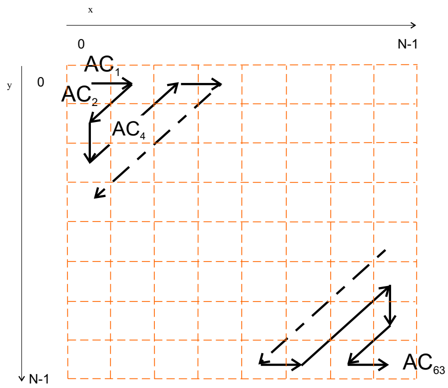

Fig. 2. Zig-zag scanning of spectral coefficients

$$EAF\left(w, \hat{w}\right) = \frac{1}{L} \sum_{i=pos}^{64} w\left(i\right) \oplus \hat{w}\left(i\right) \tag{4}$$

where $L = 64 - pos$ means the number of modified Q-DOT coefficients. The watermark extraction process and the following error detection process can be described as follows (see Fig. 4):

- testing image division into non-overlapping 8×8 blocks
- calculation of discrete orthogonal transform (DOT = DCT or DWHT) for each block
- quantization of the spectral coefficients by standard JPEG matrix defined in (3) (JPEG quality factor is equal to 50)

Fig. 3. a) Original image (NELLA - $256 \times 256 \times 256$), b) watermarked image by DCT spectrum (PSNR=32,435), c) watermarked image by DWHT spectrum (PSNR=34,522)

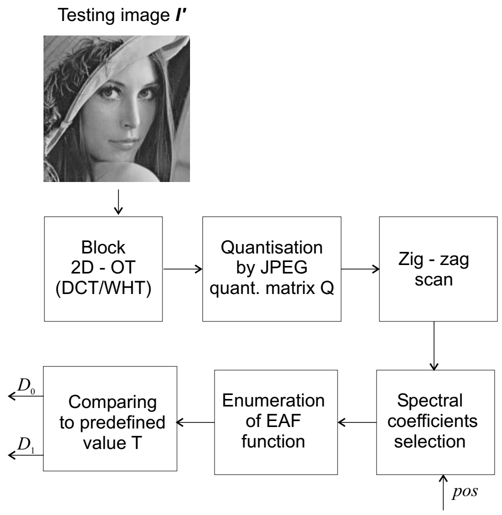

Fig. 4. Watermark extraction and error detection process

- zig-zag scanning of quantized spectral coefficients, see Fig. 2
- modification of spectral coefficients according to (1)
- selection of spectral coefficients on positions *pos* to 63
- watermark w extraction according to eqn. (2)
- enumeration of the EAF value (4) and its comparison with predefined value T
- choosing of the decision D0 for the hypothesis H0 if EAF value is less than T, choosing of the decision D1 for the hypothesis H1 if EAF value is greater than T.

The hypothesis H_0 and H_1 are specified like:
H_0: The testing block was transmitted without error
H_1: The testing block contains errors → demand on the retransmission of that block.

Table 1. Distortion of the watermarked image

Pos	PSNR	
	DCT	WHT
22	32.435	34.522
28	32.929	34.718
34	33.221	35.084
40	33.224	35.473

4 EXPERIMENTAL RESULTS

Experiments were made for the 8-bit grayscale image Nella of 256 × 256 size. The distortions caused by watermark adding into both (DCT and DWHT) spectra for various values of the position corresponding to the first modified coefficient are mentioned in Tab. 1. A watermark embedded into the DWHT spectrum causes lower distortion, not only from an objective but also subjective view. Watermarked images for position pos=22 are in Fig. 3b (DCT) and 3c (DWHT), respectively.

The obtained experimental results for randomly generated errors that are represented by setting the values of randomly chosen coefficients to zero are summarized in Tab. 2.

Table 2. DCT *vs* WHT error detectors, when several pixels were reset to zero

Pos	DCT			DWHT			Number of modified pixels
	Number of detected errorneous blocks	Number of detected wrong blocks	MSE	Number of detected errorneous blocks	Number of detected wrong blocks	MSE	
22	429	214	16.25	643	0	0	1000
28	319	324	40.36	643	0	0	1000
34	290	353	51.35	642	1	0.01	1000
40	238	405	73.79	642	1	0.01	1000

Table 3. DCT *vs* WHT error detectors, when several columns were deleted

Pos	DCT		WHT		Number of columns deleted
	Number of detected errorneous blocks	PSNR	Number of detected errorneous blocks	PSNR	
22	180	20.038	972	25.796	7
28	83	218.754	958	25.791	7
34	14	216.461	873	21.982	7
40	12	216.458	879	22.146	7

Fig. 5. Modified watermarked images: a) setting 1000 randomly chosen pixels to zero, b) deletion of 7 randomly chosen columns of pixels

Experiments were made for four values of the position of the first modified spectral coefficient.

In columns 4 and 7 there are the values of MSE for the repaired images. As we can see, DWHT transform is more sensitive to the modifications of pixels in such way.

Also we can say that the success of the detection process is more dependent on the value of pos for DCT than for the DWHT. Less modified coefficients with a fragile watermark then decrease the probability of detection of erroneous block. In our experiments a situation never occurs when an errorless block would be proclaimed as an erroneous block.

In the case of columns or rows deletion we have to take into account that we are loosing synchronization between the transmitter and receiver and also the fact that when we delete one "column" or "row" of 8×8 block, we find synchronization again in the detection process. It means the detector might give errorless blocks after every 8th deleted column (or row) while the errors do not appear again. Experimental results for that type of error in the image are in Tab. 3.

Also in this case DWHT seems to be better than DCT for error detection application in still images.

5 CONCLUSION

The tests that we realized were only for the grayscale images. How successful is the error detection depends on the size of the modification of the pixel. DWHT seems to be more sensitive to pixel modification than DCT, especially for randomly distributed pixel modifications.

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