effectively reduce distortion in the watermarked image. Additionally, the file size increase is also lessened. The modification of others AC coefficient increases the file size. This is because whenever an AC coefficient is modified, an extra symbol is needed to be coded. Therefore, the proposed method leads to smaller distortion and smaller file size increase.

2.4. Extraction and image recovery

In this proposed scheme, the payload should be extracted and the original host image should be recovered correctly without any errors. The extraction and recovery are done simultaneously.

The message or the watermark extraction and the host image restoration can be described as:

$$\tilde{b} = \begin{cases} 0 & if\ |C'| = 1 \\ 1 & if\ |C'| = 2 \end{cases} \quad (6)$$

$$\tilde{C} = \begin{cases} 0 & if\ |C'| = 1 \\ sign(C') & if\ |C'| = 2 \\ 2 * sign(C') & if\ |C'| = 3 \\ C' & else \end{cases} \quad (7)$$

where $\tilde{b}$ and $\tilde{C}$ represent the extracted message bit and the recovered AC coefficient respectively.

3. Experimental results

In our experiments, we have used 16 popular images from the popular USC-SIPI database including the Lena, Baboon, airplane (F-16), and House. These files are compressed using the JPEG standards with optimized Huffman table. The proposed method was evaluated by comparing the visual quality and file size increase. The PSNR is used to evaluate the visual quality of the watermarked JPEG image, and it is calculated between the original JPEG image and the watermarked JPEG image. File size increase is measured by calculating the number of bytes.

3.1. Visual Quality

For evaluating visual quality, the PSNR is calculated between the watermarked JPEG image and the original JPEG image. Table 4 shows the numerical results of PSNR values on the listed four images applying a quality factor of 70 and a payload size ranging from 8000 bits to 20000 bits. The complete PSNR results for the four images with payload size ranging from 2000 bits to 20000 bits are shown in Fig. 2. Fig. 3 shows the four watermarked JPEG image compressed with a factor quality of 70 and watermarked by a secret data with a payload size of 16000 bits. The experiment shows that the proposed method produces a good visual quality.

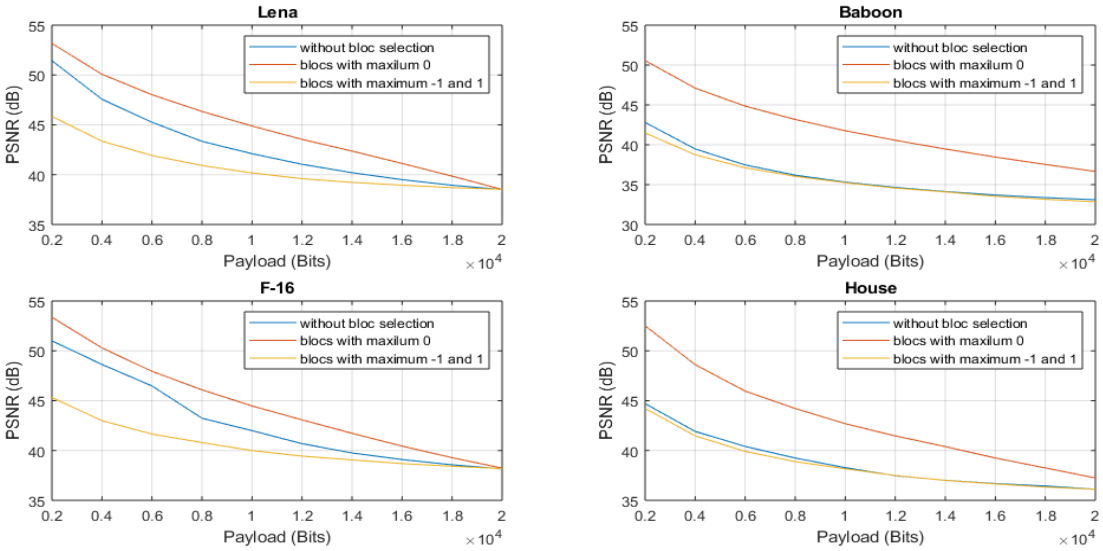

Figure 2. PSNR corresponding to different embedding payloads with and without block selection strategy

Figure 3. Watermarked JPEG images: Lena, Baboon, F-16, and House (from left to right)

Table 4. PSNR corresponding to different embedding payloads for the four test images

Test images	*Payload (Bits)*	*without block selection strategy*	*blocks with maximum of 0*	*blocks with maximum of -1 and 1*
Lena	8000	43,34	46,35	40,92
	12000	41,04	43,54	39,59
	16000	39,50	41,13	38,95
	20000	38,50	38,51	38,53
Baboon	8000	36,20	43,17	36,04
	12000	34,65	40,56	34,57
	16000	33,70	38,46	33,54
	20000	33,11	36,66	32,85
F16 Airplane	8000	43,24	46,09	40,80
	12000	40,69	43,08	39,44
	16000	39,09	40,44	38,69
	20000	38,16	38,23	38,18
House	8000	39,25	44,21	38,88
	12000	37,47	41,46	37,49
	16000	36,68	39,25	36,65
	20000	36,11	37,24	36,11

Table 5. Comparison in terms of PSNR (dB) with payload size of 8000 bits

Image	*Methods*			
	[10]	*[9]*	*[8]*	*Proposed*
F16	40,59	40,41	44,24	46,09
Lena	41,37	41,34	45,24	46,35
Baboon	38,03	37,95	42,49	43,17
Boat	40,41	39,74	43,43	44,38
Peppers	42,63	41,99	45,49	46,31
Average	40,61	40,29	44,18	45,42

Table 6 Comparison in terms of PSNR (dB) with payload size of 16,000 bits

Image	*Methods*			
	[10]	*[9]*	*[8]*	*Proposed*
F16	37,43	37,33	38,26	40,44
Lena	38,48	38,29	39,71	41,13
Baboon	34,39	34,28	36,95	38,46
Boat	37,14	36,8	38,89	40,22
Peppers	39,33	38,83	40,69	41,89
Average	37,35	37,11	38,90	40,43

The proposed method was furthermore evaluated by comparing the visual quality against the three state-of-the-art schemes [8, 9, 10]. The experiment shows that when we select the blocks with maximum 0 values the proposed method has the highest PSNR than all the previous works, but as the payload increases, the block selection has no more effect because all embeddable AC coefficients are used as we can note for Lena and F-16 images in Table 4 and Figure 2 for a payload size of 20000 bits.

Table 7. Comparison in terms of PSNR (dB) on USC-SIPI 9 images with payload size of 10,000 bits

Image	*Methods*			
	[10]	*[9]*	*[8]*	*Proposed*
4.2.01	42,65	42,33	43,9	44,82
4.2.03	37,05	36,97	40,69	41,93
4.2.05	39,68	39,36	42,71	44,47
4.2.07	41,25	41,07	43,89	44,99
5.2.08	39,38	39,21	41,47	43,03
5.2.10	38,64	38,52	39,9	42,01
7.1.01	41,02	40,82	42,62	44,06
Boat	39,01	38,78	41,92	43,20
House	38,23	38,23	40,7	42,69
Average	39,66	39,48	41,98	43,47

3.2. *File Size Preservation*

It is obvious that it is important to consider the file size preservation along with visual quality in JPEG image watermarking. The file size of the watermarked images obtained by the proposed method is on average less when we select the blocks with maximum values of -1 and 1. Table 8 shows the file size increase for each watermarked JPEG image using payload sizes ranging from 8000 bits to 20000 bits. Fig. 4 shows that embedding only in 1 and -1 AC coefficients and shifting only AC coefficients valued 2 or -2 reduce the file size increase of the marked JPEG image.

Table 8. File size increase corresponding to different embedding payloads for the four test images

Test images	*Payload size (Bits)*	*without block selection strategy*	*blocks with maximum of 0*	*blocks with maximum of -1 and 1*
Lena	8000	1349	1368	1210
	12000	1960	1999	1836
	16000	2597	2602	2490
	20000	3213	3199	3218
Baboon	8000	1265	1322	1164
	12000	1895	1927	1752
	16000	2522	2542	2364
	20000	3151	3165	2962
F16 Airplane	8000	1257	1303	1074
	12000	1837	1876	1649
	16000	2417	2444	2287
	20000	2973	2939	2949
House	8000	1226	1331	1118
	12000	1824	1922	1705
	16000	2411	2511	2299
	20000	3010	3099	2943

Similarly, the proposed method was evaluated by comparing the preservation of the image size against the three state-of-the-art schemes [8, 9, 10]. The experiment

shows that when we select the blocks with maximum values of 1 and -1, the proposed method has the highest size preservation than all the previous works, but as the payload increases, the block selection has no more effect because all embeddable AC coefficients are used.

Table 9. Comparison in terms of file size increase (Bytes) with payload size of 8,000 bits

Image	*Methods*			
	[10]	*[9]*	*[8]*	*Proposed*
F16	1377	1372	1169	1074
Lena	1375	1397	1305	1210
Baboon	1339	1375	1286	1166
Boat	1258	1315	1250	1195
Peppers	1378	1433	1400	1154
Average	1345	1378	1282	1160

Table 10. Comparison in terms of file size increase (Bytes) on USC-SIPI 9 images with payload size of 10,000 bits

Image	*Methods*			
	[10]	*[9]*	*[8]*	*Proposed*
4.2.01	1674	1714	1656	1461
4.2.03	1501	1521	1563	1466
4.2.05	1574	1666	1444	1357
4.2.07	1672	1712	1667	1460
5.2.08	1506	1524	1495	1394
5.2.10	1453	1451	1712	1509
7.1.01	1290	1475	1491	1326
Boat513	1564	1592	1588	1483
House	1629	1602	1580	1401
Average	1540	1584	1577	1429

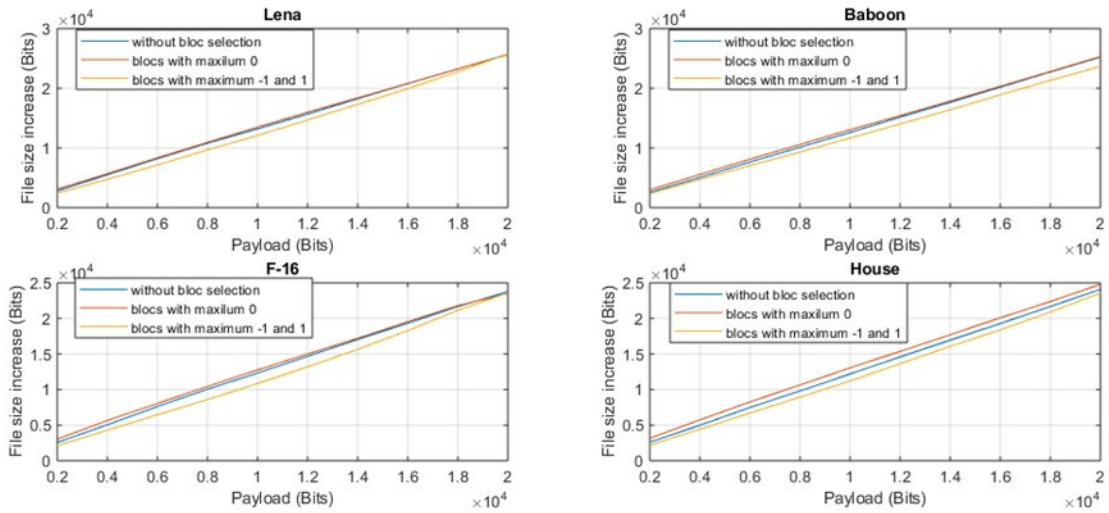

Figure 4. File size increase corresponding to different embedding payloads with and without block selection strategy

In the present work, the process of watermarking an image includes embedding some AC coefficients and shifting others which lead inevitably to increase its initial size and reduce its visual quality. Block selection strategies significantly improve the visual quality and reduce the increase of the file; by selecting the blocks with maximum values of -1 and 1, we got more AC coefficients to embed in, less coefficients to shift, and few needed blocks to embed the entire hidden message which result finally in enhancing the size preservation as shown in Tables 9 and 10. In contrast, selecting blocks with maximum 0 values which mean blocks with minimum values of -1 and 1 leads to less embeddable AC coefficients in each block and the distortion will be distributed over more blocks which results in enhancing the visual quality as shown in Tables 5, 6, and 7. In fact, there is a trade-off between these two factors; importance of each depends on the application.

4. Conclusion

A new watermarking technique for JPEG images is of great significance due to its large series of applications. However, any embedding in JPEG images introduces inevitably more distortion and increases its initial size. In this paper, we present a new scheme for JPEG images watermarking. The main contributions of this paper are as follows: 1) On the basis of the philosophy behind the encoder and the distribution of quantized DCT coefficients, a new DCT coefficient modification-based method is proposed. In the proposed method, only AC coefficients with values 1 and -1 are expanded to carry the message bits and only AC coefficients with values 2 and -2 are shifted. 2) A novel block selection strategy has been proposed in this paper, which may result in better visual quality and less storage size of the marked JPEG file. 3)

The proposed scheme has strong practicability because high embedding capacity and good visual quality can be easily obtained. Meanwhile, the storage size increase of the watermarked JPEG image can be well lessened. Experimental results demonstrate that our proposed method can achieve better performance both in visual quality and file size preservation compared to the previous works in [8-13]. The future work includes the extension of our proposed technique to other category and types of images, for example, color images, DICOM images, and JPEG 2000 which is a wavelet-based image compression standard [14-16].

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