TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol.12, No.1, January 2014, pp. 693 ~ 702
DOI: http://dx.doi.org/10.11591/telkomnika.v12i1.3323

DSDWA: A DCT-based Spatial Domain Digital Watermarking Algorithm

Jianghua Li*[1], Qing Cao[2]
[1]School of Information and Engineering, Jiangxi University of Science and Technology, Ganzhou, China
[2]College of Sciences, Henan Agricultural University, Zhengzhou, China
Corresponding author, e-mail: jxsimil@hotmail.com[1], qingcq55@163.com[2]

Abstract

DCT-based transformed domain watermarking algorithm has some flaws In the aspects of embedding position, embedding strength and embedding method, which have an important influence on watermarking embedding and watermarking extracting. In this paper we discussed these key techniques on DCT-based transformed domain watermarking algorithm and spatial domain digital watermarking algorithm, and their advantages and disadvantages respectively. We discovered the reason that error is generated during DCT and IDCT, and its influence on watermarking embedding and extracting, as well as the basic change rule of the pixel value matrix of the host image during watermarking embedding. On the basis of our analysis, a DCT-based spatial domain digital watermarking algorithm was proposed, which fully leveraged the discovered change rule during watermarking embedding using DCT-based transformed domain algorithm. Experimental results showed that the algorithm had the advantages of spatial domain algorithm and transformed domain algorithm and overcame some of their disadvantages. And itt was superior to DCT-base transformed domain watermarking algorithm. In addition, our work has the certain reference significance to other fields using DCT and IDCT.

Keywords: *digital watermarking algorithm, embedding position, embedding strength, robustness, error*

1. Introduction

Digital Watermarking technology is playing an important role in information security and copyright protection. It has gotten the attentions of academia and industrial community. At present, there are mainly two kinds of typical digital watermarking algorithms: spatial domain digital watermarking algorithm and transformed domain digital watermarking algorithm. In the former, the watermark data is embedded in a host image by changing directly the value of the sampling points in its spatial domain. But in the latter, the host image is first transformed according to different transformed methods, and then the digital watermarking data is embedded in its transformed domain.

In spatial domain, An ZhiYuan [1] proposed a digital watermarking algorithm based on least significant bit (LSB). Gulbis Michael [2] proposed a Patchwork-based method and texture block mapping coding algorithm. Zhang Fan [3] introduced chaos in watermarking algorithm. Hernandez [4] proposed a depth of 2D multi-pulse amplitude modulation method. Wang [5] proposed two kinds of digital watermarking embedding methods based on symmetrical exchange algorithm and coding exchange algorithm respectively.

In transformed domain, Cox [6] proposed a frequency domain watermarking embedding method based on spread spectrum communication. In [7], Discrete Cosine Transform (DCT) is performed to the original host image, and then the watermarking data is embedded in its DCT domain. Himanshu [8] combined Singular Value Decomposition (SVD) [9] with DCT and proposed a novel watermarking algorithm. Bei Yi-Lin [10] used human visual system (HVS) to determine the embedding position in DCT domain, as well as strength factor. Zou Jiancheng [11] thought the phase information is more important than the amplitude information, and then proposed to embed the watermarking in the image Discrete Fourier Transform (DFT) domain. In addition, the digital watermarking algorithm based on Discrete Wavelet Transform (DWT) is proposed in [12, 13].

In general, spatial domain digital watermarking algorithm possesses following advantages: easy implementation, high executing efficiency, more digital watermarking

Received May 25, 2013; Revised July 8, 2013; Accepted August 17, 2013

information to be embedded, better resistance to rotation and brightness adjustment, and it is not visually perceptible by human. But there are also several disadvantages: poor robustness, easy to be attacked, and the digital watermarking information are easily removed or destroyed by common signal processing, for example, data compression and low-pass filtering. By contrast, transformed domain digital watermarking algorithm has better invisibility and robustness by making full use of the characteristics of human perception, and better resistance to data compression and low-pass filtering. But watermarking embedding and extraction are not easy to implement. And the algorithms have high time and space complexity and less information to be embedded.

As far as transformed domain digital watermarking algorithm is concerned, DCT has been more attention and research [14-19] because of the following advantages. The DCT-based algorithm is simpler and easier to be implemented with relatively low time and space complexity than those based on DWT and DFT. What the more important is that, DCT is compatible with the international image compression standard (JPEG2000 and MPEG). This makes the algorithm has better resistance to jpeg compression. All the existing DCT-based transformed domain watermarking algorithms were based on DCT and IDCT, then some work was done to improve watermarking security and robustness. But it is the base itself that has some inherent flaws, such as the proplems of balance between embedding position and embedding strength, error and zero watermarking. These flaws will also have an important influence on watermarking embedding, watermarking extracting and robustness, which were seldom considered by the existing methods. It is what we will discuss in the paper, and we will analyze them in detail in the latter sections.

The main contributions of this paper can be summarized as follows. 1) We discovered the reason that error is generated during DCT and IDCT, and its influence on watermarking embedding and extraction. 2) On the basis of analyzing DCT, we proposed a spatial domain digital watermarking algorithm (DSDWA), which is easy to implement with low time and space complexity. In the aspect of robustness, the algorithm has the advantages of both spatial domain algorithm and transformed domain algorithm, and overcomes some of their disadvantages.

The rest of the paper is organized as follows. Section 2 analyzes digital watermarking embedding positions and embedding strength in DCT-based watermarking algorithm and their influence on watermarking embedding and extraction, and discovers the reason of the error generated during DCT and IDCT. The proposed digital watermarking algorithm is elaborated in Section 3, as well as our experiments and evaluation method. Section 4 is dedicated to results and analysis. Finally, Section 5 gives some conclusions.

2. DCT-based Transformed Watermarking Algorithm Analysis

2.1. The Basic DCT-Based Digital Watermarking Algorithm

(1) The original host image is divided in *K* non-overlapping blocks $f_K(x',y')$ sized 8×8 generally, and DCT is performed to them, and then $F_K(u',v')$ is got.

(2) The pretreated watermarking information $W=\{x_i \mid x_i \in \{0,1\},\ 0<i<L\}$ is embedded in the selected DCT coefficient of $F_K(u',v')$ according to the formula (1), where a is the embedding strength factor.

$$F_K'(u',v') = \begin{cases} F_K(u',v') + a \cdot x_i & \textit{the selected coefficient} \\ F_K(u',v') & \textit{else} \end{cases} \tag{1}$$

(3) IDCT (Inverse Discrete Cosine Transform) is performed to $F_K'(u',v')$, and then the pixel value matrix of the watermarked image is obtained as the formula (2).

$$f'(x,y) = \underset{k=0}{\overset{K-1}{Y}} IDCT\{\ F_K'(u',v')\ \} \tag{2}$$

(4) The watermark extraction is the reverse process of the watermark embedding. The original host image and the watermarked image are first divided into non-overlapping blocks sized 8×8 respectively. Next, DCT is performed to them, then the coefficient matrix F and F^* are got. According to the formula (1), the watermarking data will be obtained, as shown in formula (3), where (x,y) is the embedding position of the watermarking.

$$x_i = (F_i^*(x,y) - F(x,y))/a \tag{3}$$

2.2. The Embedding Position Analysis of the Algorithm

After DCT is performed to the host image, the original spatial domain image data is converted to the frequency domain data, namely Direct Current (DC) coefficient and Alternating Current (AC) coefficient. AC coefficient is divided into low frequency, intermediate frequency and high frequency AC coefficient. The DC coefficient represents average brightness of image, and image energy is mainly concentrated in the low-frequency AC coefficient. Cox proposed that the watermark information should be embedded in the most important parts in the visual system, i.e. the low-frequency AC coefficient [20, 21]. Some researchers [22, 23] thought that, under the premise of guaranteeing watermark invisibility, the watermarking data should be embedded in the DC coefficient. The reason is that DC coefficient is much larger than AC coefficient, and the smaller changes on a relatively large number will not cause too much change. Based on the above reasons, it can be concluded that, embedding the watermarking data in DC coefficient or low frequency AC coefficient will has a larger embedding strength and make the algorithm more robust against Low-pass filtering, lossy compression. However, embedding strength is always contradictory with invisibility of watermarking. Image quality is sensitive to the changes on DC coefficient or low frequency AC coefficient. In other words, embedding the watermarking data in these coefficients will cause changes on image vision. For the purpose of giving consideration to robustness and invisibility, some researchers proposed to embed watermarking data in intermediate frequency AC coefficient [24].

In this paper, we conducted a series of experiments to embed watermarking information in DC coefficient, low frequency (lf), intermediate frequency (if) and high frequency (if) AC coefficient. The original host image (JPEG) 1 sized 256×256 and watermarking image (binary image) sized 32×32 are shown as Figure 1 (a) and (b). The watermarked images where watermarking data is embedded in the coefficient $(0,0)$, $(0,1)$ $(3,3)$ and $(7,7)$ respectively are shown as Figure 1 (c)-(f). In our experiments, we made the embedding strength factor $a = 4$. The reasons will be given in the next section. Compared to the original host image, it can be seen that all the watermarked images changed in the visual, no matter where watermarking data is embedded. Especially, it can be indicated from the Figure 1 (c) that embedding watermarking in DC coefficient had obvious influence on brightness of the image. Then we selected another image as host image 2 with the same size shown in Figure 1 (g) and conducted the same experiments. There was no difference between the watermarked image in Figure 1 (h) and the original host image in Figure 1 (g), at least in visual. The reason was that the original image 2 had more complex texture feature than the original image 1. Apparently it is not enough to only consider embedding position in the DCT-based watermarking algorithm. We think it will be a good method to combine embedding position and the texture feature of host image in DCT-based watermarking algorithm.

2.3. The Influence of DC Coefficient Change on the Image Pixel Value Matrix

Let $A_{mn}(m = 0,1,\cdots,7, n = 0,1,\cdots,7)$ be the pixel value matrix of the original host image, A'_{mn} be the pixel value matrix of the watermarked image, $B_{pq}(p = 0,1,\cdots,7, q = 0,1,\cdots,7)$ be the DCT coefficient matrix of A_{mn}, B'_{pq} be DCT coefficient matrix of the watermarked image before IDCT, and B''_{pq} be the modification on B_{pq}, the formula (4) and (5) are got according to the formula (1).

$$B'_{pq} = B_{pq} + B''_{pq} \tag{4}$$

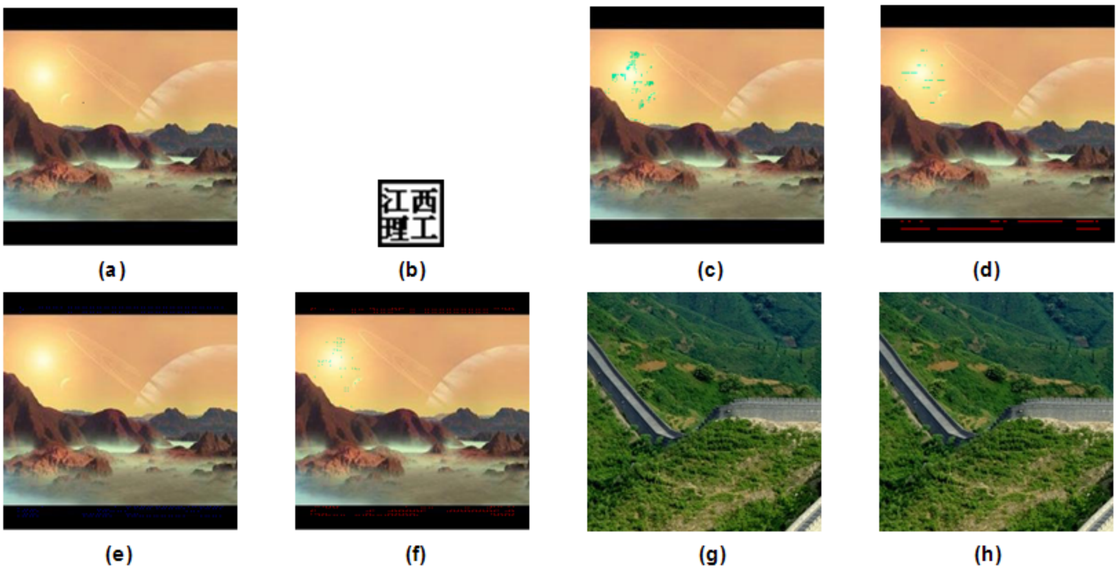

Figure 1. (a) original host image 1. (b) original watermark. (c) watermark in DC.
(d) watermark in lf AC. (e) watermark in if AC. (f) watermark in hf AC.
(g) original host image 2. (h) watermark in lf AC

$$B''_{pq} = ax_i \tag{5}$$

According to DCT, (6) is got.

$$A'_{mn} = \sum_{p=0}^{M-1}\sum_{q=0}^{N-1} a_p a_q (B_{pq} + B''_{pq}) cos\frac{\pi(2m+1)p}{2M} cos\frac{\pi(2n+1)q}{2N} \tag{6}$$

Then (7) is derived.

$$A'_{mn} = A_{mn} + \sum_{p=0}^{M-1}\sum_{q=0}^{N-1} a_p a_q (B''_{pq}) cos\frac{\pi(2m+1)p}{2M} cos\frac{\pi(2n+1)q}{2N} \tag{7}$$

Because of embedding watermarking in DC coefficient, the formula (8) is true.

$$B''_{pq} = \begin{cases} not\ \ 0 & p=0\ \ and\ \ q=0 \\ \ \ \ \ 0 & else \end{cases} \tag{8}$$

According to the formula (4) and (8), the formula (9) is got. The formula (10) is the modification.

$$A'_{mn} = A_{mn} + \frac{1}{8} B''_{00} \tag{9}$$

$$C = \frac{1}{8} B''_{00} = \frac{1}{8} ax_i \tag{10}$$

2.4 The Influence of Image Pixel Value Matrix Change on DC Coefficient

Supposed that β is the modification of the pixel value matrix after embedding watermarking information. According to the formula (1) and IDCT, the formula (11) is got.

$$B'_{pq} = a_p a_q \sum_{m=0}^{M-1}\sum_{n=0}^{N-1}(A_{mn}+\beta)\cos\frac{\pi(2m+1)p}{2M}\cos\frac{\pi(2n+1)q}{2N} \tag{11}$$

$$B'_{pq} = B_{pq} + \beta a_p a_q \sum_{m=0}^{M-1}\sum_{n=0}^{N-1}(A_{mn}+\beta)\cos\frac{\pi(2m+1)p}{2M}\cos\frac{\pi(2n+1)q}{2N} \tag{12}$$

Let $C_{pq} = a_p a_q \sum_{m=0}^{M-1}\sum_{n=0}^{N-1}(A_{mn}+\beta)\cos\frac{\pi(2m+1)p}{2M}\cos\frac{\pi(2n+1)q}{2N}$ (13)

In essence, C_{pq} is the coefficient matrix that DCT is performed to an all-1 matrix sized 8×8, so the formula (14) is true.

$$C_{pq} = \begin{cases} 8 & p=0 \ \ and \ \ q=0 \\ 0 & else \end{cases} \tag{14}$$

Then the formula (15) is true.

$$B''_{pq} = B'_{pq} - B_{pq} = 8\beta \tag{15}$$

From the formula (1), the formula (15) is the inverse process of the watermarking embedding, namely the formula for the watermarking extraction.

In ideal state (we means no error), according to the formula (1) and (15), the formula (16) is true.

$$8\beta = ax_i \quad or \quad x_i = 8\beta / a \tag{16}$$

From the formula (10), the modification of the pixel value matrix of the host image after embedding watermarking depends on the embedding strength factor a. According to the formula (16), the value of the modification β is only equal to 0.5 when $a = 4$. The pixel value matrix of the watermarked image will be got only if the following process is finished: 1) IDCT is performed to the DCT coefficient matrix having been embedded watermarking in, 2) the results of IDCT are rounded because a pixel value of image is an integer number. It is just in DCT and IDCT process that error is inevitably generated. The error makes the modification of the pixel value of the watermarked image be equal to 1 or 0. Namely if $a < 4$, the pixel value matrix of the original host image is likely same exactly with that of the watermarked image. In other word, there is no watermarking embedded in original image, i.e. zero-watermark, so it is impossible to extract it.

In conclusion, the embedding strength factor a is one of the key factors in DCT-based watermarking algorithm. When a is relatively large, the modification of the pixel value is large, and the algorithm will be more robust against various signal processing, but it can reduce the image quality and cause changes in visual. Conversely, the smaller the value of a, the worse the robustness.

In a similar way, the formula (17) can be deduced when embedding watermarking in low frequency AC coefficient $(0,1)$.

$$A'_{mn} = A_{mn} + \frac{\sqrt{2}}{8} B''_{01} \cos\frac{(2n+1)\pi}{16} \quad (17)$$

And the modification of the columns 0-7 of the original pixel value matrix are as follows when $B''_{01} = ax_i$, $\frac{\sqrt{2}}{8} B''_{01} \cos\frac{\pi}{16}$, $\frac{\sqrt{2}}{8} B''_{01} \cos\frac{3\pi}{16}$, $\frac{\sqrt{2}}{8} B''_{01} \cos\frac{5\pi}{16}$, …, $\frac{\sqrt{2}}{8} B''_{01} \cos\frac{15\pi}{16}$.

3. The Proposed Digital Watermarking Algorithm

Based on above analysis, the following conclusions can be drawn. DCT-based digital watermarking algorithm realizes watermarking embedding by modifying DCT coefficients of the pixel value matrix of the original host image, which may be DC coefficient or AC coefficient. In essence, the watermarking embedding process is a process to modify regularly the energy carried by every pixel itself of the image, which finally reflects in the pixel value matrix of the watermarked image derived from DCT and IDCT. One of the reasons that the transformed domain digital watermarking algorithm is better than the spatial domain algorithm is that, the former modifies the energy carried by image in the frequency domain, and this modification reflects evenly in every pixel value of image at last. But there are some defects in DCT-based digital watermarking algorithm as follows. 1) Both DCT and IDCT have a large number of calculations with higher time and space complexity than spatial domain algorithm. 2) Error inevitably exists in the process of DCT and IDCT, which greatly influences watermarking embedding and extraction. 3) It is hard to determine the embedding strength factor. Unsuitable value will lead to zero-watermark or reducing image quality. 4) The algorithm itself has bad resistance to some signal processing, for example brightness adjustment and horizontal rotation processing. By contrast, the spatial domain algorithm has the following advantages: easy implement and better robustness against brightness adjustment and horizontal rotation processing. According to the above analysis, we proposed a spatial domain digital watermarking algorithm based on DCT.

3.1. Watermarking Embedding Algorithm

1) Extracting the pixel value matrix of the original host image and dividing it into non-overlapping blocks sized 8×8.

2) Converting the watermark image into one-dimensional binary sequences.

3) Embedding watermarking data in the 8×8 pixel matrix of the original host image according to the following rules: if the embedded data is “1”, every pixel value of the 8×8 pixel matrix plus 1. The purpose of doing so is to ensure a smooth color change to the whole image block without visual changes. Meantime, in order to prevent substantial changes in individual pixel color caused by overflow, the pixel value of 255 would be excluded. If the embedded data is “0”, staying all the original pixels value.

4) Repeating the step 3) until all the watermark data are embedded.

As a result, the method makes the changes on the energy carried by image reflect in every pixel, which coincides with fundamental principle of DCT-based watermarking embedding algorithm. Meantime, changing evenly the pixel value matrix is beneficial to keeping the watermarked image quality.

3.2. Watermarking Extraction Algorithm

1) Extracting the pixel value matrix of the original host image and the watermarked image, and dividing them into non-overlapping blocks sized 8×8.

2) Calculating the sum of all the pixels value of every block of the original host image and the watermarked image respectively, denoted “sum1” and “sum2”.

3) If sum2 minus sum1 is larger than 0, the embedded watermark data is “1”, else “0”.

4) Repeating the step 3) until all the watermark data are extracted, and reassembling all the extracted watermark data into an image.

3.3. Experiments and Evaluation

We used the image in Figure 1 (g) as the original host image and the image in Figure 1 (b) as the watermarking image to conduct a series of experiments. In our experiments, two methods are adopted to evaluate the extracted watermarking data. One is correlation coefficient measurement shown as the formula (18), where $W^{'}$ is the extracted watermarking data, and W is the original watermarking data. $P(W^{'},W)$ indicates the correlativity between $W^{'}$ and W. $P(W^{'},W)$ is closer to 1, the correlativity between them is higher, and 1 means they are the same signal. Conversely, it is closer to 0, the correlativity is lower, and 0 means completely irrelevant. The other is similarity measurement shown as the formula (22), where $|G(W^{'})\cap G(W)|$ is the number of the same pixels between $W^{'}$ and W, and $|G(W)|$ is the total number of pixels of W. The value range of $S(W^{'},W)$ is [0, 1], which is same to $P(W^{'},W)$.

$$P(W^{'},W)=\frac{Cov(W^{'},W)}{\sqrt{D(W^{'})}\sqrt{D(W)}} \tag{18}$$

$$D(W^{'})=E\{[W^{'}-E(W^{'})]^2\} \tag{19}$$

$$D(W)=E\{[W-E(W)]^2\} \tag{20}$$

$$Cov(W^{'},W)=E[(W^{'}-E(W^{'}))(W-E(W))] \tag{21}$$

$$S(W^{'},W)=\frac{|G(W^{'})\cap G(W)|}{|G(W)|} \tag{22}$$

4. Results and Analysis

Experimental results are shown as Figure 2. The image (a)-(i) is the extracted watermarking image after the following processing is performed to the watermarked image respectively: image shear, contrast adjustment, horizontal rotation, vertical rotation, brightness adjustment, smoothing, sharpening, adding 50% noise and low-pass filtering. The image (j)-(n) is the extracted watermarking image after the watermarked image is compressed with the compressibility factor 80%, 70%, 60%, 50% and 30% respectively. Due to limited space, the processed watermarked images are omitted.

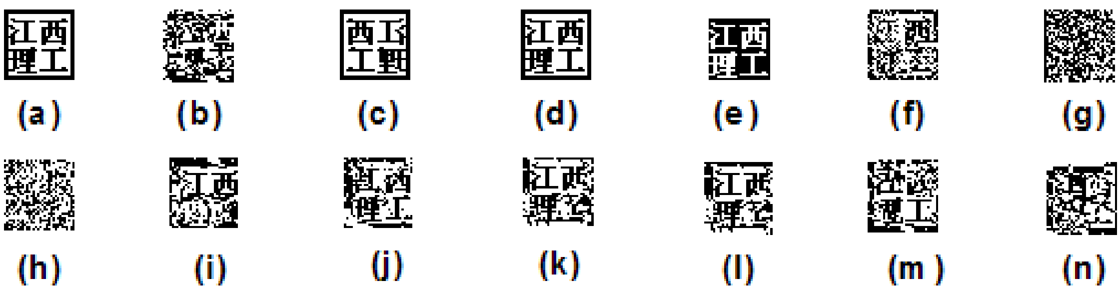

Figure 2. The extracted watermarking image

Experimental data derived from DCT-based watermarking algorithm and DSDWA is shown as Table 1. In the former experiments, watermarking is embedded in DC coefficient with the embedding strength $a=4$. From the Figure 2 and the Table 1, it can be proved that DSDWA is an effective digital watermarking algorithm. DSDWA is a spatial domain digital watermarking algorithm with easy implement, which makes it robust against brightness adjustment and rotation, and overcomes the disadvantages of the frequency domain algorithm.

Meantime, from the above analysis, DSDWA in essence used fundamental principle (i.e. modifying regularly the pixel values) to realize watermarking embedding. So it has the characteristic of the frequency domain algorithm, which makes it robust against low-pass filtering and jpeg lossy compression, and overcomes the disadvantages of the spatial domain algorithm. Different from the traditional LSB algorithm, DSDWA is not a simple replacement of the bit-plane, but superimposes the energy of the embedded watermarking upon the energy of the entire host image.This makes the safety of the watermarking information much higher than spatial domain algorithm. Compared to DCT-based transformed domain algorithm, DSDWA has the fllowing advantages: (1) DSDWA is robuster against shear, brightness and Horizontal rotation than DCT-based transformed domain algorithm. Meantime both have the similar robustness agatinst other signal processing.(2) from the aspect of the time complexity, DSDWA is $O(n^2)$, whereas both DCT and IDCT are $O(n^4)$. (3) the computation procedure of DSDWA is precise, no error and no zero watermarking. It also can be seen that both DSDWA and DCT-based transformed domain algorithm still have less robustness against sharpening and adding noise.

Table 1. Comparison between DCT-based algorithm and DSDWA

Attack method	Embedding algorithm	Similarity	Correlation coefficient	identifiably
No attack	DCT	1	1	Y
	DSDWA	1	1	Y
Shear	DCT	related to the shear position	related to the shear position	related to the shear position
	DSDWA	1	1	Y
Brightness 110%	DCT	0.4932	0.2833	N
	DSDWA	0.8728	0.8512	Y
Contrast 110%	DCT	0.4852	0.0256	N
	DSDWA	0.5018	0.0283	N
Horizontal rotation,	DCT	0.46	0.1325	N
	DSDWA	0.5453	0.7491	Y
vertical rotation	DCT	1	1	Y
	DSDWA	1	1	Y
Sharpening	DCT	0.4872	0.0823	N
	DSDWA	0.4883	0.0805	N
Smoothing	DCT	0.7021	0.8753	Y
	DSDWA	0.7261	0.8536	Y
Adding 50% noise	DCT	0.4845	0.0702	N
	DSDWA	0.3956	0.0238	N
Compression of 50%	DCT	0.8763	0.7982	Y
	DSDWA	0.8566	0.7539	Y
Low-pass filtering	DCT	0.8153	0.7523	Y
	DSDWA	0.8098	0.7631	Y

5. Conclusion

DCT-based digital watermarking algorithm was widely researched in recent years. In this paper, we discussed several basic factors that work in all DCT-based digital watermarking algorithms, including watermarking embedding position, embedding strength and error generated in DCT and IDCT and their influence on watermarking embedding and extraction. Our research shows it is not enough to only consider single aspect in DCT-based watermarking algorithm. For the purpose of trade off between invisibility and robustness, all the above factors and the image texture should be considered comprehensively. In our study, we discovered that the process of watermarking embedding with DCT algorithm was essentially a process of modifying regularly the pixel value matrix of the host image. Based on this, we proposed DSDWA in this paper. The algorithm makes full use of the advantages of spatial domain algorithm and transformed domain algorithm. The experimental results show that the proposed DSDWA is superior to DCT-based watermarking algorithm, whether in time and space complexity or robustness. But it is not perfect against all signal processing, we will improve it in our future work.

Acknowledgement

The work in this paper is supported by National Program on Key Basic Research Project (973 Program) under Grant No. 2013CB329606, the Scientific Research Found of Jiangxi Provincial Education Department of China under Grant No. GJJ13411 and the Jiangxi Provincial Ministry of Education Research Fund under Grant No.12770.

References

[1] An Zhi Yuan, Liu Haiyan. *Research on digital watermark technology based on LSB algorithm*. Proceedings of the 4th International Conference on Computational and Information Sciences. Chongqing. 2012; 207-210.

[2] Gulbis Michael, Erika Muller. *Content-based audio authentication using a hierarchical patchwork watermark embedding*. Proceedings of SPIE Photonics Europe. Brussels. 2010; 7723: 77230N-77230N.

[3] Zhang Fan, Shang Dongfang, Wang Yujing. *Adapting digital watermark algorithm based on chaos and image fusion*. Proceedings of the 2009 WRI Global Congress on Intelligent Systems. Xiamen. 2009; 3: 126-130.

[4] Hernandez JJ, Perez-Gonzalez F, Rodriguez JM, et al. Performance analysis of a 2-Dmultipulse amplitude modulation scheme for data hiding and watermarking still images. *IEEE Journal on Selected Areas of Communications*. 1998; 16(4): 510-524.

[5] Wang CM, Wang PC. Steganography on point-sampled geometry. *Elsevier Computers & Graphics*. 2006; 30(2): 244-254.

[6] Cox LJ, Kihan J, Leighton FT, Shamoon T. Secure spread spectrum watermarking for multimedia. *IEEE Transactions on Image Processing*. 1997; 6(12): 1673-1686.

[7] Chen Liwei, Li Mingfu. *An effective blind watermark algorithm based on DCT*. Proceedings of the World Congress on Intelligent Control and Automation. Chongqing. 2008; 6817-6821.

[8] Himanshu, Rawat Sanjay, Raman Balasubramanian, Bhatnagar Gaurav. *DCT and SVD based new watermarking scheme*. Proceedings of the 3rd International Conference on Emerging Trends in Engineering and Technology. Goa. 2010; 146-151.

[9] Wei Wang, Wenhui Li, Chengxi Wang, Huijie Xin. A Novel Watermarking Algorithm based on SURF and SVD. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(3): 1560-1567.

[10] Bei Yi-Lin, Yang De-Yun, Liu Ming-Xia, Zhu Li-Li. *A multi-channel watermarking scheme based on HVS and DCT-DWT*. Proceedings of the 2011 IEEE International Conference on Computer Science and Automation Engineering. Shanghai. 2011; 4: 305-308.

[11] Zou Jian-Cheng, Si Jian-Min. A watermark technology of print-scan resilient based on DFT transform. *Journal of Beijing University of Technology*. 2010; 36(4): 113-117.

[12] Song Jianhua, Wang Guoqiang, Ma Hongbin, Wang Yingli. A digital watermark method based on DWT and tent mapping. *International Journal of Advancements in Computing Technology*. 2012; 4(10): 11-21.

[13] Huming Gao, Liyuan Jia, Meiling Liu. A Digital Watermarking Algorithm for Color Image Based on DWT. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(6): 3271-3278.

[14] Cheng Mingzhi, Xi Minchao, Yuan Kaiguo, Wu Chunhua, Lei Min. Recoverable video watermark in DCT domain. *Journal of Computers*. 2013; 8(2): 533-538.

[15] Shengbing Che, Zuguo Che, Xu Shu. Research on image self-recovery algorithm based on DCT. *Journal of Multimedia*. 2010; 5(3): 290-297.

[16] Wang Cheng, Liu Shaohui, Jiang Feng, Liu Yan. A robust scalable spatial spread-spectrum video watermarking scheme based on a fast down sampling method. *Journal of Computers*. 2012; 7(9): 2256-2261.

[17] Zhang Weiwei, Zhang Ru, Liu Xianyi, Wu Chunhua, Niu Xinxin. A video watermarking algorithm of H.264/AVC for content authentication. *Journal of Networks*. 2012; 7(8): 1150-1154.

[18] Veeraswamy Kilarivs, Kumar S. Srinivas. Adaptive AC-coefficient prediction for image compression and blind watermarking. *Journal of Multimedia*. 2008; 3(1): 16-22.

[19] Chen Liwei, Li Mingfu. *An effective blind watermark algorithm based on DCT*. Proceedings of the 7th World Congress on Intelligent Control and Automation. Chongqing. 2008; 6817-6821.

[20] Guo Jing-Ming, Chang Chia-Hao. Prediction-based watermarking schemes using ahead/post AC prediction. *Signal Processing*. 2010; 90(8): 2552-2566.

[21] Hsieh Jun-Yan, Chang Long-Wen. *A high capacity watermarking for H.264/AVC based on frequency weighting*. Proceedings of 2006 International Symposium on Intelligent Signal Processing and Communications. Yonago. 2007; 899-902.

[22] Yanling Zhao, Na Li, Guangqi Liu, Qingxi Wang. *A digital image watermark algorithm based on DC coefficients quantization*. Proceedings of the World Congress on Intelligent Control and Automation. Dalian. 2006; 2: 9734-9738.

[23] Ye Yun, Jiang Xinghao, Sun Tanfeng, Li Jianhua. *An efficient video watermarking scheme with luminance differential DC coefficient modification*. Processing of the 8th Pacific Rim Conference on Multimedia. Hong Kong. 2007; 4810 LNCS: 437-440.

[24] Xuan Man, Jiang Jian-Guo. *A novel watermarking algorithm in entropy coding based on image complexity analysis*. Proceedings of the 1st International Conference on Multimedia Information Networking and Security. Hubei. 2009; 2: 126-129.