A Novel Self-adaptation Differential Energy Video Watermarking Scheme in Copyright Protection

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***Abstract*—This paper proposes a novel self-adaptation differential energy watermarking based on the Watson visual model, which inserts robust watermark into video streaming according to the differential energy theory. This algorithm can control the watermark's embedding intensity of sub-low AC coefficients in the video streaming adaptively based on the Watson visual model. And it also can be self-adaptive cheesed that the region should be embed watermarks according to the relationship between the energy adjustable threshold and their differential energy. So watermark not only meets the non-visual perception, but also has the better robustness. Experiments show that this algorithm has strong robustness and security against the usual video attacks such as noise, filter and compression attack etc with low complexity of energy computation and high capacity.**

***Index Terms*—self-adaptation, differential energy watermarking, Watson visual mode, sub-low AC coefficients, copyright protection**

I. INTRODUCTION

While the Internet facilitates data transmission and sharing, it also brought about the issue of copyright protection to the digital data owner, which led to a growing body of research interest in watermarking technology. At the entire digital watermarking algorithm, image watermarking algorithm is far more than video watermarking algorithm. However, in our daily lives, it is video products that need more protection. An effective watermark algorithm must meet three basic requirements: robustness, perceptive transparency and real-time efficiency. In fact, these three basic requirements are in conflict with each other usually, which becomes crucial to require a good balance in algorithm design.

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At present, there are some successful algorithm achieved, whose representative literatures such as [1-3] follows. In paper [1], Hartung and Girod proposed a kind of video watermarking based on MPEG-2 compressed domain, which has two defects. The watermark embedding strength is decided based on experience. And the local texture features of video frames are neglected, which will cause local perceptive distortion vulnerably. In paper [2], Langelaar put forward a kind of differential energy watermarking in VLC domain, which embeds watermark by removing the high frequency coefficient with a very good real-time. But its watermark information is very easy to be removed by low-pass filtering method. In paper [3], Liu put forward a kind of watermarking in the wavelet domain based on MPEG-2 compression formats. Because the data has to be restored to the airspace in the watermark embedding and extracting process, and then which is transformed by wavelet. It is difficult to meet the real-time requirements with high computational complexity. In summary, it is necessary to be improved for the current video watermarking algorithm on how to get a better balance among robustness, perceptual transparency and real-time.

This paper presents a novel differential energy watermarking based on Watson visual model applied at the video streaming. The algorithm embeds watermark into the sub-low frequency of AC coefficient in the video streaming and scrambles the watermark before embedding to enhance its robustness. While the watermark is being embedded, this algorithm calculates the largest modification of each DCT coefficient of watermarking space based on Watson visual model to enhance adaptability, which is called JND(Just Noticeable Difference).The algorithm reduces energy load domain and simplifies the calculating methods in order to further reduce the computing complexity and improve real-time nature. So this algorithm has a better balance among watermarking robustness, perceptive transparency and real-time nature.

This paper is divided into six parts. The first part is introduction, the second part is Watson visual model, the third part is differential energy watermarking program, the fourth part is video watermarking algorithm, the fifth part is simulation experiment and analysis and the sixth part is conclusion.

II. WATSON VISUAL MODEL

Watson visual model is one model used to measure visual fidelity, which is indicated by Watson. The perceptual model is trying to estimate JND (just noticeable difference) among images. The JND of DCT coefficient is the maximum allowable value to modify without visual impact, which is also known as the critical difference.

A. Sensitivity

Watson sensitivity model defines a frequency sensitivity table, each of which is the approximate equivalent to the minimum of each DCT coefficient that can not be resolved without masking noise [6].

TABLE 1.

8×8 DCT FREQUENCY SENSITIVITY TABLE

1.40	1.01	1.16	1.66	2.40	3.34	4.79	6.56
1.01	1.45	1.32	1.52	2.00	2.71	3.67	4.93
1.16	1.32	2.42	2.59	2.98	3.64	4.60	5.88
1.66	1.52	2.59	3.77	4.55	5.30	26.28	7.60
2.40	2.00	2.98	4.55	6.15	7.46	8.71	10.17
3.43	2.71	3.64	5.30	7.46	9.62	11.58	13.51
4.49	3.67	4.60	6.28	8.71	11.58	14.50	17.29
6.56	4.93	5.88	7.60	10.17	13.51	17.29	21.15

B. Brightness Adaption

Brightness adaptive means if the average brightness of an 8×8 block has more light, a DCT coefficient can be changed larger without any attention. To each small block, Watson adjusts the size of DC according to the sensitivity table [8]. Brightness masking threshold is:

$$t_{ijk}^{L} = t_{ij}(X_k / \bar{X})^{a_T} \tag{1}$$

Among them, t_{ij} means the size of pixels of 8×8 block, X_k means the size of DC of k-block of the original image, $\bar{X}$ is the average size of all DC coefficient of images, a_T is a constant, whose recommendation is 0.649.

C. Contrast Masking

Contrast masking property (certain frequency component of the energy makes another frequency component in the visible decline) will produce a masking threshold [9]. Defined as follows:

$$S_{ijk} = \max\left\{t_{ijk}^{L}, |X_{ijk}|^{b_{ij}} \times \left(t_{ijk}^{L}\right)^{1-b_{ij}}\right\} \tag{2}$$

Among them, b_{ij} is a constant from 0 to 1, which is defined as $b_{ij} = 0.7$ by Watson. The ultimate threshold S_{ijk} means that if the change of DCT coefficient X_{ijk} is more than S_{ijk}, there will be visual distortion.

This algorithm calculates JND_{ijk} of each DCT coefficient according to Watson model. In the embedding process, the differential energy D can be controlled by revising the value of E_A and E_B, and the amendatory value of each DCT coefficient X_{ijk} should not exceed JND_{ijk}. If $|X_{ijk}| < JND_{ijk}$, $X_{ijk} = 0$, else

$$\begin{cases} X_{ijk} = X_{ijk} - JND_{ijk}(X_{ijk} \geq 0) \\ X_{ijk} = X_{ijk} + JND_{ijk}(X_{ijk} < 0) \end{cases} \tag{3}$$

Therefore, the watermark will not have evident impact on the visual perception, thereby enhancing perceptive transparency of the watermark.

III. DIFFERENTIAL ENERGY WATERMARKING

So far, JAWS [7] and DEW [5] are classic representatives of video watermarking algorithm programs in accordance with the requirements of real-time. This paper improves the watermark's real-time and robustness according to DEW.

A. Classical Program

The idea of differential energy watermarking is put forward by Langelaar, which is a watermarking method based on discarding part of high-frequency DCT coefficient of compressed video images selectively. Watermark is decided by the differential energy of high-frequency DCT coefficient in the two adjacent regions. As shown below:

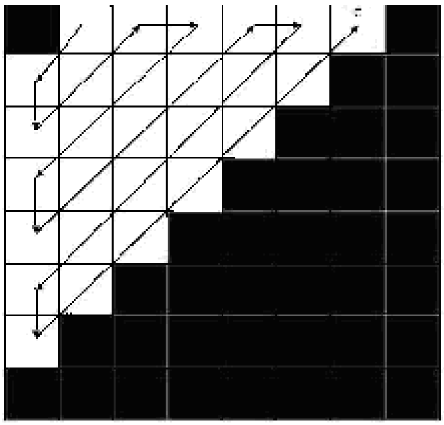


Figure 1. 8×8 DCT block

Among them, the black part of top-left corner is DC (directive coefficient), white part is sub-low frequency part of AC (alternate coefficient) and the black part of low-right corner is the high frequency part of AC.

$S_{(c)}$ is the collection of DCT coefficient after rearranging as frequency, which is scanned by Zig-Zag:

$$S_{(c)} = \{ i \in (0,63) \mid (i > c) \} \tag{4}$$

The region carrying watermark is divided into two equivalent parts of A and B[10]. The sum of all coefficient of $S_{(c)}$ is E_A:

$$E_A = \sum_{j=0}^{n/2-1} \sum_{i \in S_{(c)}} \left[DCT_{(i,j)} \right]^2 \tag{5}$$

$DCT_{(i,j)}$ is the value of DCT coefficient whose number is i of the j-DCT matrix scanned by Z in the A sub-region. Similarly the sum of energy of another sub-region B can be got:

$$E_B = \sum_{j=n/2}^{n-1} \sum_{i \in S_{(c)}} \left[DCT_{(i,j)} \right]^2 \tag{6}$$

The difference between E_A and E_B is D= E_A— E_B. The code of watermark is identified by the symbol of D. If $D > 0$, watermark is 0; If $D < 0$, watermark is 1.

B. Improved Program

There are three problems in DEW:

1) Because high-frequency of DCT coefficient is discarded easily by filter and compression, DEW based on high-frequency of DCT coefficient can not resist the attack of filter effectively.

2) Energy calculation is too complicated, high-frequency is very small, which is not only meaningless but also increases computational complexity and impact the real-time.

3) DEW doesn't consider the impact of the visual quality to discard the DCT coefficient.

To the problem that the modified form of energy is too simple. This paper's algorithm estimated the threshold JND(the largest margin which can be amended without visual distortion caused) of each DCT energy coefficient by using Watson visual model before embedding watermark, which can be modified. And DCT energy coefficient should be modified in the scope of JND.

To the problem that energy load region is lack of randomness. In the energy load region of sensitive texture features, energy difference is Generally speaking too large. It is too costly to modify the energy difference coefficient of these regions, which leads to distortion easily. Therefore, this paper's algorithm chooses the appropriate energy load region to embed watermark. But after estimating the JND of each DCT energy coefficient through Watson visual model, theoretically in an energy region S, it is possible to create a situation that the energy difference D between block A and block B is too large to change the positive and negative attributes of D. For example, if D>0, we should reduce D to D<0. Assume the sum of all JND as Sum.

$$Sum = \left| \sum_{j=0}^{n/2-1} \sum_{i \in S_{(c)}} \left[DCT_{(i,j)} + JND_{(i,j)} \right]^2 - \sum_{j=n/2}^{n-1} \sum_{i \in S_{(c)}} \left[DCT_{(i,j)} - JND_{(i,j)} \right]^2 \right| \tag{7}$$

In Formula 7, $JND_{(i,j)}$ means the threshold modified of DCT coefficient i of DCT coefficient matrix named j according to the Z-shaped scanning in the region A.

Generally speaking, $JND_{(i,j)} < DCT_{(i,j)}$.However, if $E_A >> E_B$,then D is still D>0 after modify the energy Sum.This situation actually means this energy load region has more complex texture features, which is not suitable to embed watermark or leads to distortion easily. Therefore, this paper's algorithm carried out this inappropriate energy load region before embedding watermark.

Therefore, this paper has three improvements according to the three problems:

1) The algorithm will only consider the sub-low frequency of AC and embed the watermark in this part according to texture Properties, and adjust the critical value of C to reduce the number of DCT coefficients of each energy region.

2) The algorithm will simplify the energy calculating formula, which only calculates the sum of absolute value of each coefficient replacing the square value:

$$E_A = \sum_{j=0}^{n/2-1} \sum_{i \in S_{(c)}} \left[| DCT_{(i,j)} | \right] \tag{8}$$

$$E_B = \sum_{j=n/2}^{n-1} \sum_{i \in S_{(c)}} \left[| DCT_{(i,j)} | \right] \tag{9}$$

So this will reduce the calculating complexity doubled. Adjust the DCT coefficient according to the value of JND estimated by Watson model to reduce the impact on the visual quality.

3) The algorithm will modify the necessary DCT coefficient according to the JND (Just Noticeable Difference) value based on Watson visual model replacing simply discarded and give up embedding watermark in the region with complicated texture features in order to reduce the impact on visual quality.

IV. VIDEO WATERMARKING ALGORITHM

A. Main Framework

The basic idea of this algorithm is:

1) Embed the original watermark into the key

frames of video (Generally speaking I frame).

2) When watermark is embedding, this algorithm adjusts the DCT coefficient according to the value of JND estimated by Watson model to reduce the impact on the visual quality.
3) The video embedded watermark should through the attack experiment to test the ability of this algorithm's anti-attack.
4) Extract and recover the watermark from video stream after attacking.

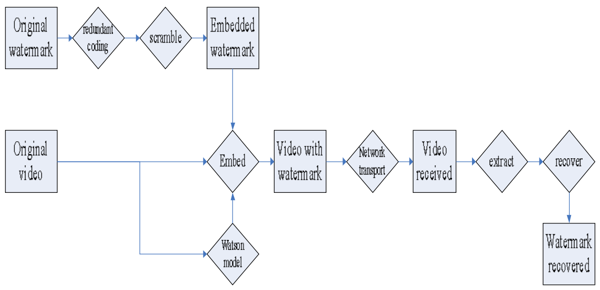


Figure 2. Algorithm flow diagram

B. Algorithm Research

This algorithm contains four elements: watermark redundant coding and scrambling algorithm, watermark recovery algorithm, video watermark embedding algorithm and video watermark extraction algorithm.

1) Watermark Redundant Coding and Scrambling Algorithm

Redundant coding and scramble the watermark before embedding it in the image block:

a) Modulate the watermark into binary matrix sequence $L_{M\times N}$.
b) S is scrambling seed, and scrambling matrix $R_{M\times N}$ can be produced by $R = random(M, N, S)$.
c) Watermark sequence can be scrambled by scrambling matrix $R_{M\times N}$:

$$L = R \otimes L \tag{10}$$

If $S_1 \neq S_2$, $R_1 = random(M,N,S_1)$, and $R_2 = random(M,N,S_2)$, thus $R_1 \neq R_2$. In addition, function $R = random(M, N, S)$ is one-way function:

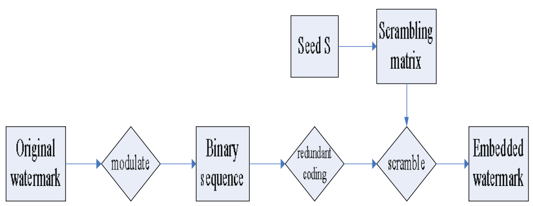


Figure 3. Watermark scrambling process

2) *Watermark Recovery Algorithm*

Watermark recovery algorithm is an irreversible process as shown in Figure 4:

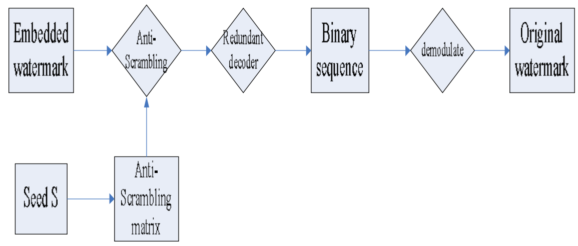


Figure 4. Watermark recovery algorithm

From Figure 4, please note that:

a) Only both sides of communication have the seed S.
b) The form of redundant coding is CRC (cyclical redundancy code).
c) Rule of redundancy judgment is the principle of simple majority. For example, when redundancy is 1:5, then if the number of "1" is more than 3, the watermark is "1". Similarly, when redundancy is 1:10, then if the number of "1" is more than 6, the watermark is "1".

3) *Video Watermark Embedding Algorithm*

Embedding process is shown in Figure 5:

a) Extract the key frame I from video.
b) Transform the frame I by 8×8 DCT.
c) Estimates the JND of DCT coefficient according to Watson model.
d) Select the block number of area A (A must be even) and the critical point C ($2 \le C \le 28$), then the number of watermark embedded into each frame can be calculated, which is indicated as n.
e) Read the watermark W, traverse all I frames, and select n bits to embed.
f) Calculate the energy difference D of each region. If $D > 0$, the watermark is 0, else if $D < 0$, the watermark is 1. If D doesn't match the watermark, it is easy to adjust the value of each DCT coefficient of each region.

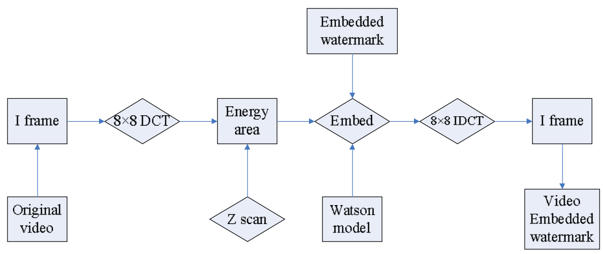


Figure 5. Watermark embedding process

4) *Video Watermark Extracting Algorithm*

Watermark embedding and extraction is an irreversible process as shown in Figure 6:

a) Extract the key frame I from video.
b) Transform the frame I by 8×8 IDCT.
c) Read A and C, establish region and critical point value.
d) Calculate the energy difference D of each region. If $D > 0$, watermark is 0. If $D < 0$,

watermark is 1.

e) Traverse all I frames, and reorganize the watermark.

f) Generate recovery matrix R through the same seed S, and restore the binary sequence of the original watermark.

g) Demodulate and restore the original watermark.

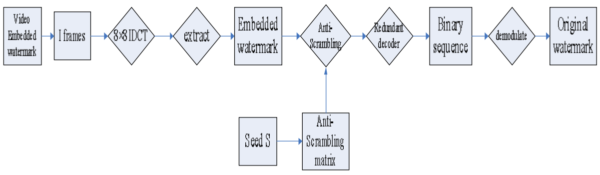


Figure 6. Watermark extracting process

Anyway, the main advantages of this algorithm are:

1) The watermark scrambled is conducive to decentralize the error codes and improve the robustness of watermark.
2) Even if watermarking algorithm was broken, others can only get the watermark scrambled not the real watermark.
3) Resist the attacks of low pass filter and compression effectively.
4) Reduce the computational complexity significantly.
5) Reduce the impact on the visual perceptions by watermark and enhance the perceptive transparency.

V. Simulation and Analysis

A. Experimental Conditions

The experiment uses five MPEG-4 encoding videos. The first and second video are 256×256 format, frame-rate is 15 fps, block number is A=8, the critical point C=28, frame-number is 300. The others are 512×512 format, frame-rate is 30 fps, block number is A=16, the critical point C=25, frame-number is 500. Among them, key frames are I frames, every one of which is embedded 64 bit information.

In the experiment, the watermark is text: Shanghai Jiao Tong University formerly the Nang Yang Public School was founded in 1896. So if the watermark is redundantly coded 1:5, there needs 55 frame to embed a complete watermark.

Simulation software tool is Matlab7.0b; the following parameters involved are Matlab parameters.

B. Watermark Embedding and Extraction Experiment

From the experimental conditions, the watermark is redundantly coded as 1:5 and 1:10 separately. So there needs 55 and 110 frames to embed the watermark. separately. Main comparisons are:

- Compare the visual effect between the original video and video with watermark.
- Compare the PSNR difference between the DEW and the algorithm of this paper.

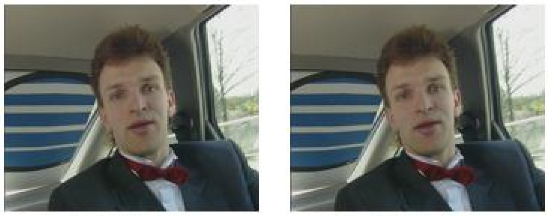
1) Visual Perception Comparison

Original video Embedded video

Figure 7. First video contrast

Original video Embedded video

Figure 8. Second video contrast



Original video Embedded video

Figure 9. Third video contrast

Original video Embedded video

Figure 10. Fourth video contrast

Original video Embedded video

Figure 11. fifth video contrast

The watermark is: Shanghai Jiao Tong University formerly the Nang Yang Public School was founded in 1896.

The result of watermark encoding redundantly by

CRC is : 83 104 97 110 103 104 97 105 32 74 105 97 111 32 84 111 110 103 32 85 110 105 118 101 114 115 105 116 121 32 102 111 114 109 101 114 108 121 32 116 104 101 32 78 97 110 103 32 89 97 110 103 32 80 117 98 108 105 99 32 83 99 104 111 112 108 32 119 97 115 32 102 111 117 110 100 101 100 32 105 110 32 49 56 57 54 46

The watermark extracted is: Shanghai Jiao Tong University formerly the Nang Yang Public School was founded in 1896.

From Figure 7 to Figure 11, it is easy to know that the watermark has no visual impact on the video in this paper's algorithm, which has well perceptive transparency. Original watermark is encoded by CRC cyclic redundancy coding to enhance the ability of anti-error.

2) Capacity Comparison

According to the algorithm flow, the formula for calculating capacity of the watermark which can be embedded into each frame is shown as follow:

$$capacity = (\min(m,n) \div block)^2 \div area - extra \quad (11)$$

In formula 11, $capacity$ is the capacity of the watermark which can be embedded into each frame. m and n represent the frame's line height and column width separately. $block$ is on behalf of sub-block size. $area$ is on behalf of sub-area size, which contains even number of blocks. $extra$ is on behalf of the number of energy overload region, which is the region with too large differential energy to regulate.

According to formula 11, we calculated the capacity of watermark embedded of each single video frame. The result is shown in Table 2:

TABLE 2.

WATERMARK CAPACITY CONTRAST TABLE

Video	Frame	Block	Area	Extra	Capacity
1	256×256	8	4	17	239
2	256×256	8	4	21	235
3	512×512	8	4	73	951
4	512×512	8	4	64	960
5	512×512	8	4	69	955

According to Table 2, it is easy to know that the watermark algorithm has high capacity. Factors that affect the capacity are frame, block, area and extra. Capacity will increase with the raise of frame, though the same to extra, the former grows faster obviously. Meanwhile, the capacity will expand with the decrease of blocks and areas, which will weak the ability of watermark's anti-attack. Therefore, it is necessary to get a balance between capacity and security.

C. Attack Experiment

To first video as an example, through some kinds of attack successively such as noise, filter, and compression and so on, it is easy to get the comparison with DEW algorithm. Please note that C is the threshold of AC sub-low coefficients embedded watermark and BER is the error rate.

1) Noise Attack

The video is attacked by Gaussian noise with zero mean and variance followed by 0.01, 0.02, 0.05, 0.1 and 0.5, as shown in Figure 12.

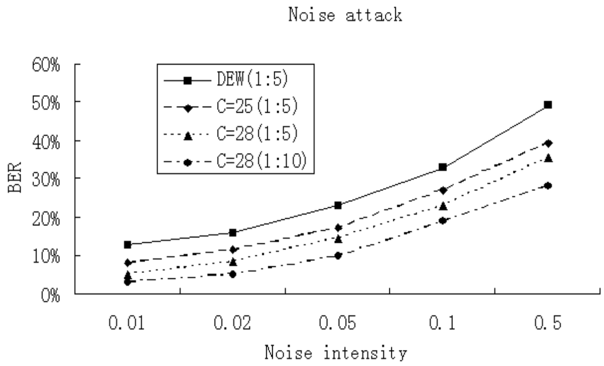


Figure 12. Noise attack

From Figure 12, it shows that:

- This paper's algorithm is better than DEW in the same situation.
- when C increases from 25 to 28, the BER declines. So there can be a conclusion that the bigger C is, the greater watermark's robustness is, and it is easy to improve the ability of anti-noise of watermark by enhancing the value of C.
- when redundancy increases from 1:5 to 1:10, the BER declines. So that the bigger redundancy is, the greater watermark's robustness is.

But it also should be known that the bigger C is, the greater computational complexity is; the bigger redundancy is, the lower efficiency is. So it needs to have a good balance in the Practical application.

In the experiment, when the BER is less than 19%, the watermark can be recovered completely. Otherwise, there will be wrong information. From Figure 10, C=28 (1:10) can resist the noise attack with 0.1 variance, C=28 (1:5) and C=25 (1:5) can resist the noise attack with 0.05 variance, DEW (1:5) only can resist the noise attack with 0.02 variance. Therefore, the ability of resisting noise attack of this paper's algorithm is superior to DEW.

2) Filter Attack

The video embedded watermark is attacked by filter, omitting the high-frequency part of image, and selecting D as the smallest cut-off frequency of filter. As shown in Figure 13.

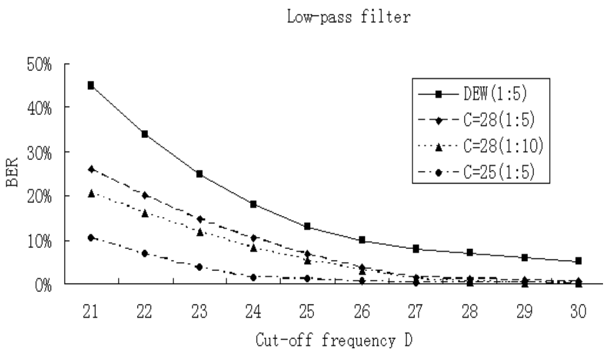


Figure 13. Filter attack

From Figure 13, it shows that:

- This paper's algorithm is better than DEW in the same situation.
- There is a certain relationship between the C and the cut-off frequency D of filter. If C enhances, the quality of watermark will deteriorate with the declination of the D.
- If redundancy enhances from 1:5 to 1:10, it also is easy to enhance the robustness of the watermark.

In the experiment, when the BER is less than 10%, the watermark can be recovered completely. Otherwise, there will be wrong information. From Figure 11, C=25(1:5) can resist the filter attack with cut-off frequency 21, C=28 (1:10) can resist the filter attack with cut-off frequency 24, C=28(1:5) can resist the filter attack with cut-off frequency 25, DEW (1:5) only can resist the filter attack with cut-off frequency 27. Therefore, the ability of resisting filter attack of this paper's algorithm is superior to DEW.

3) *Compression Attack*

The video with watermark is compressed separately, the average compression rate in turn is 17.8:1, 25.4:1, 31.5:1, 36.4:1, 40.6:1,43.9:1,48.1:1,and 51.0:1. As shown in Figure 14.

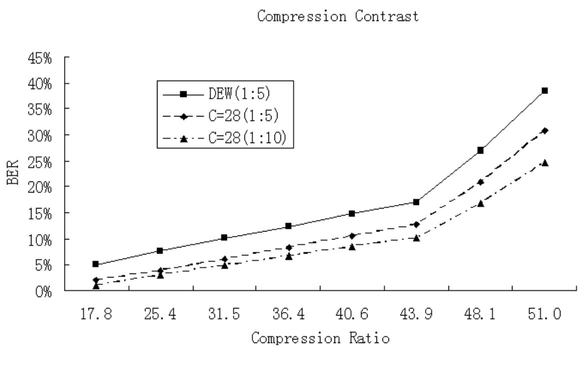


Figure 14. Compression Attack

From Figure 14, it shows that:

- This paper's algorithm is better than DEW in the same situation.
- The bigger redundancy of watermark is, the better robustness of watermark is.

In the experiment, when the BER is less than 16%, the watermark can be recovered completely. Otherwise, there will be wrong information. From Figure , C=28 (1:10) can resist the compression attack with compression ratio 48.1, C=28 (1:5) can resist the compression attack with compression ratio 43.9, DEW(1:5) can resist the compression attack with compression ratio 40.6. Therefore, the ability of resisting filter attack of this paper's algorithm is superior to DEW.

Anyway, it is necessary to consider the C and redundancy carefully to balance the robustness, perceptive transparency, computational complexity and efficiency. Meanwhile, there is a conclusion that this paper's algorithm is far superior to DEW in the overall performance.

4) *Frame Attack*

Generally speaking, frame attack refers to the loss of frame, frame cropping, frame restructuring and so on. In the experiment, watermark signals are randomly divided for resisting most kinds of frame attack. And each group of signals must be in compliance with odd-even parity. When this group of signals is extracted, if it isn't in compliance with odd-even parity, it will be replaced by the average value of adjacent group of signals. The total number of frames is 32. The result of frame attack experiment is shown in Figure 15.

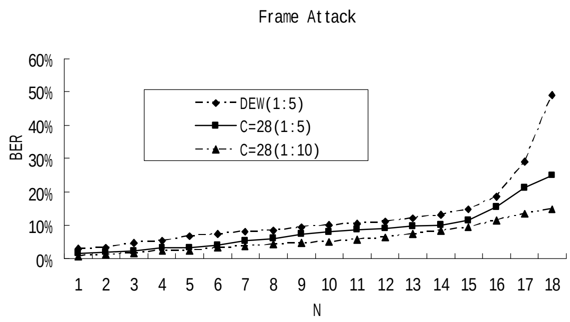


Figure 15. Frame attack

In Figure 15, N is on behalf of the number of frames which is missed, cut or restructured. From Figure 15, it shows that:

- When the number of frames attacked is in the certain range, BER (bit error rate) maintains at a lower level and it only has little change. As shown in Figure 15, when the number of loss of frames is less than 16, it means the number of loss of frames is less than 50%. Redundant information can offset the interference of error bits. In other words, the watermark has a certain anti-attack capability at this time.
- BER will increase rapidly when the number of frames attacked is more than 50%, especially in the case of the attack of frame lost experiment, watermark almost can not be recovered.

Therefore, under a certain intensity of attack (lost, cut, restructure). This watermarking algorithm has a strong anti-attack capability to be effective in the restoration of the watermark. While the number of loss of frames is more than certain range, watermark can't be recovered.

VI. CONCLUSION

It is put forward an adaptive video watermark algorithm based on Watson's visual model in the paper. Firstly, a permutation to strengthen the watermark's safety; secondly, to adaptively establish the size of energy domain and threshold value according to Watson's visual model, which minimizes the influence on video qualify and enhances its robustness and transparency; thirdly, a simplification of the arithmetic complexity by devising a new calculation method which improves computational complexity. From the analysis of the experiment, it is showed that this paper's algorithm has a strong robustness, well perceptive transparency, high safety and low computational complexity.

Concerning the future work, in short terms, we plan to implement some improvements for the three watermarking schemes: for the robust watermark, we want to combine our scheme with more advanced error-correction coding methods in order to enhance robustness; for the high-capacity watermark, we intend to design an error-correction code for the adopted permutation coding so as to make it less fragile. future prospect of the watermarking algorithm is that the algorithm will be real time dealing with video and have more capacity of hiding data by using some new methods such as chaos, artificial intelligence, neural networks, fuzzy control etc. This algorithm not only can be used for copyright protection, but also can be used for secure communication. Therefore, it has a high economic and social value.

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REFERENCES

[1] Lei Li, Vaisyanathan K, Trivedi K S. An Approach for Estimation of Software Aging in a Web Server[C]. Proceedings of the International Symposium on Empirical Software Engineering, 2006: 91-100.

[2] Trivedi K S, Vaidyanaman K. Software Rejuvenation-Modeling and Analysis[C]. IFIP Congress Tutorials, 2008: 151-182.

[3] Vaidyanathan K, Trivedi K S. A Measurement-based Model for Estimation of Resource Exhaustion in Operational Software Systems [C]. Proc. of the 10th IEEE Intl. Symp on Software Reliability Engineering, 2003: 84-93.

[4] A.B.Watson. DCT quantization matrices visually optimized for individual images [J].Human Vision, Visual Processing, and Digital Display IV, Bernice E. Rogowitz, Editor, Proc. SPIE 1913-14, (2001): 202-216.

[5] G C Langelaar, R L Lagendijk. Optimal differential energy watermarking of DCT encoded images and video [J]. IEEE Transactions on Image processing, 2005, 10 (1): 148-158.

[6] I.J.Cox, M.L.Miller and J.A.Bloom. Digital Watermarking [J]. Morgan Kaufmann, 2006, 09 (1): 7-12.

[7] Ton kalker, Geert Depovere, Jaap Haitsma, Maurice Maes. A video watermarking system for broadcast monitoring [C]. Proceedings of the SPIE.Vol.3657, 2003(1):103-112.

[8] Xinshan Zhu. Image-adaptive Spread Transform Dither Modulation Using Human Visual Model [C]. Computational Intelligence and Security, 2006 International Conference on Volume 2, 3-6 Nov. 2006 Page(s):1571-1574.

[9] Gui Xie, Swamy M.N.S, Omair Ahmad M. Perceptual-Shaping Comparison of DWT-Based Pixel-Wise Masking Model with DCT-Based Watson Model [C]. Image Processing, 2006 IEEE International Conference on 8-11 Oct. 2006 Page(s):1381-1384.

[10] Das T.K, Maitra S, Mitra J. Cryptanalysis of optimal differential energy watermarking (DEW) and a modified robust scheme [C]. Signal Processing, IEEE Transactions on Volume 53, Issue 2, Part 2, Feb.2005 Page(s):768-775.

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