Video Watermark Technique in Motion Vector

JUN ZHANG[1]
JIEGU LI[2]
LING ZHANG[3]
[1]TSI, Ecole Nationale Superieure des Telecommunications, Paris, 75013, France.
JUN_ZHANG1@yahoo.com
[2]Institute of Image Processing and Pattern Recognition, Shanghai Jiaotong University, Shanghai, 200030, China
[3]Department of Electronics, JingDeZhen Ceramic College, Jiangxi, 333001, China

Abstract. In this paper, we propose a video watermarking technique to hide copyright information in MPEG motion vector. In this method, watermark is embedded in larger value motion vectors, and specially in the less phase angle changed component. Then, the motion vector is modified into a new bitstream from which the watermark information can be easily retrieved. From the experimental results, it indicates that to embed watermark in motion vector has the advantage of little degrading the video quality, little influence on the MPEG decoding speed, capability to embed watermark in a short video sequence, and can be used to watermark on both the uncompressed and compressed video sequence.

1 Introduction

With the development of digital technology, infrastructures such as computers, printers, digital storage media and high rate digital transmission facilities (e.g. digital network) are becoming inexpensive and widely available. These all make it easily and expeditiously to provide an efficient cost-effective means of distributing digital media. Unfortunately, by comparing with the analog media, digital media copyright information can be more easily infringed by pirate. By simply making a copy, an exact duplication of the original digital media can be easily constructed. And right now, with the rapidly development of digital storage techniques, people can use cheap equipment, like CD-RW driver, to do duplication with the digital entertainment media, such as DVD, video CD and internet real-time audio and video delivery media. Effective copyright protection techniques are therefore necessary, either to prevent unauthorized copying, or at least as an evidence of copyright infringement. So comes video watermarking technique, and it has become a very active area of research for the digital video copyright protection.

Video watermark technique is to hide copyright information into video sequence to prevent copyright infringement. A first possibility to embed watermark in video is to individually mark all the frames of the video using a still image watermarking technique. Doing so would allow inheriting the robustness of the 2D approaches; the drawback however would be the vulnerability to averaging attacks, where consecutive frames are averaged to remove the embedded mark [1]. Typically, in DCT domain, Dittmann proposed a video watermarking scheme [2]. First, a position sequence is generated from the user key as a seed with a secure random number generator. Then, to improve the visual quality of the watermarked frame and integrate an error correcting code, inducts the smooth block and edge detection to check for HVS-characteristics. Finally, watermark information with the error corrections and redundancy is embedded. A second possibility is to take into account the temporal dimension of the video. Hartung consider the whole video as one-dimensional signal acquired by line scanning and embed a watermark in form of spread spectrum into the direct domain of the video stream [3]. And Zhu propose to mark the static and dynamic temporal components generated from a temporal wavelet transform of the video [4]. In this paper, we explore the way to embed watermark in motion vector. It is available for both uncompressed and compressed video watermarking.

2 Video watermarking in motion vector

In the MPEG compression algorithms, the motion compensated prediction techniques are used for reducing temporal redundancies between frames and only the prediction error images - the difference between original images and motion compensated prediction images - are encoded. In general, the correlation between pixels in the motion compensated inter frame error images is reduced

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by comparing to the correlation properties of intra frames, because the prediction is based on the previous coded frame. Most of the frames in MPEG video sequence are in motion compensated prediction coding except the intra frame. So, to hide watermark information in motion vectors can more efficiently utilize the information in video bitstream. Kutter et al. have proposed a way to hide watermark information in the motion vector, by slightly modify the motion vectors into a data sequence which can make watermark be easily retrieved [5]. In this paper, according to 2 principles, we improve this watermarking scheme. One is to embed watermark in the macroblocks which are in the larger motion vector magnitude, The other is to embed watermark in the motion vector component which will be in less change with motion vector phase angle.

2.1 Embedding scheme

1. Get the motion vector $PMV[i]\big|_{0<i<MB}$ from the original video bitstream.
2. Calculate the magnitude,

$$|PMV[i]| = \sqrt{H^2[i]+V^2[i]} \qquad (0<i<MB)$$

where, $H[i]$ is the horizontal component of motion vector PMV in the *ith* macroblock; $V[i]$ is the vertical component of motion vector PMV in the *ith* macroblock
3. Give threshold ε, select the macroblocks for watermark embedding, and use ε to generate secrete key.

$$E[i] = P[i]\cdot F[i]$$

where, F is the frame; E is the selected macroblocks for watermark embedding.

$$P[i] = \begin{cases} 1 & |PMV[i]| > \varepsilon \\ 0 & |PMV[i]| \le \varepsilon \end{cases} \qquad (0<i<MB)$$

4. In the selected watermark embedding macroblocks, calculate the phase angle of motion vector,

$$\theta[j] = \arctan\left(\frac{V[j]}{H[j]}\right) \qquad (j\in E[i] \quad and \quad E[i]\neq 0)$$

5. Embedding watermark.
a. If θ is acute angle,
If $\{(H[j]*q+T)\ Modulo\ 2\} \neq mark[k]$, then $H_w[j] = H[j]+d$;
If $\{(H[j]*q+T)\ Modulo\ 2\} = mark[k]$, then $H_w[j] = H[j]$.
Where, $H_w[j]$ is the horizontal component of motion vector PMV in the *jth* macroblock after watermarking; T = 2*<*Search Window used for Motion Estimation*>; $d=(2n+1)/q$, n is integer; q is used to specify the amplitude of the motion vector modification.
b. If θ is obtuse angle,
If $\{(V[j]*q+T)\ Modulo\ 2\} \neq mark[k]$, then $V_w[j] = V[j]+d$;
If $\{(V[j]*q+T)\ Modulo\ 2\} = mark[k]$, then $V_w[j] = V[j]$;
Where, $V_w[j]$ is the vertical component of motion vector PMV in the *jth* macroblock after watermarking; The others are defined same as above.
c. if $\theta = 45^\circ$, then modify both the horizontal component $H[j]$ and the vertical component $V[j]$, according to the above watermark embedding scheme.

2.2 Retrieving scheme

1. Get the motion vector $PMV_w[i]\big|_{0<i<MB}$ from the watermarked video bitstream.
2. Calculate the magnitude,

$$|PMV_w[i]| = \sqrt{H_w^2[i]+V_w^2[i]} \qquad (0<i<MB)$$

3. Decode ε, determine the macroblocks for watermark retrieving.

$$E_w[i] = P_w[i]\cdot F_w[i]$$

where, F_w is the watermarked frame; E_w is the selected macroblocks where watermark embedded inside.

$$P_w[i] = \begin{cases} 1 & |PMV_w[i]| > \varepsilon \\ 0 & |PMV_w[i]| \le \varepsilon \end{cases} \qquad (0<i<MB)$$

4. In the watermarked macroblocks, calculate the phase angle of motion vector,

$$\theta_w[j] = \arctan\left(\frac{V_w[j]}{H_w[j]}\right) \qquad (j\in E_w[i] \quad and \quad E_w[i]\neq 0)$$

5. Retrieving watermark.
a. If θ is acute angle,

$$mark[k] = \{(H[j]*q+T)\ Modulo\ 2\}$$

b. If θ is obtuse angle,

$$mark[k] = \{(V[j]*q+T)\ Modulo\ 2\}$$

c. if $\theta = 45^\circ$,

$mark[k] = \{(H[j]*q+T)\ Modulo\ 2\}$ or $mark[k] = \{(V[j]*q+T)\ Modulo\ 2\}$

2.3 Decision scheme

Watermark decision scheme is shown in Figure 1.

Suppose GOP to be N frames group, watermark to be m bits bitstream.

1. In GOP, select inter frame (B or P frame) f_n, decode watermark by using watermark retrieving scheme.

2. In f_n, determine the existence of watermark by using intra watermark decision scheme (error correction and calculate the repeatability of these decoded m bits marks). If there is watermark in f_n, then go to step 3; if there is no watermark in f_n, then go to step 4; if no enough information for intra decision (e.g. number of selected blocks < 2m), then go to step 5.

3. Do inter watermark decision in successive M frames. Decode the first m bits in each frame. After error correction, calculate the repeatability of the decoded marks. If a watermark in these frames, then go to step 6; else select the next GOP, repeat step 1 - 5. If reach the end of video sequence, then go to step 7.

4. Select the next frame f_{n+1}, repeat step 1 – 5. If reach the end of GOP, then go to the next GOP, repeat step 1 – 5. If reach the end of video sequence, then go to step 7.

5. Do 1.5M frames inter watermark decision. If a watermark in these frames, then go to step 6; else select the next GOP, and do step 5. If reach the end of video sequence, then go to step 7.

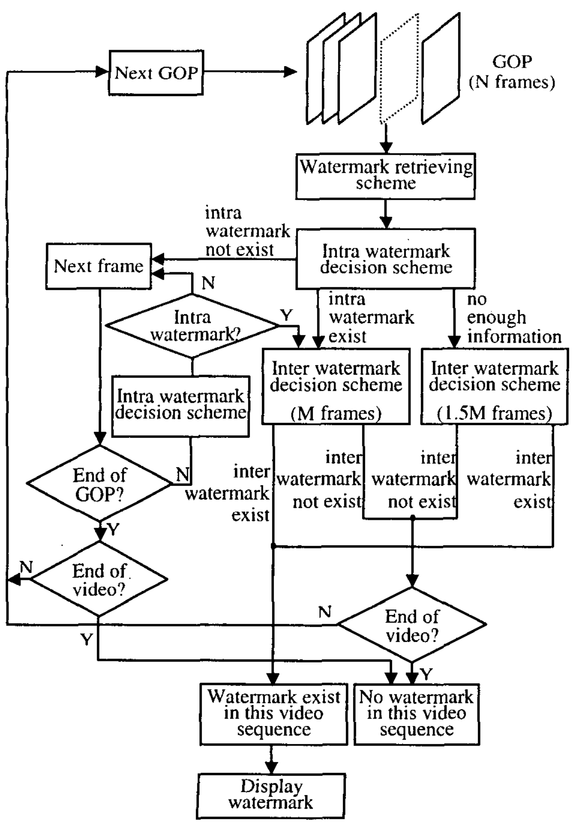

Figure 1 Decision scheme

6. There is a watermark in this video sequence, display watermark, and stop.

7. There is no watermark in this video sequence, print message, and stop.

3 Experimental results

In this experiment, one testing video sequence can be seen in Figure 2, and the profile is showing in Table 1. Select 6 frames in the video sequence, the first frame *f0*, the 5th frame *f4*, the 9th frame *f8*, the 13th frame *f12*, the 17th fame *f16* and the 21st frame *f20*. The correspondent 6 watermarked frames, which have embedded 64 binary bits "ENST-tsi", can be seen in Figure 3. The quality of watermarked frames by comparing with the original frames can be estimated from the data in the Table 2, with the 8 measures [6], NMSE (Normalized Mean Square Error), SC (Structural Content), AAD (Absolute Average Difference), CQ (Correlation Quality), NCC (Normalized Cross-Correlation), PMSE (Pulse Mean Square Error), IF (Image Fidelity) and PSNR. Seen from the experimental results, it indicates that this approach to embed watermark in motion vector has little change with the video quality.

Table 1

Profile ID	Main
Level ID	Main
Frames in GOP	12
Frame rate	25
Horizontal size	352
Vertical size	240
I/P frame distance	3
Bit rate (bits/s)	1152000
Chromatic format	4:2:0
Video Format	PAL
Aspect ratio information	CCIR601 625 line

4 Conclusion

To embed watermark information in motion vector has some good performances for hiding copyright information in the MPEG video sequence, such as little change with the MPEG decoding speed, good watermarked video quality, little degrading the perceptive effect, efficient exploitation with the information in inter frames, more place to embed watermark information in video sequence, capability to embed watermark in a short video sequence, and can be used to watermark directly on both the compressed and uncompressed video bitstream. However, motion vector normally is not in so unique quantity. So, there are still some works to do on enhancing the robustness of embedded location, the watermarking scheme and the combination scheme with other video watermarking techniques.

Table 2

	f0	*f4*	*f8*	*f12*	*f16*	*f20*
NMSE	**0.0011**	**0.0007**	**0.0007**	**0.0007**	**0.0009**	**0.0008**
SC	**1.0050**	**1.0065**	**1.0052**	**1.0078**	**1.0043**	**1.0055**
AAD	**0.7094**	**0.6420**	**0.6440**	**0.6415**	**0.7051**	**0.6566**
CQ	**123.645**	**123.789**	**123.660**	**123.308**	**123.008**	**122.398**
NCC	**0.9970**	**0.9964**	**0.9971**	**0.9958**	**0.9974**	**0.9969**
PMSE	**6.539e-5**	**4.347e-5**	**4.388e-5**	**4.581e-5**	**5.346e-5**	**4.582e-5**
IF	**0.9989**	**0.9993**	**0.9993**	**0.9993**	**0.9991**	**0.9992**
PSNR	**41.8450**	**43.6178**	**43.5772**	**43.3908**	**42.7193**	**43.3898**

Figure 3 Video sequence for embedding watermark

Figure 4 Watermarked video sequence with watermark "ENST-tsi"

References

[1] I. J. Cox and J. P. M. G. Linnartz, "Some general methods for tampering with watermarks", *IEEE Journal on Selected Areas in Communications*, 16(4) (1998), 587-593.

[2] J. Dittmann, M. Stabenau, and R. Steinmetz, "Robust mpeg video watermarking technologies", *Proc. Of ACM Multimedia*, (1998).

[3] F. Hartung and B. Girod, "Watermarking of uncompressed and compressed video", *Signal Processing* 66(1998), 283-301.

[4] B. Zhu, M. D. Swanson and A. H. Tewk, "Multiresolution scene-based video watermarking using perceptual models", *IEEE Journal on Selected Areas in Communications*, 16(4) (1998), 540-550.

[5] M. Kutter, F. Jordan and T. Ebrahimi, "Proposal of a watermarking technique for hiding/retrieving data in compressed and decompressed video", *Technical report M2281, ISO/IEC document, JTC1/SC29/WG11*, (1997).

[6] M. A. Hazem, "Evaluation of reconstruction quality in image vector quantization using existing and new measures", *IEE Proceedings Vision, Image and Signal Processing*, 145(1998), 349-357.