A video watermarking scheme based on motion vectors and mode selection

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***Abstract*—In this paper, a video watermarking technique is proposed to hide copyright information in H.264 motion vectors. In this method, watermark is embedded in the motion vectors, and the region of motion vector is restricted to hide watermarking information. In order to obtain the good watermarked video quality, intra mode can be used to encode those macroblocks badly affected by restricting the region of the chosen motion vectors in inter mode. The watermark can be easily retrieved by the encoding mode of the macroblocks or the region of its motion vectors. The experimental results demonstrate that the video quality is almost the same as that of the original. The increase of bit rate is less than 1%. The proposed method keeps the excellences of hiding watermark by using the region of motion vectors. The capacity of watermark can be increased by choosing more macroblocks to the watermarks.**

Keywords- video, watermark, motion vector, mode selection, H.264

I. INTRODUCTION

Digital videos become more and more popular. Now we can easily download any video we want from internet. Meanwhile, the illegal uses and distribution also grow as well. It also arise author problems such as users can copy vast amount of digital data at will for their own use. Even piratical DVD sells everywhere. The digital watermark [1] is an effective method of protecting copyright of digital contents. It is a logo belongs to the owner and watermarking is the technique which is created for protecting the copyright. Digital watermark can become an evidence of copyright infringement.

There are many particular characters in video still compared with image. The character of motion is one of the most important characters. In video motion vector indicates the motion of every macroblock. Therefore embedding watermark in motion vectors could be a method to protect copyright. Kutter [2] first proposed a video watermarking scheme in motion vectors. In order to simplify the extraction process of watermark, only one macroblock was chosen to embed watermark. The parity of motion vectors was used to embed watermark. For example, odd abscissa of motion vectors indicated 1 in binary system and even one indicated 0. So motion vectors which were used to embed watermark only need be modified slightly according to the watermarking information. Jun Zhang [3] proposed a video watermarking technique to hide copyright information in MPEG motion vectors. In this method, watermark was embedded in larger value motion vectors, especially in the less phase angle changed component. This principal was used to choose the motion vectors which would be used to embed watermarking information. The embedding scheme was similar to the method of [1]. In [4], scramble operation and permutation were used before embedding the watermarking information. The parameters used in these operations were kept for security considerations. In this paper, parity of motion vectors was also used to embed watermark. Meanwhile, there are many schemes [5]~[9] which improve the scheme of embedding watermark by the parity of motion vectors.

The region information of motion vectors also can be used to embed watermark. In [10], a novel video watermarking scheme was proposed. In motion estimation of H.264, the search region of macroblcks which were used to embed watermark was restricted in particular area. For example, the case that the matching macroblock was in the left region of current macroblock indicates 1. And 0 can be embedded if the matching macroblock was in the right region of current macroblock. But there will be a special case that the current macroblock can't find a good matching macroblock in the region we restrict. In this case, the bit rate will increase more, and the video quality is likely to decrease. So if the case occurs, the intra mode can be used instead of inter mode.

II. THE PRINCIPAL FOR WATERMARK EMBEDDING

H.264 is the newest video compression standard, which meets the growing need for higher compression of moving pictures for various applications such as videoconferencing, digital storage media, television broadcasting, internet streaming, and telecommunication. Compared with other video compression, H.264 has higher compression, higher video quality and much higher calculate complexity. Because of the character of high compression, if we use traditional watermarking scheme, it is likely that the watermarks we embedded are regarded as redundancy by H.264 and the

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Foundation item: This work is Supported by Innovation Program of Shanghai Municipal Education Commission, under search grant number 08YZ75

978-0-7695-3336-0/08 $25.00 © 2008 IEEE
DOI 10.1109/CSSE.2008.306

watermarks can't be retrieved from the H.264 video stream. So it is a good way that the watermarking information is embedded in motion vectors which wouldn't be removed by H.264 encoding.

A. Embedding steps

Figure 1 is a sketch map of motion vectors in the second frame of foreman sequence.

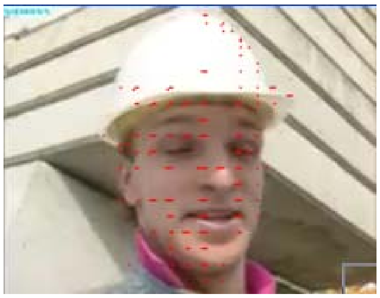

Figure 1. the sketch map of motion vectors

Motion vector can be described as:

$$MV(i) = (H[i],\ V[i])$$

Where, H[i] is the horizontal coordinate of the ith motion vector and V[i] is the vertical coordinate of the ith motion vector.

Motion vector indicate the position of the best matching macroblock relative to the current macroblock which is being encoded. In order to get the best matching macroblock, many search arithmetic are used such as full search, EPZS, UMHexagonS etc.

In search arithmetic, we can restrict the search range in order to embed watermarks. Figure 2 is an example that search range is divided into two regions. In figure 2, the address of the current macroblock is 27. When the current macroblock searches its best matching macroblock, region I or region II, not the entire image, is searched.

Figure 2. Example of dividing regions of motion vectors

Unlike [10], mode selection is taken into account to embedding watermarks. We suppose that the motion direction of this macroblock is left. In other words, this macroblock is moving to region I.

$$\begin{cases} \text{inter mode MV(i)} \in \text{I}, & \text{mark[j]} = 1 \\ \text{inter mode MV(i)} \in \text{II} & \\ \quad \text{or} \quad \text{intra mode}, & \text{mark[j]} = 0 \end{cases} \tag{1}$$

Where, mark[j] is the jth watermark. MV(i) is the motion vector of the ith macroblock in which the watermark will be embedded. Equation (1) indicates that if we want to embed a binary digit--0, the macroblock can be encoded by inter mode and the motion vector of it must in region II, or this macroblock can be encoded by intra mode. The Lagrangian cost, J, is used to decide the encoding mode.

$$J = Distortion + \lambda_{MODE} * Rate \tag{2}$$

Where, λ_{MODE} is the Lagrangian multiplier. It can be calculated by (3) and (4) Distortion and Rate are both measurement.

$$\lambda_{MODE,I,P} = 0.85 \times 2^{(QP-12)/3} \tag{3}$$

$$\lambda_{MODE,B} = \max(2, \min(4, \frac{QP-12}{6})) \times \lambda_{MODE,I,P} \tag{4}$$

Where, Equation (3) is used for Intra mode and P slice inter mode and Equation (4) is used for B silice. QP is the macroblock quantization parameter.

λ_{MOTION} is used in computing the motion vector in P or B slices. The motion vector cost is computed by:

$$J = Distortion + \lambda_{MOTION} * Rate \tag{5}$$

Where, λ_{MOTION} is calculated by:

$$\lambda_{MOTION} = \sqrt{\lambda_{MODE}} \tag{6}$$

Equation (6) is used when Distortion is computed using SAD(Sum of absolute differences).

In JM(joint model) implementation, Distortion is calculated by SAD. So the Lagrangian cost can be calculated by:

$$J(m, \lambda_{MOTION}) = SAD(s, c(m)) + \lambda_{MOTION} \bullet R(m-p) \tag{7}$$

With m being the motion vector, p being the prediction for the motion vector, and λ_{MOTION} being the Lagrange multiplier.

SAD is computed as:

$$SAD(s, c(m)) = \sum_{x=1}^{M} \sum_{y=1}^{N} | s(x,y) - c(x - m_x, y - m_y) | \tag{8}$$

With **s** being the original video block. **c** is the predicted video block at the position designated by **m** in the reference picture considered.

In order to embed watermark, the steps are described as following:

a) Based on the motion vector of the first P frame, get the predictive motion direction of the macroblock which is used to embed watermark.

b) Confirm the search range of the current macroblock based on (1).

c) If the search range is the same as the predictive motion direction, the best matching macroblock is searched in the search range. Then go to g).

d) If the search range is not same as the predictive motion direction, calculate the Lagrangian cost of the inter mode.

e) Calculate the Lagrangian cost of the intra mode.

f) Based on the cost of d) and e), decide the encoding mode of current macroblock.

g) Go to next macroblock.

B. Retrieving steps

According to the watermark embedding scheme, retrieving watermark is inverse. Watermark can be retrieved by:

$$mark[j] = \begin{cases} 1, \text{when inter mode MV(i)} \in \text{I} \\ 0, \text{when inter mode MV(i)} \in \text{II} \\ \qquad \text{or} \quad \text{intra mode,} \end{cases} \tag{9}$$

From (9), we find that retrieving watermark is very easy and convenient. The steps is as following:

a) Get the encoding information of the macroblock.

b) If the macroblock is encoded by intra mode, get the watermark by (1) and go to e).

c) If the macroblock is encoded by inter mode, get the motion vector of it.

d) Based on the region of the motion vector, Get the watermark by (1).

e) go to next macroblock.

III. EXPERIMENTAL RESULTS

In our experiment, three H.264 test video sequences can be seen in Figure 3. The motion speed of these three video sequences is different. The motion speed of akiyo is slow. The motion speed of foreman sequence is medial. The motion speed of mobile is much higher than first two.

Foreman sequence

Akiyo sequence

Mobile sequence

Figure 3. test video sequence

H.264 JM software is used to test our video watermarking scheme. JM can be free download from [11]. The parameter of JM can refer to [12]. TABLE I shows the parameters we set in testing our scheme.

TABLE I. PARAMETER OF TEST ENVIRONMENT

Profile	**baseline**
YUV	4:2:0
Sequence type	IPPP
Chromatic format	4:2:0
Image size	QCIF
Number of reference	5
Motion estimation	Full search

The test watermarking image can be seen in Figure 4. It is a binary image of 64 bits.

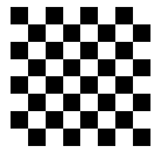

Figure 4. watermarking image for test

A. validity test

In this test, foreman sequence was used to test our scheme. First, the watermarking image was embedded into foreman sequence. Then tool, Elecard StreamEye, was used to get every motion vector of macroblock which watermark was embedded in. From this test, the change of motion vectors would be seen clearly.

The first 8 bits in watermarking image were embedded in foreman sequence. In another word, the watermark is 10101010. And the address of macroblock which watermarks were embedded in was 7. Result can be seen in TABLE II.

TABLE II. THE RESULT OF VALIDITY TEST

Frame	**Original motion vector**	**Watermarked motion vector**	**Watermark retrieved**
1	***(19,20)***	***inter(-3,-1)***	***1***
2	***(-2,-1)***	***inter(16,16)***	***0***
3	***(-1, 0)***	***inter(-6,-5)***	***1***
4	***(-1,-1)***	***intra***	***0***
5	***(2, 1)***	***inter(-2,-1)***	***1***
6	***(-1 ,0)***	***inter(1, 2)***	***0***
7	***(-3,-2)***	***inter(-5,-4)***	***1***
8	***(-11,-8)***	***inter(1, 2)***	***0***

From TABLE II, we found that after embedding watermarks, the regions of motion vectors and the encoding mode of the macroblocks were changed by our principle. The watermarks were accurately retrieved. The 4th frame used intra mode to encode the macroblock which the watermark embedded in because the cost of intra mode was less than that of inter mode.

B. *test of video quality and bit rate*

From this test, we will find how the video quality changes, including the personal quality and impersonal quality, and how the bit rate changes.

In this test, we will embed the test image into three test video sequence of 65 frames. In every frame of video sequence, one bit watermark is embedded. The address of macroblock which watermarks embed in is described in TABLE III:

TABLE III. The macroblock address in whichwatermarks embedded

Video sequence	address
Foreman	***7***
Akiyo	***38***
Mobile	***84***

TABLE IV. The result of impersonal video quality

Video sequence	Y PSNR		U PSNR		V PSNR	
	org	***wat***	***org***	***wat***	***org***	***wat***
foreman	***35.96***	***35.99***	***40.45***	***40.48***	***41.77***	***41.76***
akiyo	***38.13***	***38.13***	***40.83***	***40.81***	***41.86***	***41.87***
mobile	***33.08***	***33.09***	***35.42***	***35.43***	***34.89***	***34.88***

Org: original; wat: watermarked.,

From TABLE IV, we found that after embedding watermarks, the PSNR was almost the same as the original.

TABLE V. The result of total bits

Video sequence	Total bits		Bit rate changed （%）
	original	***watermarked***	
foreman	***324512***	***325112***	***+0.1%***
akiyo	***71344***	***72048***	***+0.98%***
mobile	***1039464***	***1046976***	***+0.7%***

From TABLE V, we found that the increase of bit rate was less than 1% in all three video sequences.

TABLE VI. The result of personal test

Original	**watermarked**
	
	
	

In TABLE VI, the panes in the images were the positions which the watermarks embedded in.

From TABLE VI, it was so difficult for us to see any different between the original video sequence and the watermarked video stream.

IV. CONCLUSION

In this paper, a video watermarking scheme based on motion vectors and mode selection is proposed. The experimental results indicate that the video quality is almost the same as that of the original and it is so difficult for us to see any different between the original video sequence and the watermarked video streams. Above all, the increase of bit rate is less than 1%, which keeps the high video compression rate of H.264. As compared with hiding watermarking information only using the region information of motion vectors, the scheme in this paper can decrease the bit rate of the video stream in some cases. By this token, the video watermarking scheme based on motion vectors and mode selection has some good performance. But there is still some work to do on doing more tests, the combination scheme with other video watermarking techniques and enhancing the robustness.

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