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Multilevel Reversible Video Watermarking with Improvement on Occluded Areas

İbrahim Yıldırım*[1]

ABSTRACT

In this paper, affect of occlusion for reversible video watermarking algorithms is focused in a multilevel concept. Motion compensated prediction error become higher between video frames which include occlusion areas. Thus, watermarking algorithm which exploits prediction error has small embedding capacity and poor image quality. In order to get maximum efficiency in a motion compensated video watermarking, occlusion detection algorithms should be taken into consider. In this study, a multilevel reversible video watermarking algorithm exploits histogram modification and occlusion detection algorithms has been proposed. Our method has better visual quality and embedding capacity.

Keywords: Occlusion Detection, Reversible Video Watermarking, Video Watermarking, Data Hiding, Motion Estimation

1. INTRODUCTION

Since the developments in internet and digital multimedia technologies, distribution of multimedia data has become easier and faster. Therefore, copyright protection of multimedia content has become critical for the rights of content providers and owners against illegal copying and publishing. As a solution, embedding secret data into the digital media content can be proposed. This operation is generally referred to as digital watermarking [1].

The modifications in the original signal may be irreversible while extracting secret data and reconstruction of the original data. Thus, the original media can not be reconstructed without distortions from the watermarked signal. In military and medical aplications whose data is very critical, distortion on the original signal can not be ignored. Reversible watermarking which provides lossless recovery of original and secret data may be a good solution in such critical applications. In this study, a new reversible video watermarking technique has been proposed.

A video signal consists of consecutive images. Therefore, video watermarking methods frequently take advantage of the principles developed for image watermarking. Correlation exists among images in a given temporal neighborhood in a video sequence. This correlation can be exploited to develop efficient video watermarking algorithms by employing image watermarking techniques. It is important, then, to comprehend the idea behind the reversible image watermarking approaches if one wishes to develop a reversible video watermarking algorithm.

There are several reversible image watermarking techniques in the literature. Difference Expansion

* Corresponding Author
[1] Sakarya University, ibrahimxyildirim@gmail.com

(DE) technique is based on embedding the watermark to the difference between adjacent pixels of the original iamge [2]. The DE method was extended by using the prediction error of neighboring pixels in [3]. Reversible data hiding algorithm based on histogram modification (HM) which has better embedding capacity and visual quality was presented in [4]. Embedding capacity of the HM method was improved by employing the correlation between neighboring pixels in [5]. In [6], HM algorithm was applied to the interpolation errors of neighboring pixels.

Compared to the image case, there exist limited studies for reversible video watermarking. Prediction error between consecutive frames is utilized in [7] and [8] while interpolation error is used in [9]. A new data hiding method called recursive histogram modification is applied on video sequences in [10]. Chung et al. applied the HM on video sequences also exploit the correlation between adjacent frames [11]. The method ignores the prediction errors resulting from incorrect motion estimation on occluded areas. Consequently, its embedding capacity is low and the watermarked image it gives has poor visual quality especially on occluded regions. The magnitude of the prediction error determines both capacity and distortion made to the original image. Hence, if we can reduce the prediction error, the performance of the HM will be higher.

In this paper, a new reversible video watermarking algorithm avoiding huge prediction errors on occluded areas is poroposed. Proposed method has better embedding capacity and visual quality than algorithm in [11]. This superiority is shown with computer simulations. Occluded areas are determined by using the occlusion detection algorithm proposed in [12]. Conventional motion estimation techniques which uses unidirectional block matching algorithms lead to high prediction errors on occluded areas. Proposed watermarking algorithm uses a bidirectional motion estimation method to obtain smaller prediction errors and increase performance of the HM in occluded areas.

This paper is organized as follows. In Section II, reversible video watermarking method developed in [11] is summarized for the sake of completeness. The proposed reversible video watermarking algorithm is presented in section III. Simulation results are given in section IV to demonstrate the visual quality and embedding capacity. Finally, conclusions are drawn in Section V.

2. RELATED STUDY

In [11], HM algorithm which is developed for images is applied to the motion compensated prediction error blocks between adjacent frames in a video sequence. In this section we briefly explain this method.

2.1. Motion Compensated Prediction Error Between Video Frames

For the sake of easy understandable, Let I_k represents the k-th image frame of the video sequence and the gray scale value of the pixel located at position (x,y) is denoted by $I_k(x,y)$. According to the block matching algorithm, I_k is divided into a set of $n \times n$ blocks. Each block can be represented by $B_{j,k}$. For each block $B_{j,k}$ in I_k, block matching algorithm is carried out to determine its best matched block $MB_{j,k+1}$, which is in I_{k+1}. $MB_{j,k+1}$ can be written as,

$$MB_{j,k+1}(x,y) = I_{k+1}(x + x_{j,c} + Vx_j\,,\; y + y_{j,c} + Vy_j) \quad (1)$$

In (1), $(x_{j,c}, y_{j,c})$ is the coordinate of up-left corner of $B_{j,k}$, Vx_j and Vy_j form the motion vector of $B_{j,k}$. Block matching method is illustrated in Figure1.

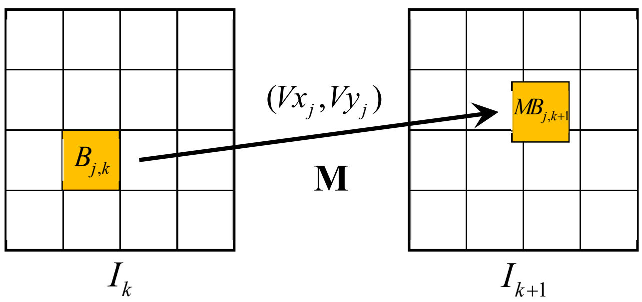

Figure 1. Motion estimation (ME) between video frames.

Motion compensated prediction error block $PE_{j,k}$ can be obtained by (2).

$$PE_{j,k}(x,y) = |B_{j,k}(x,y) - MB_{j,k+1}(x,y)|,\quad (x,y) \in \{0,1,\dots,n-1\} \quad (2)$$

Reversible data embedding algorithms, proposed for images, can be applied to motion compensated prediction errors between video frames. This approach improves the embedding capacity and visual quality of embedding algorithm by employing the correlation between video sequences. But, conventional motion estimation techniques get higher prediction errors in occluded areas.

Occlusion can be defined as the appearance of new objects and disappearance of existing objects in a video frame. Conventional unidirectional motion estimation techniques estimate wrong motion vectors in occluded areas giving rise to high motion compensated prediction errors at those regions. Therefore, any data hiding method using prediction error perform inefficient in occluded regions. In this paper, we developed a new data hiding method which has better performance in occluded areas.

3. PROPOSED METHOD

Occluded areas between video frames should be detected first to improve the prediction error of motion estimation technique. Occlusion Detection (OD) is itself a main research topic about which there exist approaches. A through review of OD algorithms is beyond the scope of this study. Instead, we briefly discuss the OD algorithm in [12] that we used in this study.

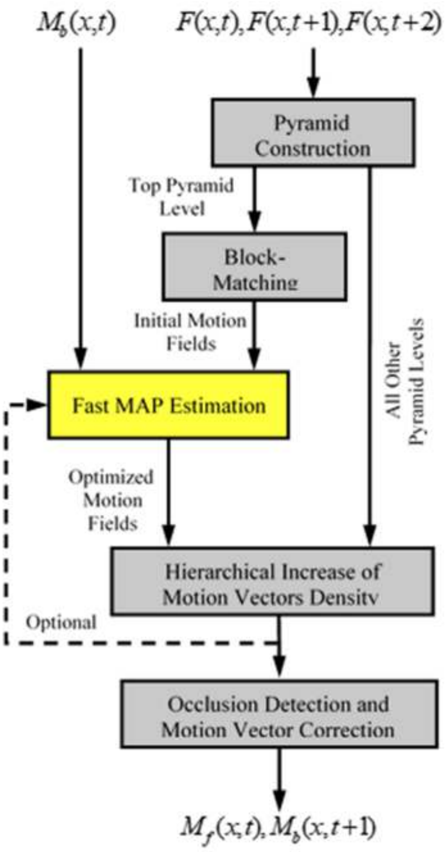

Figure 2. Occlusion detection algorithm.

3.1. Occlusion Detection Algorithm

A new motion estimation algorithm which has better performance in occluded areas was developed in [12]. This method exploits the maximum a posteriori probability (MAP) estimation and hierarchical block-matching algorithm (HBMA). Figure 2 illustrates the occlusion detection based motion estimation algorithm used in our data hiding algorithm.

MAP estimation exploits four frames while obtaining the motion in occluded areas. It uses three consecutive frames and one previously estimated motion field. Let $F(x,t)$, $F(x,t+1)$ and $F(x,t+2)$ denote the three consecutive frames and $M_b(x,t)$ denote the previously estimated motion field as shown in Figure 3. This algorithm exploits the forward motion vector $M_f(x,t)$ and backward motion vector $M_b(x,t+1)$ together. In occluded areas, motion in forward and backward manner will be different because appearance and disappearance of objects are observed only in one of the two frames $F(x,t)$ and $F(x,t+1)$. Using more frames in forward and backward manner will provide a more reliable estimate in occluded areas.

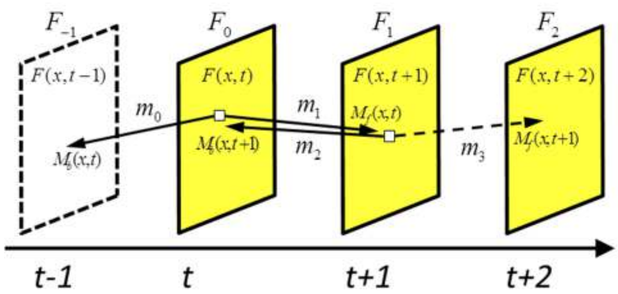

Figure 3. Three frames and one previously estimated motion vector are used to find $M_f(x,t)$ and $M_b(x,t+1)$.

The OD algorithm described in [12] is used to determine occlusion between video frames. In occluded areas, a decision is made about using the backward or forward motion vectors for motion compensation according to their prediction errors. If the backward motion compensated prediction error (MCPE) is smaller than the forward MCPE, the backward motion vector and MCPE are used in the watermarking process. The information about occluded blocks is stored in a binary occlusion map (OMAP). Otherwise, the forward motion vector and MCPE are utilized in the watermark embedding and decoding. These smaller prediction errors can be used to develop a new video watermarking method. In this way, the effect of occlusion is minimized.

In this work, we generated an occlusion map by using occlusion detection method proposed in [12]. Occlusion map can be expressed like (3).

$$OMAP = \begin{cases} 1 & \text{is occluded} \\ 0 & \text{other} \end{cases} \quad (3)$$

Proposed method customizes the occlusion map to define whether prediction error of backward motion vector is smaller or not. Occlusion map used in this work is described in (4).

$$OMAP = \begin{cases} 1 & \text{is occluded and } P_B < P_F \\ 0 & \text{other} \end{cases} \quad (4)$$

In (4), P_B and P_F denotes the prediction error of backward and forward motion vectors respectively. Figure 4 shows the backward and forward motion estimation.

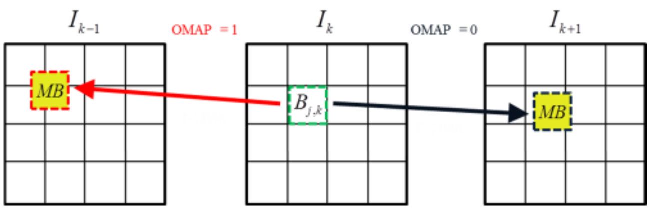

Figure 4. Forward and backward motion vector.

3.2. Data Embedding in Motion Compensated Prediction Errors

Obtained occlusion map can be used to determine best matched block of any block in anchor frame. Best matched block $MB_{j,k+1}$ can be obtained by (5).

$$MB_{j,k+1}(x,y) = \begin{cases} I_{k+1}(x + x_{j,c} + Vx_j, \; y + y_{j,c} + Vy_j) & OMAP(x_{j,c}, y_{j,c}) = 0 \\ I_{k-1}(x + x_{j,c} + Vx_j, \; y + y_{j,c} + Vy_j) & OMAP(x_{j,c}, y_{j,c}) = 1 \end{cases} \quad (5)$$

Absolute difference blocks between $B_{j,k}$ and $MB_{j,k+1}$ can be generated by (2). After generating all of the prediction errors, HM technique can be applied to all the difference blocks using (6).

$$WPE_{j,k}(x,y) = \begin{cases} PE_{j,k}(x,y) + 1, & PE_{j,k}(x,y) > P_{j,k} \\ PE_{j,k}(x,y) + h, & PE_{j,k}(x,y) = P_{j,k} \\ PE_{j,k}(x,y), & Other \end{cases} \quad (6)$$

In (6), $h \in \{0,1\}$ and $P_{j,k}$ denote the hidden bit and peak value of histogram respectively. Watermarked frame can be generated by reversing the procedures described above.

Watermarking Algorithm:

For a given video sequence, watermarking consists of the following five steps:

- **i.** k=2.
- **ii.** Obtain $MB_{j,k+1}$ for each block $B_{j,k}$ in I_k by (5). Then absolute difference block between $B_{j,k}$ and $MB_{j,k+1}$ can be generated by (2).
- **iii.** For each absolute difference block $PE_{j,k}$, HM technique can be employed by (6).
- **iv.** Modified prediction error block $WPE_{j,k}$, best matched block $MB_{j,k+1}$ and $B_{j,k}$ can be used to generate watermarked block $W_{j,k}$ by (7). After all prediction error blocks are modified, watermarked image frame W_k can be obtained.

$$W_{j,k}(x,y) = \begin{cases} B_{j,k+1}(x,y) + WPE_{j,k}(x,y) & B_{j,k+1}(x,y) \geq MB_j \\ B_{j,k+1}(x,y) - WPE_{j,k}(x,y) & other \end{cases} \quad (7)$$

- **v.** k=k+1 and go to step 2.

In this method, motion vectors, peak values of each block and occlusion map required for extraction process should be added to overhead information. For overflow/underflow problem, values and coordinates of related pixels should be added to overhead information.

Extraction Algorithm:

For a given video sequence, extraction consists of the following seven steps:

- **i.** Peak values, motion vectors and occlusion map are obtained from overhead information. Extraction process starts from last frame, $k = n - 1$.

ii. Watermarked frame W_k is divided into a set of the blocks, each with size $n \times n$. Next, for each block $W_{j,k}$ in watermarked frame, using motion vectors obtained from overhead information, best matched block $MB_{j,k+1}$ can be generated by (8).

$$MB_{j,k+1}(x,y) = \begin{cases} W_{k-1}(x + x_{j,c} + Vx_j, \\ \quad y + y_{j,c} + Vy_j) & OMAP(x_{j,c}, y_{j,c}) = 1 \\ I_{k+1}(x + x_{j,c} + Vx_j, \\ \quad y + y_{j,c} + Vy_j) & OMAP(x_{j,c}, y_{j,c}) = 0 \end{cases} \quad (8)$$

Then watermarked absolute difference blocks can be obtained by (9).

$$WPE_{j,k}(x,y) = |W_{j,k}(x,y) - MB_{j,k+1}(x,y)|, \quad (x,y) \in \{0,1,\dots,n-1\} \quad (9)$$

iii. Embedded watermark can be extracted by (10) with the help of P_j^k peak values.

$$h = \begin{cases} 1 & WPE_{j,k}(x,y) = P_{j,k} + 1 \\ 0 & WPE_{j,k}(x,y) = P_{j,k} \end{cases} \quad x,y \in \{0,1,\dots,n-1\} \quad (10)$$

iv. Original difference block can be obtained by (11).

$$PE_{j,k}(x,y) = \begin{cases} WPE_{j,k}(x,y) - 1 & WPE_{j,k}(x,y) \geq P_{j,k} + 1 \\ WPE_{j,k}(x,y) & other \end{cases} \quad (11)$$

v. Extracted original block can be generated by (12).

$$R_{j,k}(x,y) = \begin{cases} T_{j,k}(x,y) + PE_{j,k}(x,y) & W_{j,k}(x,y) \geq T_{j,k}(x,y) \\ T_{j,k}(x,y) - PE_{j,k}(x,y) & other \end{cases} \quad (12)$$

$$T_{j,k} = \begin{cases} W_{j,k-1} & OMAP(x_{j,c}, y_{j,c}) = 1 \\ I_{j,k+1} & OMAP(x_{j,c}, y_{j,c}) = 0 \end{cases}$$

vi. k=k-1.

vii. Go to step 2 if k>1

Since our proposed video watermarking algorithm is reversible, a watermarked video sequence could be re-watermarked. Based on multilevel concept, this algorithm can be performed to watermarked images iteratively.

4. EXPERIMENTAL RESULTS

The proposed video watermarking algorithm has been performed on two most popular test video sequences, "bus" and "mother and daughter". Figure 3 illustrates the first image frames of two test video sequences. Results have been compared with the method proposed by Chung et al. [11]. Algorithms are applied to each video sequence which includes ten frames sized 288x352. PSNR and BPP measures are used to evaluate the performance of the two video watermarking algorithms. PSNR and BPP measures can be obtained by (13).

$$PSNR = 10 \log_{10} \frac{255^2}{MSE}$$
$$BPP = \frac{Embedded\ Bit\ Count}{N \times W \times H} \quad (13)$$

In (13), N, W, H denote the frame count, frame width and frame height respectively.

Figure 4 and Figure 5 illustrate the average PSNR of watermarked video sequences obtained by running two concerned methods five rounds. Simulation results confirm that proposed algorithm has better image quality performance compared with [11]. Since "mother and daughter" video sequence has less occluded area than "bus" sequence, improvement of the proposed method is less than it is in "bus" sequence in "mother and daughter" sequence.

Table 1. Embedding Capacity For Bus Sequence

"BUS"	Level-1	Level-2	Level-3	Level-4	Level-5
Chung et al.	0.2227	0.4064	0.5666	0.7123	0.8470
Proposed	0.2249	0.4076	0.5682	0.7138	0.8490

(a) (b)

Figure 3. First frames of test video sequences.

Tables 1 and 2 demonstrate the payload performance of two concerned methods in terms of BPP at five embedding levels. Although our proposed method has higher image quality, in "mother and daughter " video sequence which has less occluded area, embedding capacity of our proposed method could be almost equal to Chung et al. [11]'s.

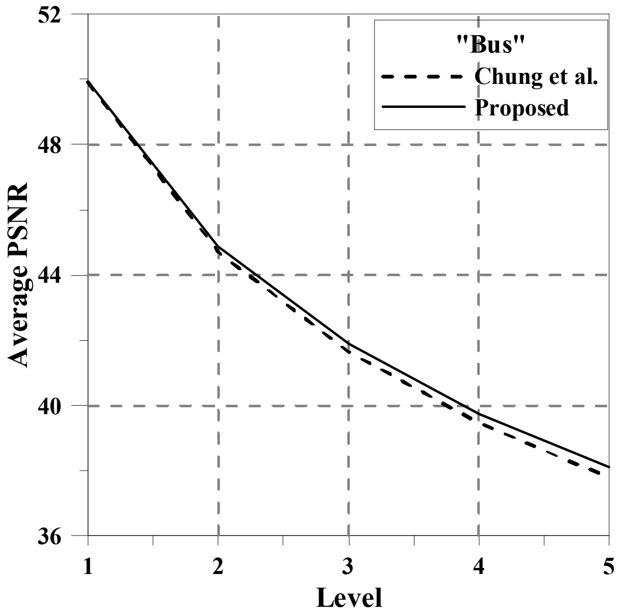

Figure 4. Average PSNR for "Bus" sequence.

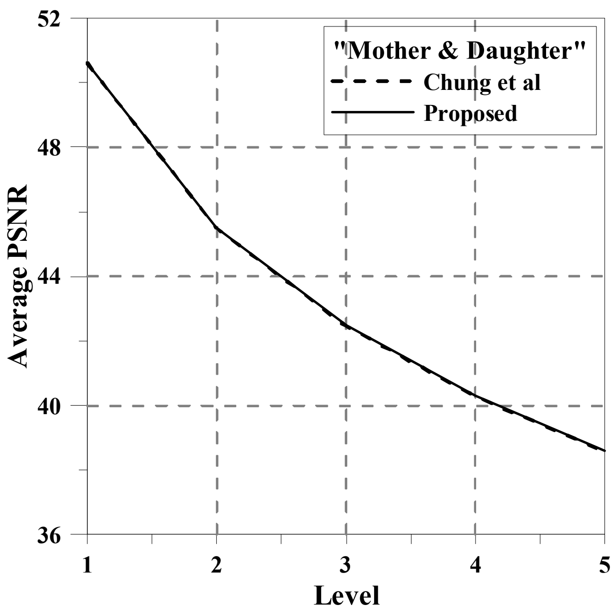

Figure 5. Average PSNR for "Mother and Daughter" sequence.

Table 2. Embedding Capacity For Mother & Daughter Sequence

"Mother& Daughter"	Level-1	Level-2	Level-3	Level-4	Level-5
Chung et al.	0.4281	0.7614	1.0400	1.2814	1.4945
Proposed	0.4281	0.7609	1.0397	1.2804	1.4932

5. CONCLUSION

In this paper, we proposed a new multilevel reversible video watermarking method which has better performance in occluded areas. In a given video sequence, occluded areas should be determined by using occlusion detection algorithm. Next, in this occluded areas, we can choose smaller prediction error from backward and forward motion vectors to embed watermark. Obtained prediction errors are watermarked by Histogram Modification method. Simulation results show that the proposed method gives better performance in occluded areas.

REFERENCES

[1] G. Langelaar, I. Setyawan and R. Lagendijk, "Watermarking digital image and video data: a state-of-the-art overview," IEEE Signal Processing Magazine, vol. 17, pp. 20–46, Sept. 2000.

[2] J. Tian, "Reversible data embedding using a difference expansion," IEEE Transactions on Circuits and Systems for Video Technology, vol. 13, no. 8, pp. 890–896, Aug. 2003.

[3] Y. Hu, H. K. Lee and J. Li, "DE-based reversible data hiding with improved overflow location map", IEEE Transactions on Circuits and Systems for Video Technology, vol. 19, no. 2, pp. 250–260, Feb. 2009.

[4] Z. Ni, Y.Q. Shi, N. Ansari and W. Su, "Reversible Data Hiding", IEEE Transactions on Circuits and Systems for Video Technology, vol. 16, no. 3, pp. 354-362, Mar. 2006.

[5] W.L. Tai, C. M. Yeh and C. C. Chang, "Reversible data hiding based on histogram modification of pixel differences", IEEE Transactions on Circuits and Systems for

Video Technology, vol. 19, no. 6, pp. 906–910, June 2009.

[6] B. Baraklı, İ. Yıldırım and C. Yüzkollar, "Aradeğerleme Hatalarının Histogram Değiştirilmesine Dayalı Tersinir Görüntü Damgalama", Düzce Üniversitesi Bilim ve Teknoloji Dergisi, vol. 1, no. 1, pp. 58-68, 2013.

[7] İ. Yıldırım and C. Vural, "Reversible video watermarking based on histogram modification of motion compansated prediction error", Signal Processing and Communications Applications Conference (SIU), 2012 20th.

[8] C. Vural and B. Baraklı, "Adaptive reversible video watermarking based on motion-compensated prediction error expansion with pixel selection", Signal, Image and Video Processing, vol. 10, no. 7, pp. 1225-1232, 2016.

[9] C. Vural and B. Baraklı, "Reversible video watermarking using motion-compensated frame interpolation error expansion", Signal, Image and Video Processing, vol. 9, no. 7, pp. 1613-1623, 2015.

[10] C. Vural and İ. Yıldırım, "Reversible video watermarking through recursive histogram modification", Multimedia Tools and Applications, vol. 76, no. 14, pp. 15513-15534, 2017.

[11] K. L. Chung, W. J. Yang, T.C. Chang and H. Y. M. Liao, "Efficient multilevel reversible data hiding for video sequences using temporal and spatial approach", Proceedings of 2009 APSIPA Annual Summit and Conference, Sapporo, Japan, Oct. 4-7, 2009.

[12] D. Wang, L. Zhang, A. Vincent, "Motion-compansated frame rate up-conversion—Part I: Fast multi-frame motion estimation", IEEE Transactions on Broadcasting, vol. 56, no. 2, pp. 133-141, June 2010.