DIRECT MODE CODING FOR B PICTURES USING VIRTUAL REFERENCE PICTURE

Da Liu[1], Debin Zhao[1], Jun Sun[2], Wen Gao[2]
[1]Department of Computer Science, Harbin Institute of Technology, Harbin 150001, China
[2] Institute of Digital Media, Peking University, Beijing 100080, China

ABSTRACT

The direct mode used in the bi-predictive pictures (B-pictures) can efficiently improve the coding performance of B pictures, because it has small overhead and obtains a predictive picture from two reference pictures. The traditional temporal direct mode (TDM) derives the motion vector of the current block by scaling the motion vector of the co-located block in the backward reference picture. However, when the current block and its co-located block in backward reference picture belong to different objects with different motion directions, the prediction efficiency of TDM is drastically reduced. In this paper, we propose an improved direct mode prediction method. In the method, a virtual reference picture is generated using the pixel projection technique. Then the virtual reference picture is used to predict the direct mode blocks in B pictures. The proposed method can enhance the prediction performance of the direct mode blocks and achieve a higher coding efficiency.

1. INTRODUCTION

Bi-directional prediction used for bi-predictive pictures (B-pictures) is a very efficient tool to improve coding efficiency. But a considerably higher percentage of bits are needed for encoding motion information. It causes the problem that the coding efficiency is decreased even if the prediction efficiency is improved. In the H.264, H.263 and MPEG-4 [1][2][3] video coding standards, the direct mode has been proposed to solve this problem. In the temporal direct mode (TDM), two motion vectors for bidirectional prediction are computed using the time continuity of motion. The direct mode does not need bits for the motion vectors, therefore, the overhead is quite small. And direct mode prediction generates a predictive image from the forward and the backward reference pictures, which leads to even further performance benefit.

In TDM of B-pictures, the forward and backward motion vectors are derived from the motion vector used in the co-located block of the backward reference picture [4], as shown in Fig.1. The forward motion vector MV_F and backward motion vector MV_B of direct mode block were originally calculated as follows:

$$MV_F = (tb/td) \times MV_C \quad (1)$$

$$MV_B = ((tb - td)/td) \times MV_C \quad (2)$$

but were later replaced with equations:

$$X = 16384 + abs(td/2)/td \quad (3)$$

$$ScaleFactor = clip(-1024, 1023, (tb \times X + 32) >> 6) \quad (4)$$

$$MV_F = (ScaleFactor \times MV_C + 128) >> 8 \quad (5)$$

$$MV_B = MV_F - MV_C \quad (6)$$

where MV_C represents the motion vector of the co-located block in the backward reference picture, td is the temporal distance between the backward reference frame RL_1 and forward reference picture RL_0, and tb is the temporal distance between the current B frame and the forward reference frame RL_0. Variables X and $ScaleFactor$ are pre-computed at the slice or picture level to reduce the number of divisions required [5].

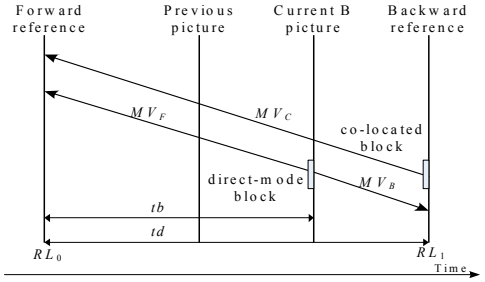

Fig.1. Temporal direct mode used in H.264/AVC

TDM can efficiently exploit the temporal redundancy between adjacent pictures. However, the current block is not always located in the motion trajectory of its co-located block, particularly when the current block and its co-located block in backward reference picture belong to different objects with different motion directions. In order to improve the motion vector accuracy of direct mode block, Xiangyang Ji [6] proposed a motion vector tracking scheme in B pictures. As shown in Fig. 2, block M_{t+1} in the backward reference picture P_{t+1} has in its motion vector MV_{t+1} projecting to block M_{t-1}, which is the reference block of block M_{t+1} in the forward reference picture P_{t-1}. M_t is the projection block of M_{t+1} in the B picture. For every block M_{t+1} in the backward reference picture, there is always a projection block M_t in the B picture. The motion vector of the block M_t which covers the largest part of the block M_C in current B picture is selected to derivate the forward and backward motion vector of block M_C.

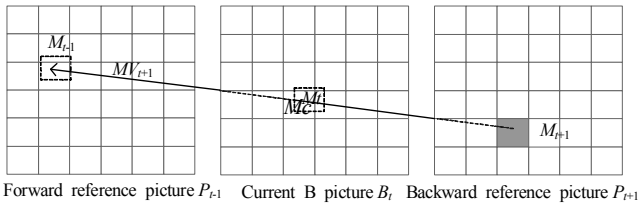

Fig.2. Motion vector tracking (the basic block size in the picture is 4×4)

The scheme in [6] can bring more accurate motion vector for direct mode block M_C in B picture. But sometimes the block M_C is consisted of more than one moving object. When the different moving objects in the block M_C have different motion vectors, it is not accurate to derive the forward and backward motion vectors of block M_c only by the motion vector of block M_t, which is projected from block M_{t+1}.

In this paper, we propose a virtual reference picture, which is located in the same temporal position as current B picture. And we present a pixel projection algorithm to generate the virtual reference picture using the temporally subsequent and previous predictively-coded pictures (P pictures). The virtual reference picture is used to predict the direct mode block in B pictures to bring better prediction performance.

The rest of the paper is organized as follows: section 2 describes the formation of the virtual reference picture and its utilization to obtain direct mode blocks in B pictures. The simulated results are presented in section 3. Finally, section 4 concludes this paper.

2. VIRTUAL REFERENCE PICTURE FOR DIRECT MODE CODING

2.1. The location of the virtual reference picture

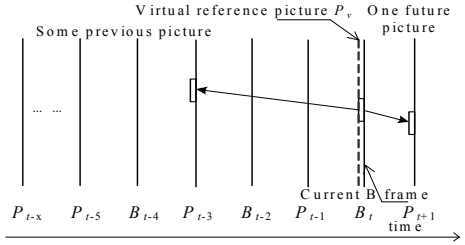

Fig.3. Multiple reference pictures used in H.264

The H.264 standard has adopted multiple reference pictures to predict the values in B picture [7]. Fig. 3 illustrates the basic idea of multiple reference pictures, some previous and one future P (or I) picture in display order are used for B picture prediction. Excepting the existing reference pictures, a virtual reference picture is proposed by us. The virtual reference picture exists in a virtual formation and is only used to predict the direct mode blocks in the B picture. As shown in Fig. 3, the dotted line is the virtual reference picture P_v. The temporal position of the virtual reference picture P_v is the same as that of the current B picture. Only the integer pixel values are stored in the virtual reference picture, so the size of the virtual reference picture is the same as that of the other reference pictures.

2.2. The formation of the virtual reference picture

The virtual reference picture is formed after the coding of the temporally subsequent P picture P_{t+1}, and just before the coding of the current B picture. As shown in Fig.4, since the block M_{t+1} in the temporally subsequent P picture P_{t+1} has its motion vector MV_{t+1} pointing to the temporally previous P picture, and the virtual reference picture P_v is located in the same temporal position as current B picture B_t, there is an intersection block M_t between the virtual reference picture P_v and the projection block of M_{t+1}. After finding the projection block M_t in the virtual reference picture, the forward and backward motion vector of block M_t can be obtained by scaling the motion vector MV_{t+1}. Then the pixel values in the block M_t can be obtained by bi-prediction. The size of the block unit used for pixel projection in the temporally subsequent P picture P_{t+1} is different among different macroblocks. It is the same size as that of the motion compensation block. In 16×16 mode macroblocks, there is only one block used for pixel projection (such as block M_{t+1} in P picture P_{t+1}). In 8×8 mode macroblocks, there are four blocks used for pixel projection (such as block $\hat{M}$ in P picture P_{t+1}, its size is 8×8). In intra mode macroblocks, the whole macroblock is not used for pixel projection.

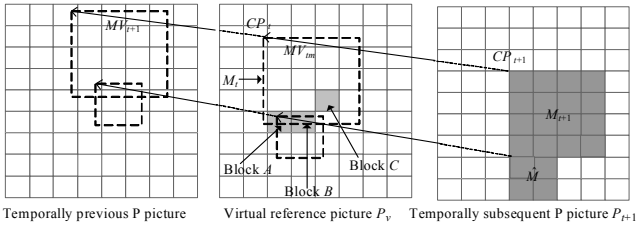

Fig.4. Pixel projection for virtual reference picture

In the pixel projection process, we generate the motion vector trajectory of projection from the up-left corner of each block M_{t+1} in the temporally subsequent P picture P_{t+1}, as shown in Fig.4. The position and motion vector of the projection block M_t in the virtual reference picture P_v is calculated as follows:

$$MV_t = ((td - tb)/td) \times MV_{t+1} \quad (7)$$

$$MV_{tm} = (MV_t >> 2) \times 4 \quad (8)$$

$$CP_t(x,y) = CP_{t+1}(x,y) + MV_{tm} \quad (9)$$

$$MVB_m = ((tb - td)/td) \times MV_{t+1} \quad (10)$$

$$MVF_m = MV_{t+1} + MVB_m \quad (11)$$

where td is the temporal distance between the subsequent P frame P_{t+1} and the previous P picture, tb is the temporal distance between the virtual reference picture P_v and the previous P picture, MV_{t+1} is the motion vector of the block M_{t+1} pointing to one block in the previous P picture. MV_t is the scaled motion vector of block M_{t+1}. MV_t is intended to point to the projection block in the virtual reference picture P_v. But the accuracy of MV_{t+1} and MV_t is in units of one quarter of the distance between luma samples [8], and the virtual reference picture only has integer pixel value, so MV_t is modified to MV_{tm} according to equation (8). Motion vector MV_{tm} points to the integer pixel projection block M_t in the virtual reference picture. $CP_{t+1}(x, y)$ denotes the up-left corner of the block M_{t+1}. $CP_t(x, y)$ is the up-left corner of the block M_t. The accuracy of $CP_{t+1}(x, y)$, $CP_t(x, y)$ and MV_{tm} is also in units of one quarter of the distance between luma samples. Block M_t is the same size as block M_{t+1}. MVF_m and MVB_m denote the forward and backward motion vectors of M_t respectively.

The virtual reference picture is divided in 4×4 blocks. After the pixel projection of every block in the temporally subsequent P picture P_{t+1}, for some 4×4 blocks in the virtual reference picture, not every pixel within it has a bidirectional predicted value (such as block A in picture P_v), because some pixels are not covered by projection block. For some 4×4 blocks in the virtual reference picture, some pixels within it have more than one bidirectional predicted value (such as block B in picture P_v), because it is covered by more than one projection block. We can deal with these cases as follows:

1) If every pixel in the 4×4 block has only one bidirectional predicted value (such as block C in picture P_v), the pixel values of the 4×4 block are set to the bidirectional predicted values.

2) If some pixels in the 4×4 block have more than one bidirectional predicted value, the pixel values are set to the last bidirectional predicted values in projection order.

3) If some pixels in the 4×4 block have no bidirectional predicted value, we derive all the pixel values of the 4×4 block by spatial motion vector prediction. The forward and backward motion vectors of the block are separately obtained by median prediction technique [9]. The motion vector of current block is the median of the three motion vectors from the left, the upper, and the upper-right blocks.

2.3. Obtaining direct mode block from virtual reference picture

For every B picture, there is a virtual reference picture in its same temporal position. The pixel values of virtual reference picture are obtained by bidirectional prediction just before the coding of the B picture. When coding the current B picture, for every direct mode block (the size of direct mode block is 16×16 in 16×16 mode macroblocks or 8×8 in 8×8 partitions type macroblocks), we can obtain its values using the co-located block in the virtual reference picture, as shown in Fig.5. For the other modes in the B picture, the coding method is unchanged.

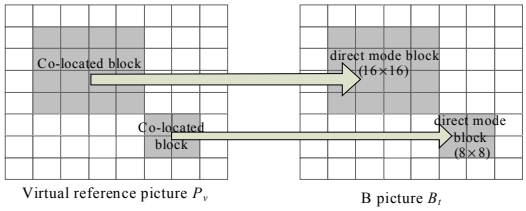

Fig.5. Adopting co-located block in the virtual reference picture as the direct mode block in current B picture

3. EXPERIMENTAL RESULTS

The proposed method is implemented based on the H.264/AVC reference software JM98 [10]. The test sequences with CIF format, including *foreman*, *tempete*, *bus*, *container* and *paris*, are 160 frames with the frame rate of 30fps. The main test conditions are shown in Table 1. To evaluate the average rate distortion performance, we employ the method described in [11].

The performance comparison of our method with TDM in H.264 is shown in Table 2. In our method, for sequences *foreman, tempete, bus, container* and *paris,* the bitrate reduction is separately 4.38%, 6.95%, 4.56%, 6.28% and 4.48%. The performance comparison of scheme [6] with TDM in H.264 is also shown in Table 2. It can be observed from the results that, for sequences with constant motion and sequences with irregular motion, the proposed method is always better than scheme [6].

Fig.6 shows that when the proposed virtual reference picture is used, the number of the blocks coded with direct mode in each B picture is always larger than that of scheme [6] and TDM in H.264, which proves that the virtual reference picture does bring better prediction performance for direct mode.

Table 1. Test conditions

Search Range	±16
MV resolution	1/4 pixel
Reference Frames	2
RD optimization	ON
Symbol Mode	CABAC
GOP structure	IBBPBBP
QP	24,28,32,36

Fig.7 shows the Rate Distortion curves of the proposed method in sequences *foreman* and *tempete* compared with TDM in H.264. We can observe that the benefits of the proposed method tend to increase at lower bitrates, which is to be expected considering that motion information at these bitrates tends to take an even larger percentage of the coded information.

In the proposed methods, all the pixel values of the virtual reference picture are obtained by bidirectional prediction along the motion vectors of moving objects in the temporally subsequent P picture. The pixel values of the virtual reference picture are closer to the actual pixel values in the B picture. Therefore, for every direct mode block in the B picture, especially the block which has different moving objects with different motion vectors, obtaining the direct mode block values from co-located block in the virtual reference picture can bring better prediction performance. The coded residual bits in the direct mode block is reduced, the coding efficiency of whole picture is enhanced.

As for the complexity, in the pixel projection process, our method needs to calculate the location of the projection block, and the size of the block unit used for pixel projection in the temporally subsequent P picture is in accordance with the size of the motion compensation block (from 16×16 to 4×4). The scheme [6] needs to calculate the location of the projected motion vector, and the size of the block unit used for motion vector tracking in the temporally subsequent P picture is 4×4. So the number of projection calculation in our scheme is less than that of [6]. Our method needs to read the pixel values from temporally previous P picture and temporally subsequent P picture to virtual reference picture, then read the pixel values from virtual reference picture to direct mode block in current B picture. One more read operation is needed in our scheme, but it is not too much time consuming. The virtual reference picture requires some increase of the memory. It can be used to predict the other block modes of the B picture in the future study.

4. CONCLUSION

When the current block and its co-located block in backward reference picture belong to different objects with different motion directions, or there is more than one moving object with different motion vectors in current block, the traditional TDM can not bring accurate motion vector for current block in B picture. To resolve this problem, this paper have proposed a virtual reference picture to predict the direct mode blocks in B pictures, and present a pixel projection technique to generate the virtual reference picture using the temporally previous and subsequent P pictures. Experimental results show that the proposed method can bring better coding efficiency than TDM scheme and motion tracking scheme [6]. In the next step, we will further study the utilization of the virtual reference picture to predict the other block modes in the B pictures.

5. ACKNOWLEDGEMENT

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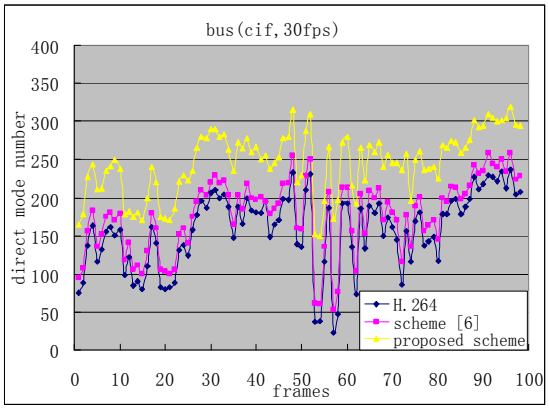
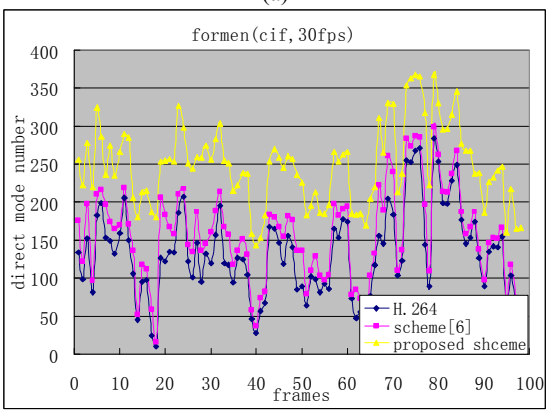
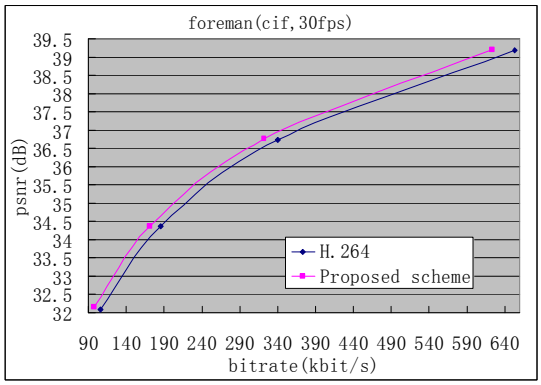


(a)

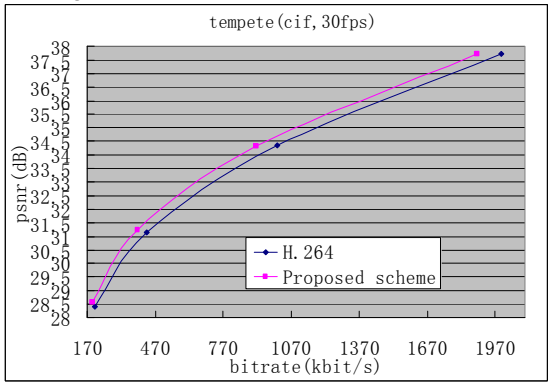


(b)

Fig.6. Number of blocks coded with direct mode in each B frame



(a)



(b)

Fig.7. Rate-distortion curves of proposed scheme for sequences *foreman* and *tempete* (compared with TDM in H.264)

Table 2. Performance evaluation of the proposed scheme and scheme [6] (compared with TDM in H.264)

Sequence		*Foreman*	*Tempete*	*Bus*	*Container*	*Paris*
Proposed scheme	**Ave PSNR gain**	0.267	0.372	0.281	0.346	0.283
	Ave BR saving	4.38%	6.95%	4.56%	6.28%	4.48%
Motion tracking scheme [6]	**Ave PSNR gain**	0.053	0.205	0.072	0.172	0.114
	Ave BR saving	0.89%	3.92%	1.09%	3.23%	1.81%