國立交通大學

資訊科學與工程研究所

碩 士 論 文

基於 H.264 視訊編碼在畫面略過轉換下之區塊模式決定與移動向量預測

Block Motion Decision and Motion Vector Composition in H.264 Video Frame skipping Transcoding

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中 華 民 國 九 十 七 年 十 月

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摘　要

近年來，許多應用如即時線上播放系統、視訊會議、手持式多媒體、網路媒體快速瀏覽等需求大量提升。使用者期望在有限的網路傳輸速率以及既有的硬體設備下，能夠接收高品質的視訊畫面；而系統開發者除了追求能將高畫質的視訊影片，能以較低的位元壓縮率傳輸外，尚能提供流暢地視訊快速播放閱覽的功能。

在這篇論文當中，我們提出了一個適用於H.264/AVC視訊壓縮編碼標準下，利用畫面省略的轉換編碼方式來降低傳輸位元大小以及所需的視訊壓縮時間。其中的議題包含在省略畫面的情形下如何解決區塊分割大小模式的決定、區塊移動向量計算方法。

由實驗的結果可知，我們所提出的方法相較於H.264/AVC畫面略過的壓縮以及其他方法，在維持一定的視訊品質之下，大量的縮減壓縮的時間，並亦能傳輸於在低位元傳輸率中。

關鍵字：畫面略過轉換、區塊模式決定、移動向量計算

Block Mode Decision and Motion Vector Composition in H.264 Video Frame Skipping Transcoding

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Abstract

In recent years, many multimedia applications such as real-time video streaming systems, videoconference, handheld media systems, and high-speed video browsing through networks are required. Users expect to receive high quality of video under limited network bandwidth and established hardware equipments. Oppositely, system providers pursue services of high video quality through low bit-rate transmission in order to reduce the cost and provide more services.

In this thesis, we focus on a frame-skipping transcoding methods to reduce the bit-rate for H.264/AVC video coding. We have proposed block mode decision methods, motion vector composition methods for frame-skipping transcoding.

Experimental results show that, compared with H.264/AVC and other algorithms, the proposed methods can save a lot of computational cost. The performance can be improved by maintaining visual quality at low bit-rate.

Keywords: frame skipping transcoding, mode decision, motion vector composition

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Chapter 1 Introduction

The video coding standard MPEG-4 Part10 AVC/H.264 [1] was developed by the joint video team (JVT) of ISO/IEC (MPEG) and ITU-T (VCEG). The video coding standard is based on traditional hybrid coding scheme but with several additional methods to attain high coding efficiency such as adaptive motion compensation with variable block sizes, multiple reference frames, intra coding with various spatial prediction directions, and so on. The new technologies mentioned above are quite important to many networked multimedia services such as multipoint video conferencing, distance learning, video on demand, and digital TV. Transmission of compressed video over heterogeneous networks with different transmission bandwidths may require a reduction in bit rate.

The compressed video bit stream is often converted to the reduced frame rate video bit stream in order to reduce the bit rate. Video transcoding provides not only the format conversion but also resolution scaling (spatial transcoding), bit-rate conversion (quality transcoding), and frame rate conversion (temporal transcoding). Because different networks may have different bandwidths, if a gateway or receiver end can include a transcoder to adapt the video bit rates, video services can be provided on different networks. When the bandwidth in a wireless network is very limited, the quality transcoding can cause high degradation of the transcoded video quality, if the frame rate is held constant.

The most straightforward way of implementation a transcoder is to cascade a decoder and an encoder. The basic transcoding architecture is shown in Fig. 1.1. In pixel-domain transcoding [2][3], the incoming video bitstream is decoded fully in the pixel domain, and the decoded video frames are then re-encoded at the desired output bit rate. This technique, however, is computationally expensive. DCT-domain transcoding [4] overcomes to some degree this computational complexity by decoding the incoming bitstream into the intermediate discrete cosine transform (DCT) domain and then re-encoding new bitstream from this DCT domain information.

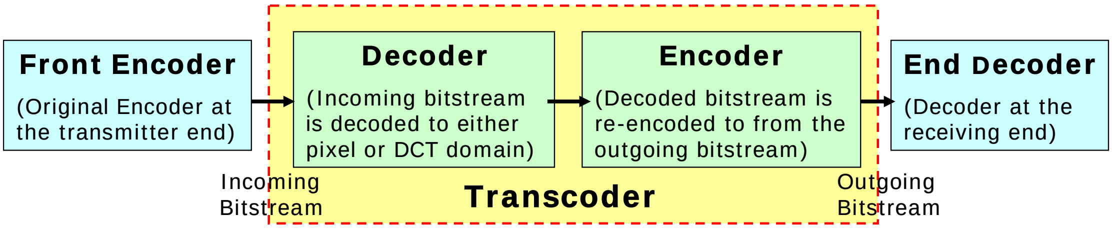


Fig. 1-1 Basic Transcoding Architecture

In both of above mentioned transcoding methods, bit rate reduction is primarily achieved by re-encoding DCT coefficients using coarser quantization. This approach suffers the following two problems. First, the quantization error would accumulate due to different quantization levels used in the front encoder. This causes poor video quality, especially for DCT-domain transcoding. Second, employing re-quantization does not reduce the output bit rate significantly.

Frame skipping trasncoding [5][6] is often used to reduce the output bit rate by skipping some of the incoming frames at regular or dynamic intervals while maintaining sustainable image quality. When some incoming frames are dropped for frame-rate conversions, the incoming motion vectors pointed to the dropped frames become invalid in the transcoded bitstream. One of the most straightforward solutions to overcome this problem is to re-estimate all the invalid motion vectors through full-scale full search algorithm using the non-skipped frames as reference frames. However, motion estimation is the most computationally expensive stage in the encoding process. To speed up the operation, a video transcoder usually reuses the decoded motion vectors from the incoming bitstream. Reuse of incoming motion vector can be achieved by bilinear interpolation, forward dominant vector selection (FDVS) [7], activity dominant vector selection (ADVS) [6], parametric activity dominant vector selection (PADVS) [8] techniques, etc.

In this thesis, except the original FDVS, ADVS, and PADVS(n) are used on all 16x16 modes in H.264/AVC, the enhanced FDVS and ADVS methods we proposed are also applied to all variable block sizes in H.264/AVC video coding standard.

The remaining of the paper is organized as follows. In section 2, we first introduce the background of H.264/AVC video coding techniques, including some H.264/ AVC important features and video transcoding technologies, and then some related works about block mode decision and motion vector composition are discussed. In section 3, the system architecture flow chart and the proposed method are presented. The experimental results of the proposed methods are shown in section 4. Finally, conclusion of this thesis will be presented in section 5.

Motivation

Due to requirement of many multimedia applications and expectation of good quality of video under limited network transmission, the thesis is based on H.264/AVC video coding standard and frame-rate conversion of video transcoding technology. Macroblock mode decision methods and motion vector in position methods are proposed. In the proposed methods, we make a choice about what information we need to obtain from the compressed video stream in H.264/AVC format and then re-use the information to decide the block mode types and the motion vectors in the retained frame so that we can reduce transcoding time and gain the acceptable video quality.

Besides, there are few topics discussing about how to decide block mode and motion vector in H.264/AVC frame skipping. Most of existing methods are used to resolve in MPEG-2 or H.263. Moreover, the distance between remaining frames become estranged so that the motion vector referred to previous frame may become invalid or imprecision and original macroblock modes may not suitable after frame skipping. H.264/AVC provides variable block size and quarter pixel precision in motion vector. The issues we are interested in are how to change block modes and motion vector in order to reduce encoding time and enhance the compressed ratio.

Chapter 2 Background and Related Work

In this section, we will introduce the following video techniques sequentially which we adopted. First, we will describe the H.264/AVC which is a video coding standard. Then we will present some concepts in the video transcoding methods, especially in frame skipping transcoding. Finally, some motion vector composition methods will be described.

2.1 H.264/AVC

H.264/AVC is a standard for video compression. It is also known as MPEG-4 Part 10, or MPEG-4 AVC (for Advance Video Coding). It is one of the latest block-oriented motion-estimation-based codecs developed by the ITU-T Video Coding Experts Group (VCEG) and ISO/IEC Motion Picture Expert Group (MPEG), partnership known as the Joint Video Team (JVT). Fig. 2.1 shows the encoder of H.264/AVC codec.

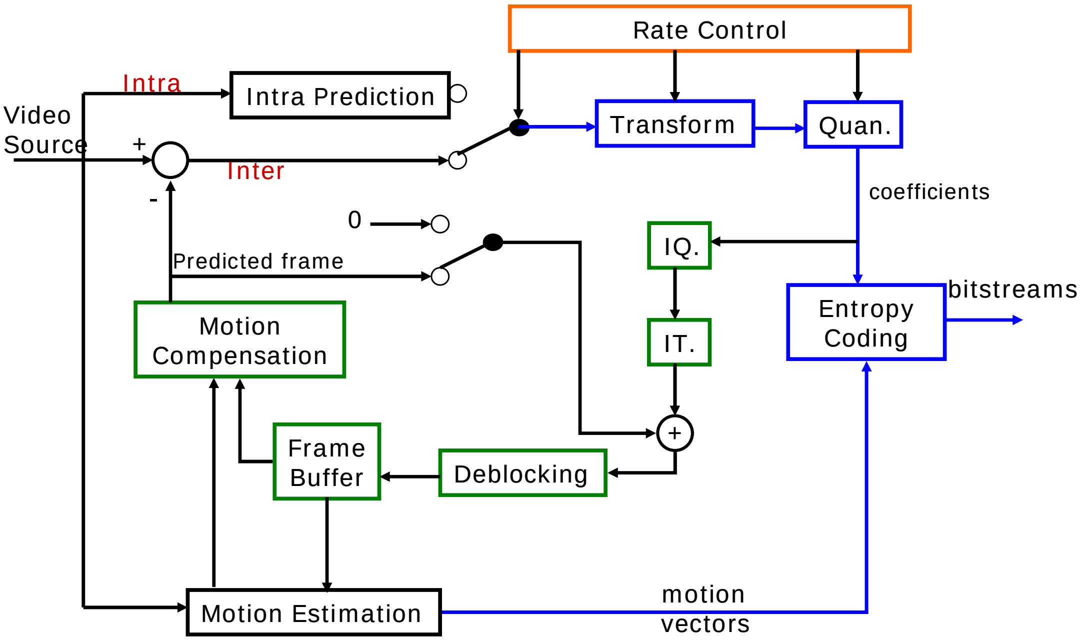


Fig. 2-1 H.264/AVC Encoder

H.264/AVC contains a number of new features that allow it to compress video much more effectively than older standards and to provide more flexibility for application to wide variety network environments. There are several key features including multiple reference frames, variable block size motion compensation to find out accurate motion vectors, quarter pixel precision motion vectors, new transform design features like integer 4x4 spatial block transform, in-loop deblocking filter which helps prevent the block artifacts, entropy coding design such as context adaptive binary arithmetic coding (CABAC) and context-adaptive variable length coding (CAVLC) and so forth used for high compression performance compared to previous video coding standards.

Among them, the inter mode decision process with variable block size motion estimation part is the most complex and time consuming. The block sizes are 16x16, 16x8, 8x16, 8x8, 8x4, 4x8, and 4x4. Fig. 2.1 shows the possible macroblock modes. Except the above seven kinds of mode, there are three more possible modes SKIP, I4MB, and I16MB in inter frame coding. The SKIP mode is a direct copy from the previous frames; I4MB and I16MB are the intra modes predicted from encoded adjacent block size. In general, SKIP, 16x16, 16x8, and 8x16 are called large block size modes, 8x8, 8x4, 4x8, and 4x4 are called small size block or sub block modes (P8x8).

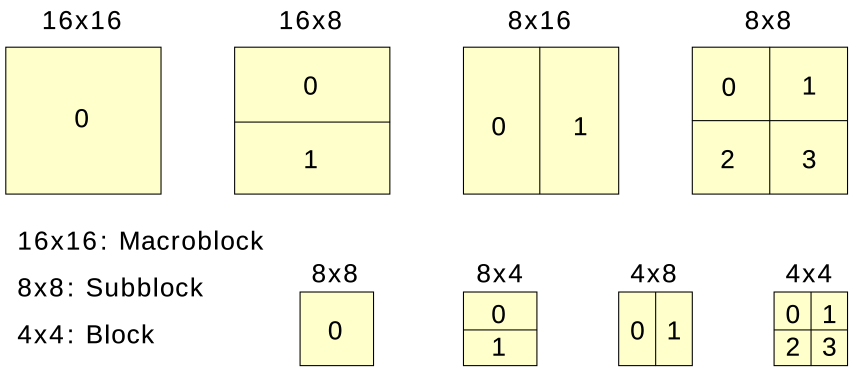


Fig. 2-2 Variable Block Size in H.264/AVC

To achieve the highest coding efficiency, the H.264/AVC reference software encoder, JM [9], uses a non-normative technique called Lagrangian rate-distortion optimization (RDO) technique to decide the block coding mode. Fig. 2.3 shows the RDO process. In order to choose the best coding mode for a macroblock, H.264/AVC encoder calculates the rate-distortion (RD) cost (RDcost) of every possible mode and chooses the mode having the minimum value, and this process is repeatedly carried out for all the possible modes for a given macroblock.

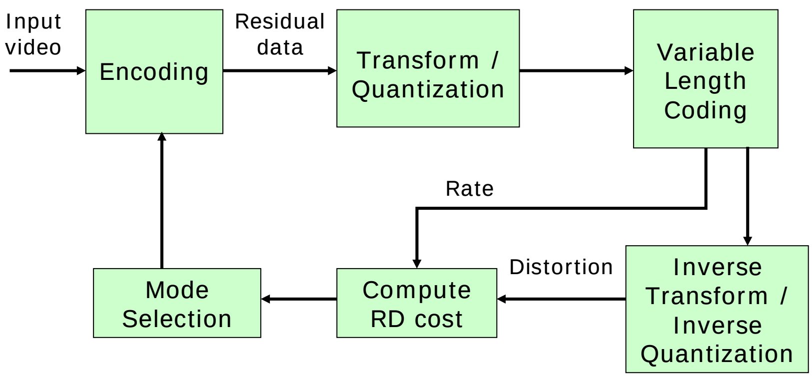


Fig. 2-3 Computation of RDcost

The best mode selected and used for coding must have the minimum cost. The cost function is given as follows:

$$J(m, \lambda_{motion}) = SAD(s, c(m)) + \lambda_{motion} \cdot R(m - p)$$

where $m = (m_x, m_y)^T$ is the current motion vector (MV), $p = (p_x, p_y)^T$ is the predicted MV. $R(m - p)$ represents the bits used to encode the MV information. $SAD(s, c(m))$ stands for the sum of absolute difference between current MB and reference MB, where s represents reference macroblock and $c(m)$ stands for a function of current macroblock with a parameter motion. λ_{motion} is the Lagrange multiplier, which is a function of QP,

$$\lambda_{motion}(QP) = 0.85 \times 2^{(QP-12)/3}$$

From equation (1), we know that choosing a larger partition size means that fewer bits are used to signal the MVs and other information, but the residue may contain much higher energy, especially with more details. On the other hand, choosing a smaller partition size may give a low residue after motion estimation but it needs to use more bits to signal the MVs and other information. Therefore, the multiplier, λ_{motion}, can be considered as a trade-off parameter between the rate and distortion. In this case, if encoder pays one bit to reduce more than λ_{motion} distortion in SAD, then less Lagrange cost, $J(m, \lambda_{motion})$, is obtained. The optimal coding efficiency can be achieved by checking all available modes and selecting the minimum cost. To sum up, how to select the best mode is very important to get the best performance of the H.264 codec.

2.2 Video Transcoding

Multimedia communication has become one of the faster growing parts of the information industry. Multimedia services and applications for a network environment, such as videoconferencing, video streaming on web application, distance e-learning, and video on demand, are widely used recently. With video being an important part of multimedia communications, new video compression techniques like MPEG-2, MPEG-4 and H.26x are proposed to satisfy new applications.

Transcoding is a process of converting a previously compressed video bitstream into a lower bit-rate video bitstream. The main function of video transcoding is that it can provide different format conversion, resolution scaling, bit-rate conversion, and frame rate conversion. Format conversion, for example, from MPEG-2 as input video stream converting to H.264/AVC as output video bitstream or from MPEG-4 to H.264/AVC, transform from original high bit-rate or low video quality format to superior video standard, low bit-rate or high video quality video format. Bit-rate conversion uses different quantization parameter (QP) to control the video quality and then obtain different bit-rate. Resolution scaling makes use of the video frame up-sizing or down-sizing to attain higher or lower bit rate. Frame rate conversion by means of skipping some frames regularly or dynamically to reduce the frame rate but guarantee an acceptable video quality.

In general, there are two approaches for implementing transcoding, commonly known as pixel-domain transcoding and discrete cosine transform (DCT) domain transcoding. The basic component of transcoding has mentioned above in Fig. 1.1. In pixel-domain transcoding, both of the incoming video bitstream and output of the transcoded video bitstream are decoded/re-encoded in the pixel domain. This involves high complexity, memory, and time consuming. Discrete cosine transform (DCT) domain transcoding which the incoming video bitstream is partially decoded to form the DCT coefficients and downscaled by the requantization of the DCT coefficients. The processing complexity is reduced since DCT-domain transcoding is carried out in the coded domain where complete decoding and re-encoding are not required. The problem with this approach is that the quantization errors will accumulate, and a prediction memory mismatch at the decoder will cause poor video quality called "drift" degradation.

In this thesis, we focus on frame skipping approach in the pixel domain because it is a good strategy for controlling the bit-rate and maintaining the picture quality within the acceptable level. The reason is that it is difficult to perform frame skipping in the DCT-domain since the prediction errors of each frame are computed from its immediate past frames. This means the incoming quantized DCT coefficients of the residual signal are no longer valid because they refer to the frames which have been dropped.

Frame skipping transcoding for bit-rate reduction of compressed video have been researched in many literatures [10][11]. Fig. 2.4 shows the architecture of frame skipping transcoder. In the front encoder, the motion vector, mv_t, for a macroblock with $N \times N$ pixels in frame f_t, the current frame, is computed by searching for the best matched macroblock within a search window S in the previous reconstructed frame, R_{t-1}, and is obtained as follows:

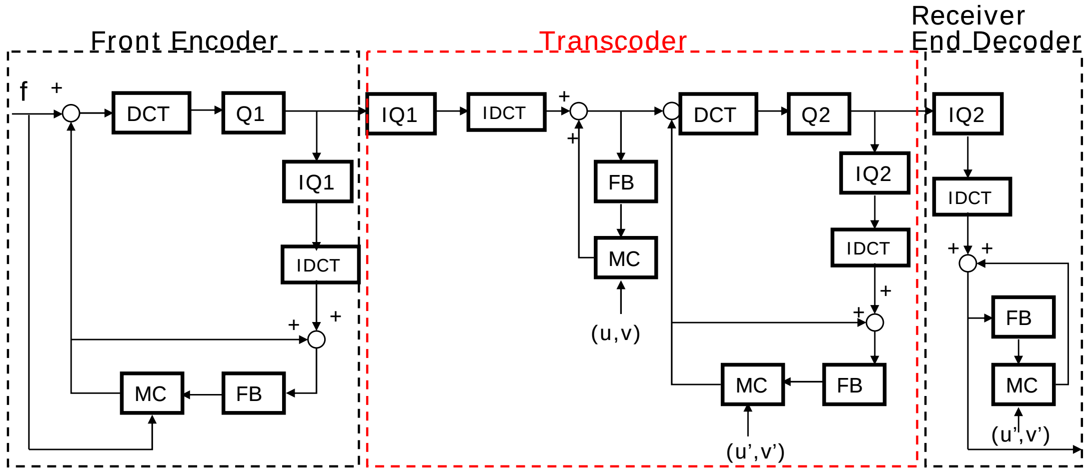


Fig. 2-4 Frame Skipping Transcoder in Pixel Domain

$$mv_t = (u_t, v_t) = \arg\min_{(m,n)\in S} SAD(m,n)$$

$$SAD(m,n) = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} \left| f_t(i,j) - R_{t-1}(i+m, j+n) \right|$$

where m and n are the horizontal and vertical components of the displacement of a matching macroblock, $f_t(i,j)$ and $R_{t-1}(i,j)$ represents a pixel in f_t and R_{t-1}, respectively.

2.3 Motion Vector Composition

In the transcoder, the optimized motion vectors (MVs) for the outgoing video stream can be obtained by applying the full-scale full-search motion estimation. However, the full-scale motion estimation for the Transcoder requires a high computational complexity. Besides, in frame skipping transcoding, some incoming frames are dropped, and the incoming motion vectors (MVs) are not valid because they point to the dropped frames that do not exist. Generally, motion estimation has not been computed again because of this high computational complexity. Furthermore, using the extracted MVs from the incoming video stream for the outgoing video stream would be almost as good as re-calculating the new motion estimation. The re-use of MVs extracted from an incoming video bitstream during transcoding has been widely adopted.

To find the MV for a macroblock in the current frame, a best matching macroblock is searched within a predefined search window in the previous reconstructed reference frame, as shown in Fig. 2.5. The MV is defined as the displacement of the best matching block from the position of current macroblock. The motion estimation is performed on the luminance macroblocks and is usually based on the sum of absolute differences (SAD) of the pixels in current video coding standards.

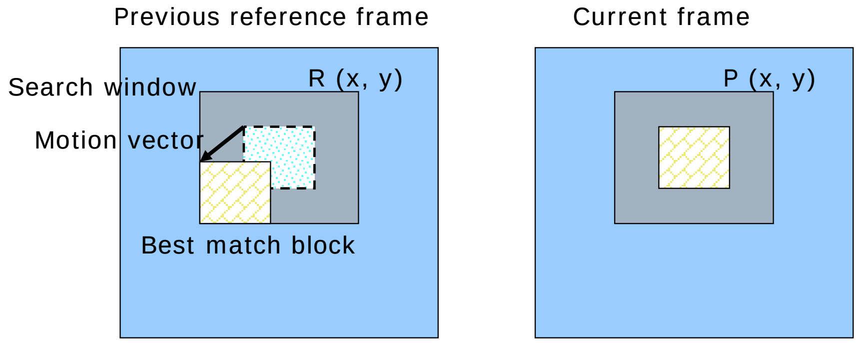


Fig. 2-5 Block Matching Motion Estimation Algorithm

Re-use of incoming motion vector can be achieved by bilinear interpolation and forward dominant vector selection (FDVS) [7]. In [12], bilinear interpolation is defined as:

$$MV_{BI} = (1-\alpha)(1-\beta)MV_1 + \alpha(1-\beta)MV_2 + \beta(1-\alpha)MV_3 + \alpha\beta MV_4$$

where MV_1, MV_2, MV_3, and MV_4 are the motion vectors of the four macroblocks overlapping the reference area in the skipped frame pointed by the incoming motion vector. α and β are determined by the horizontal and vertical pixel distance of this reference area from MV_1. Fig. 2.6 illustrates the interpolation of the motion vector.

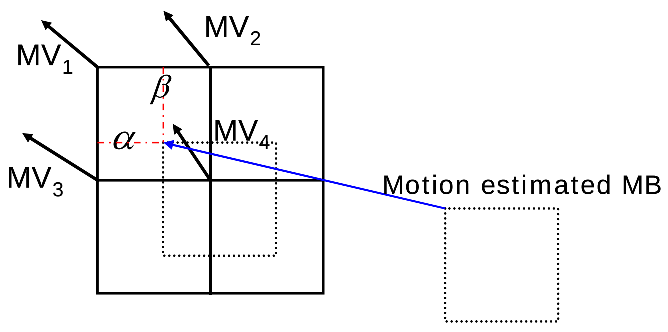


Fig. 2-6 Interpolation of Motion Vectors

The typical strategy adopted for motion vectors computation when a frame is skipped, is Motion Vector Composition (MVC) shown in Fig. 2.7. The goal of motion vector composition scheme is to find a motion vector in the last skipped frame, to be composed with the motion vector of the current frame, in order to obtain a motion vector for the current frame that points to the last skipped frame. The advantage of MVC is that, it is very easy to compute a motion vector for such macroblocks, given that their reference area exactly overlaps a macroblock in the skipped frame.

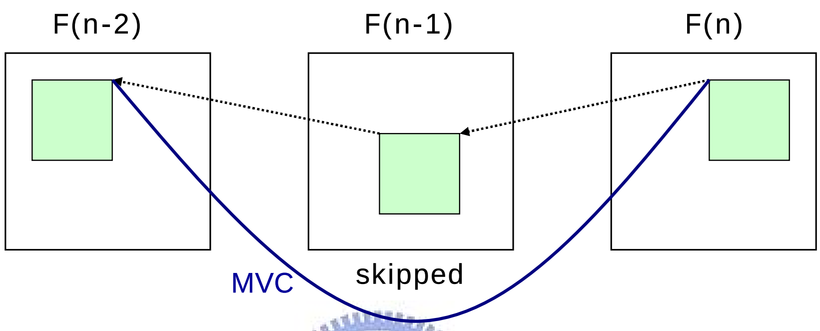


Fig. 2-7 Motion Vector Composition

Forward dominant vector selection (FDVS) [7] is used for composing the target MV from the four MVs of the four neighboring macroblocks. Combine with the concept of MVC mentioned above, as Fig. 2.8 shows, we assume that MV2 and MV3 represent the MV for the block in frame (n-1) and frame (n-2), respectively. Since frame (n-1) is dropped, we need to find a MB pointing to a block in frame (n-2). A feasible solution to generate a MV without performing motion estimation is to use the vector sum of MV. However, there is no block on macroblock boundary actually. Hence, MV2 is not available from the incoming video bitstream. The approach of FDVS selects one dominant MV from the four neighboring macroblocks. A dominant MV is defined as the MV carried by a dominant macroblock and the dominant macroblock is a macroblock that has the largest overlapping area with the block pointed by the incoming MV. Fig. 2.9 illustrates the FDVS composition scheme.

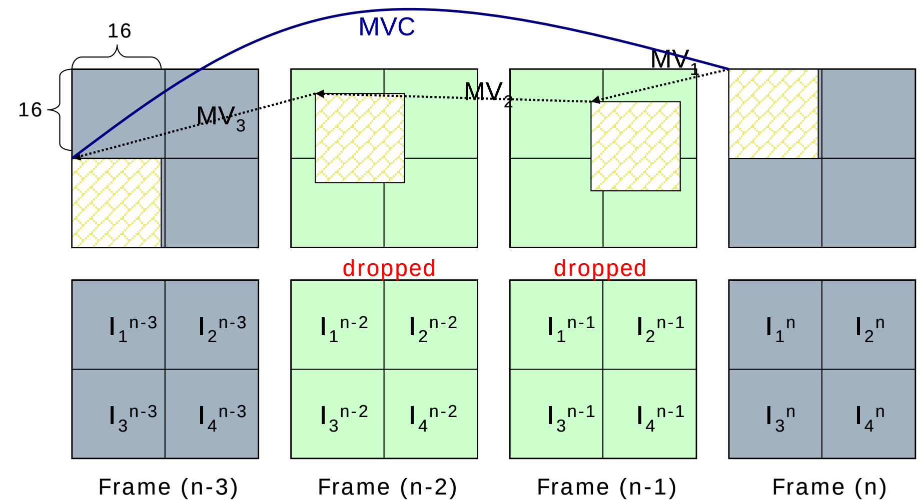


Fig. 2-8 Backward MV Composition: MVC = MV1+MV2+MV3

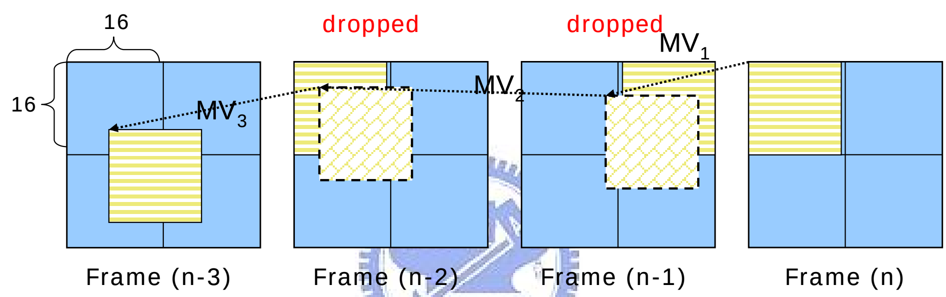


Fig. 2-9 FDVS Composition Scheme

The FDVS gets much better performance than the bilinear interpolation scheme, and the bilinear interpolation for composition for MVs is with high computation.

Next, we introduce another algorithm that it also decides the dominant MV from four neighboring macroblocks called activity dominant vector selection (ADVS) [6]. The conception of ADVS is the decided MV should be toward the MV with the larger prediction error. To gain a measure of the prediction error directly from the existing compressed bitstream, the DCT energy in the residual blocks is measured. ADVS algorithm utilizes the activity of the macroblock to decide the choice of the MV. Here, the activity information of a macroblock is represented by counting the number of nonzero quantized DCT coefficients of covered 8×8 residual blocks. These quantities are proportional to the spatial-activity measurement. As shown in Fig. 2-10, the MV of the macroblock with the maximum NZ (number of nonzero quantized DCT coefficients) is selected by the ADVS scheme as the dominant MV.

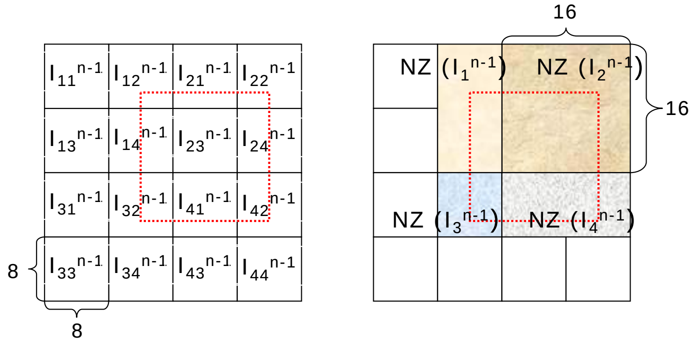


Fig. 2-10 Illustration of the ADVS Algorithm

where $NZ(I_1^{n-1}) = NZ(I_{12}^{n-1}) + NZ(I_{14}^{n-1})$

$$NZ(I_2^{n-1}) = NZ(I_{21}^{n-1}) + NZ(I_{22}^{n-1}) + NZ(I_{23}^{n-1}) + NZ(I_{24}^{n-1})$$

$$NZ(I_3^{n-1}) = NZ(I_{32}^{n-1}))$$

$$NZ(I_4^{n-1}) = NZ(I_{41}^{n-1}) + NZ(I_{42}^{n-1})$$

$NZ(.)$: number of nonzero quantized DCT coefficients

The bigger the activity (NZ) of the macroblock, the more significant the motion of the macroblock. Sine the quantized DCT coefficients of prediction errors are available in the incoming stream of transcoder, the computation for counting the nonzero coefficients is very low.

Chapter 3 The Propose Method

In this chapter, we describe the proposed frame skipping transcoding algorithm in detail. Section 3.1 includes the overall system architecture and the flowchart of the proposed method. Section 3.2 focuses on how to select block mode type. Section 3.3 contains not only applying the original approaches like FDVS, ADVS, and PADVS(n) to several macroblock types in H.264/AVC video frame skipping transcoding, but also introducing our proposed algorithm suitable for all block mode types in H.264/AVC.

3.1 System Architecture

Figure 3.1 shows our H.264/AVC video frame skipping transcoding architecture. The transcoding architecture includes a full H.264/AVC decoder and a H.264/AVC transcoding encoder. Comparing Figure 2.4 to Figure 3.1, both the segments of the red dotted line show the most important part in our transcoding architecture.

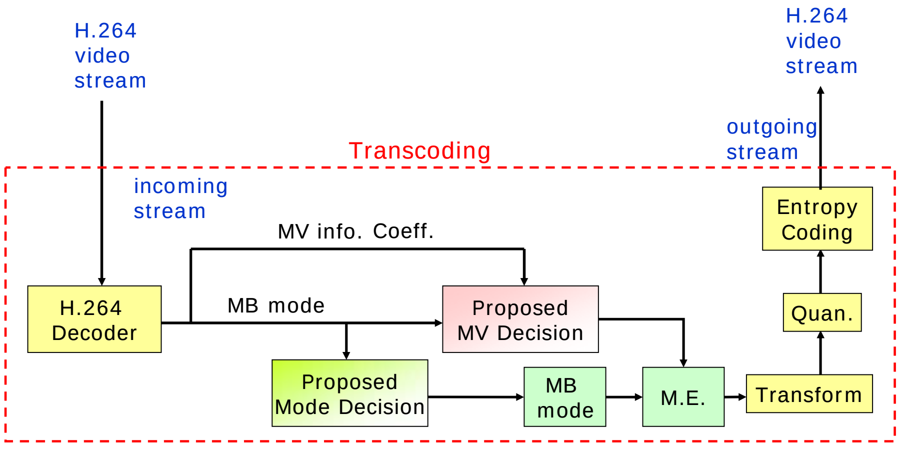


Fig. 3-1 Proposed H.264/AVC video frame Skipping Transcoding Architecture

Both of input and output streams are H.264/AVC standard format, the main operating units of transcoding architecture according to the chapter 1. We divide them into four parts. They are front-end encoder, front-end decoder, back-end encoder, and back-end decoder which have been shown in figure 1.1. Among them, front-end decoder and back-end encoder are the focus of this thesis so they are depicted in figure 3.1, where both the incoming stream and outgoing stream are in H.264/AVC format.

In this architecture, when the H.264/AVC video stream has been decoded, we would save some information including motion vectors, macroblock types, and residual coefficients from the compressed video stream. And then in the H.264/AVC transcoding part, we concentrate on mode decision and motion vector decision parts. Other parts follow the standard H.264/AVC encoding procedures to produce the stream. The propose mode decision uses the macroblock types and residual coefficients obtained from incoming H.264/AVC compressed video stream while the propose motion vector decision uses the motion vectors and macroblock types. Both of the propose methods reuse the information from incoming video stream, so that we can save a lot of time cost and computational complexity in doing motion estimation and rate-distortion optimization, both of which take a great majority of time consuming in the transcoding process.

Figure 3.2 shows the flowchart of the proposed block mode decision and motion vector decision methods. The first stage performs block mode decision which makes the decision of the block mode. The second stage of the flowchart is to do the motion re-estimation which determines new motion vector for each macroblock.

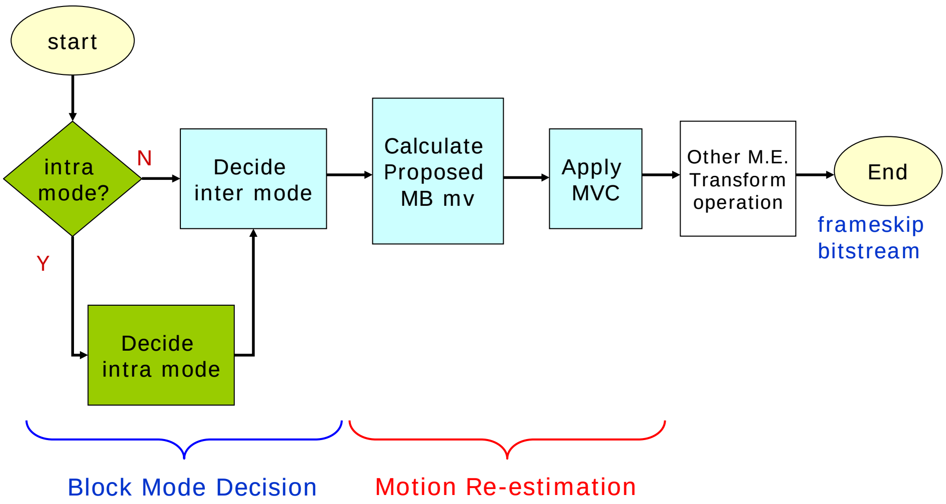


Fig. 3-2 Flowchart of Proposed Block Mode and MV Decision Methods

3.2 Proposed Block Mode Decision Method

In H.264/AVC video coding standard, it employs several different macroblock mode types in intra and inter blocks. They are I16MB and I4MB in intra macroblocks, and PSKIP, P16x16, P16x8, P8x16, SMB8x8, SMB8x4, SMB4x8 and SMB4x4 in inter macroblocks, respectively. H.264/AVC standard software, JM, uses Lagrangian rate-distortion optimization (RDO) technique to decide the block coding mode and motion vector. However, the computation complexity of calculating Lagrangian function for every block is quite high. Therefore, a fast block mode decision to determine block mode is important.

Figure 3.3 shows the flowchart of the proposed block mode decision method, where the input is a video stream including skipped frames and non-skipped frames. The next paragraph would show how to do the block mode decision.

Let f_{cur} denote the current frame, and f_{skip} denote the corresponding reference frame which will be dropped. The following steps are performed to determine the mode for each macroblock in f_{cur} .

First, Read in the i-th macroblock from f_{skip} and f_{cur} frames. We refer to the macroblocks as MB_{skip}^{i} and MB_{cur}^{i}, respectively. If anyone of MB_{skip}^{i} and MB_{cur}^{i} is intra mode then intra mode is selected and rate-distortion optimization is applied on MB_{cur}^{i} to decide whether intra4x4 or intra16x16 to be used. However, if none of MB_{skip}^{i} and MB_{cur}^{i} is intra mode, the mode-change rules in Table 3.1 are applied to obtain a candidate block mode for MB_{cur}^{i}. All these mode-change rules follow the principle that the smaller block mode between MB_{skip}^{i} and MB_{cur}^{i} is selected as the candidate mode. It is due to the fact that, after f_{skip} has beed dropped, the sidtance between f_{cur} and its new reference frame increases, and therefore, smaller block mode should be more suitable.

In final step of the flowchart, we sub-divided the inter block with candidate block mode into more blocks with smaller block modes in order to gain better visual quality and lower rate-distortion cost. Figure 3.3 presentd four macroblocks as examples. For the left-top macroblock, the candidate block mode resulting from mode change step is P8x16 and will be sub-divided into SMB8x8 for rate-distortion cost (RDcost) evaluation. If the resulting four 8x8 blocks get a better RDcost than the two P8x16 blocks, the sub-division process repeat; otherwise, the block mode of P8x16 is selected. For the left-down macroblock, the block P16x16 could be sub-divided into two P8x16 blocks, or two P16x8 blocks as shown in the right side of the two arrows. For each sub-division case, the RDcost is calculated, if it is smaller than the one RDcost of the one without division, then we should adopt the divided one and the dividing process repeat again. Otherwise, we stop dividing the inter block. Theoretically, the visual quality would be improved through this stage.

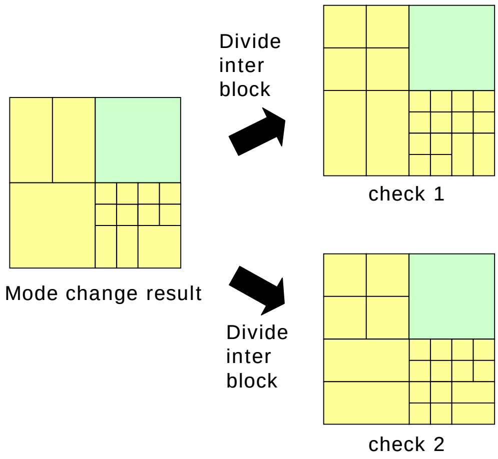


Fig. 3-3 Divide Inter Block

Rule 1	Select intra mode if it exists among co-located macroblock in the either current frame or previous frame	
Rule 2	Select the smaller mode type between skipped and non-skipped frames	
	Rule 2.1	Choose P16x16 if one of them is P16x16 or PSKIP and the other is P16x16
	Rule 2.2	Choose P16x8 if one of them is P16x16, P16x8, or PSKIP and the other is P16x8
	Rule 2.3	Choose P8x16 if one of them is P16x16, P8x16, or PSKIP and the other is P8x16
	Rule 2.4	Choose SMB8x8 if one of them is P16x16, P16x8, P8x16, PSKIP, or SMB8x8 and the other is SMB8x8
	Rule 2.5	Choose SMB8x4 if one of them is P16x16, P16x8, P8x16, SMB8x8, or SMB8x4 and the other is SMB8x4
	Rule 2.6	Choose SMB4x8 if one of them is P16x16, P16x8, P8x16, SMB8x8, or SMB4x8 and the other is SMB4x8
	Rule 2.7	Choose SMB4x4 if one of them is P16x16, P16x8, P8x16, SMB8x8, SMB8x4, SMB4x8, or SMB4x4 and the other is SMB4x4
Rule 3 Special Case	Select SMB8x8 if one of them is P16x8 and the other is P8x16 Select SMB4x4 if one of them is SMB8x4 and the other is SMB4x8	
Rule 4	Select SKIP mode only if both of skipped and non-skipped are SKIP modes	

Table 3-1 Rules of Mode Change

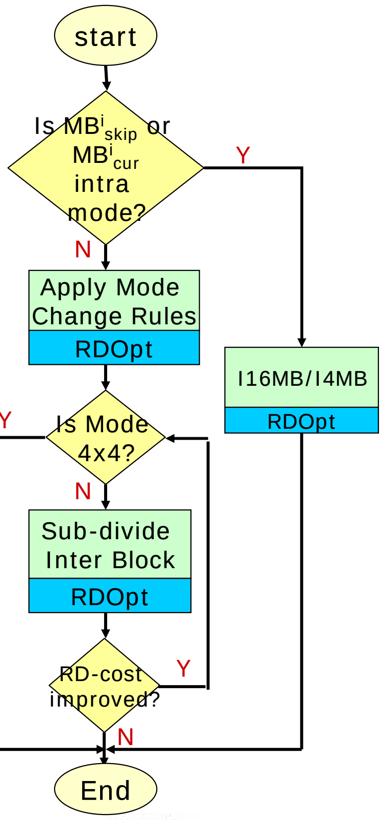


Fig. 3-4 Flowchart of Mode Decision

We take an example in figure 3.6 to explain the mode change rules. All of the variable block type drawings are shown in figure 3.5.

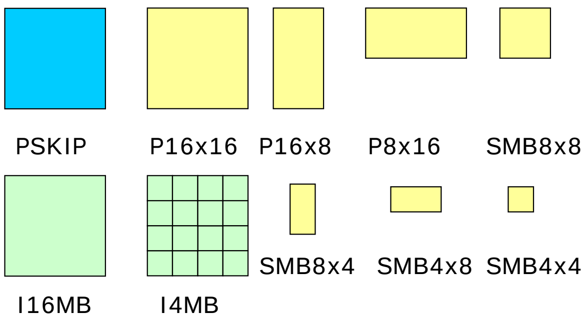


Fig. 3-5 Variable Block Mode

In figure 3.6, f_{cur} is the current frame for mode decision and f_{skip} is the corresponding reference frame that will be skipped after transcoding. To simplify the illustration, each frame consists of four macroblocks.

The block mode of upper-left macroblock is P16x16 in f_{skip} and P8x16 in f_{cur}. Therefore, after applying mode change rule 2.2, the resulting block mode for f_{skip} should be P8x16. As for block mode decision of upper-right and lower-left macroblocks, the resulting modes should be intra16x16 and P16x16, respectively, due to rule 1 and rule 2.1. The final part of the example is more complicated and it contains four sub-macroblocks. The upper-left sub-macroblock is SMB4x8 in f_{skip} and SMB8x4 in f_{cur}, so after applying rule 3, the resulting block mode should be SMB4x4. Similar processes are performed for all the other three sub-macroblocks, and the resulting sub-block modes are shown in the right hand side of figure 3.6.

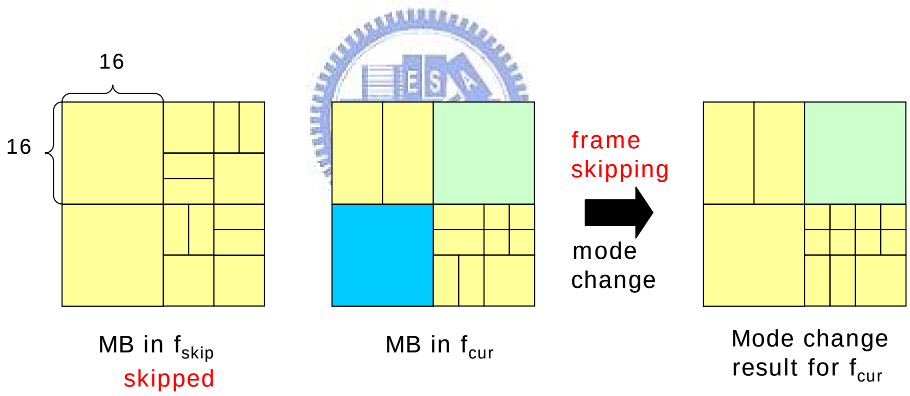


Fig. 3-6 Mode Change Result

3.3 Proposed Motion Vector Composition Method

Motion estimation is also an important segment in video frame skipping transcoding. In this section, we discuss about how to employ the motion re-estimation by using the motion vectors obtained from front-end transcoder. An enhanced FDVS method is presented in section 3.3.1 and an enhanced ADVS method in section 3.3.2.

3.3.1 Enhanced FDVS Method for H.264/AVC

The enhanced FDVS method mentioned in this section is suitable for all kinds of mode including variable block size of inter, intra, and SKIP mode. Owing to the fundamental conception of implementing FDVS method is to find out macroblcok that has the largest area overlapped with the area pointed by the motion vector of current macroblock as dominant macroblock, and then use the motion vector of the dominant macroblock as dominant motion vector. However, there exist two problems if we directly apply the FDVS idea to H.264/AVC video coding. Firstly, finding the largest overlapping area in the variable block size in H.264/AVC is much complicated due to the quarter-pixel precision and complex combinations of various block modes. Secondly, the dominant macroblock may be the smallest block size such as SMB4x4. Therefore, in some cases, the results of motion vector selected by original FDVS and by enhanced FDVS method may be different. The reasons will be explained in this section by examples.

For above reasons, we suggest another flexible manner to prevent from the foregoing conditions. We divide all inter block modes into different numbers of inter 4x4 FDVS unit, as shown in figure 3.7. For instances, a P16x16, P16x8, SMB8x8, and SMB4x4 blocks would be divided into sixteen, eight, four, and one 4x4 FDVS units, respectively.

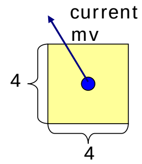
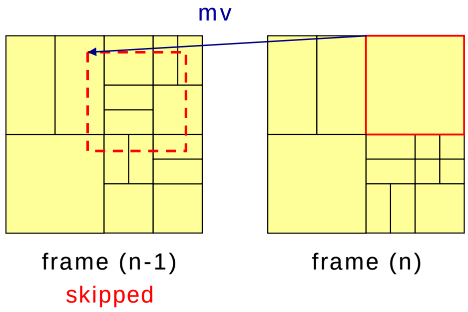


Fig. 3-7 An Inter 4x4 FDVS Unit

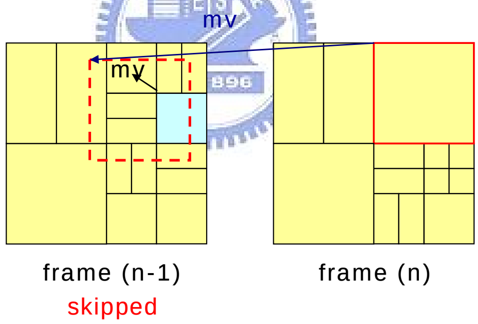
The center of each FDVS unit can be found out. The center position is marked as a blue circle as illustrated in figure 3.7. After obtaining the current motion vector of each 4x4 FDVS unit, we add up center location and current motion vector. The motion vector of macroblock which is pointed to is one of the candidate motion vectors. The program takes down all candidate motion vectors, and looks for the motion vector appearing most frequently as the dominant motion vector. Take an example, suppose four candidate motion vector of a SMB8x8 macroblock are (1, 0), (0, 1), (2, 0), and (1, 0). The candidate motion vector of (1, 0) appears twice so that it becomes the most frequent candidate motion vector. And then (1, 0) would be the dominant motion vector of the SMB8x8 macroblock. The results of using center point methods can save a lot of time without calculating the overlapped area.

Take an example in figure 3.8 to explain the difference between original FDVS method and enhanced FDVS method. We focus on the upper-right part of P16x16 macroblock in frame (n). Figure 3.8 describes that after adding the current motion vector, P16x16 refers to the red dotted line in the frame (n-1). The macroblock type under the red dotted line contains a P8x16, a P16x16, two SMB8x8, two SMB8x4, and four SMB4x8. If we choose the original FDVS method, we have to pick up the largest overlapped area referenced in the frame (n-1). For an instance, suppose the largest overlapped area is SMB8x8 located at the lower-right partition, as figure 3.8 (b) shows. The blue area of SMB8x8 block is selected by original FDVS method which it contains the largest partition. In our propose method, enhanced FDVS method, we not only check all the center points that current macroblock refers to, but also accumulate the same length of motion vectors. As figure 3.8 (c) shows, assume that the length of three motion vectors mv_1, mv_2, and mv_3 are (2, 1), (2,1), and (1,1). If the macroblocks of mv_1 and mv_2 contain two 4x4 FDVS units while the macroblock of mv_3 contains three 4x4 FDVS units. However, the length of mv_1 and mv_2 is the same so that we accumulate the same length of motion vector even if they belong to different macroblocks.

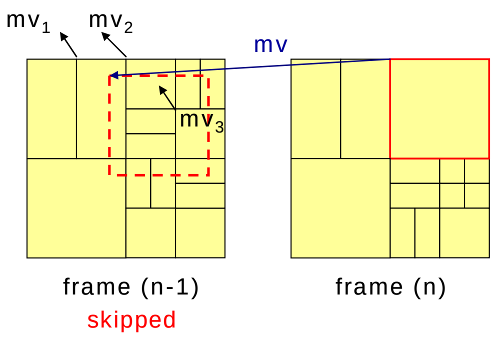
Hence, we select mv_3 as dominant motion vector if we use original FDVS method, while we will choose mv_1 or mv_2 as dominant motion vector if we use our propose enhanced FDVS method. The main difference between original FDVS and enhanced FDVS is that our propose method selects the motion vector which appears most frequently.



(a) FDVS example



(b) Original FDVS method



(c) Enhanced FDVS method

Fig. 3-8 (a) FDVS example (b) Original FDVS method (c) Enhanced FDVS method

The above example shows that even if there is no mode change on the current macroblock, the dominant motion vector selected by the proposed enhanced FDVS is different from that selected by original FDVS. Now assume the mode change step determines to use 8x8 block mode (instead of 16x16) for current macroblock.

As the figure 3.9 shows, P16x16 macroblock should be divided according to the block mode decision. Each 8x8 block then is sub-divided into 4x4 FDVS units which are mapping to the reference frame (n-1). On frame (n-1) it shows that the upper-left SMB8x8 is overlapped with a 8x16 bocks with mv_1, a 8x8 block with mv_2, and a 8x4 block with mv_3, respectively. Since there are two central points of FDVS units located in the block with mv_1, and only one in mv_2 and mv_3, the dominant motion vector is set to mv_1.

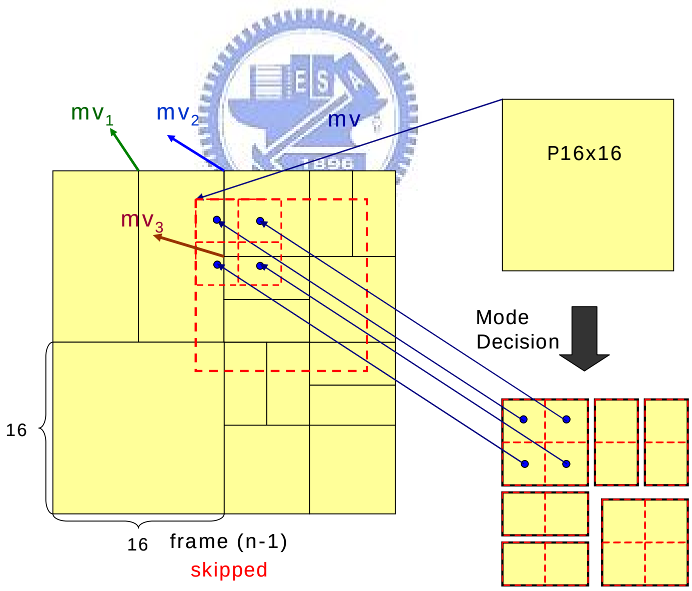


Fig. 3-9 Enhanced FDVS Example Result

3.3.2 Enhanced ADVS Method for H.264/AVC

Another proposed method, enhanced ADVS, is derived from the conception of ADVS method. It is also suitable for all kinds of block modes. The basic idea of

ADVS is to accumulate each non-zero quantized coefficients of block covered in. Unlike the way applying ADVS to all 16x16 modes, applying ADVS to all kinds of block modes produce some different issues. As figure 3.10 shows an 4x4 inter ADVS unit. Other kinds of macroblock types are based on the 4x4 inter ADVS unit and divided into several ADVS units. As we can see in figure 3.11 illustrates SMB8x4, SMB4x8, and SMB8x8 block type divided into ADVS units.

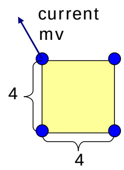


Fig. 3-10 An 4x4 Inter ADVS Unit

We propose to check the endpoints of ADVS unit point to the location after adding the current motion vector. The endpoints are labeled as small blue circles as in the figure 3.10 and 3.11. Each 4x4 inter ADVS unit would have four endpoints. Similarly, there are six endpoints in a SMBx4 or SMB4x8 block, nine endpoints in a SMB8x8 block, fifteen endpoints in a P16x8 or P8x16 block, and twenty-five endpoints in a P16x16 block.

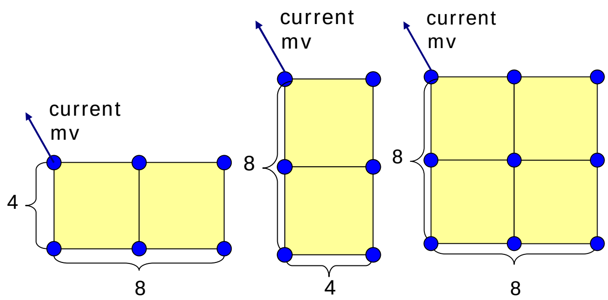


Fig. 3-11 SMB8x4, SMB4x8, SMB8x8 Check Endpoint

As figure 3.12 shows, we explain the overall process by an example. Suppose current macroblock is a P16x16 block mode. After applying mode decision as before, assume the new block mode is SMB8x8, we find out nine endpoints of each 8x8 block and map them to the previous frame (n-1). For the left-top SMB8x8 block, there are three endpoints locating at the P8x16 with mv_1 in the previous frame (n-1) we have to calculate its non-zero quantized coefficients. Four endpoints are located at the SMB8x8 with mv_2 in the previous frame and we have to count its non-zero quantized coefficients. The remaining two endpoints are located at the SMB8x4 we also calculate its nonzero quantized coefficients. By comparing the NZ(.) results of three different groups, presume that the one with maximum of non-zero quantized coefficients is the block SMB8x8 with mv_2, then we would consider the motion vector mv_2 as our dominant motion vector.

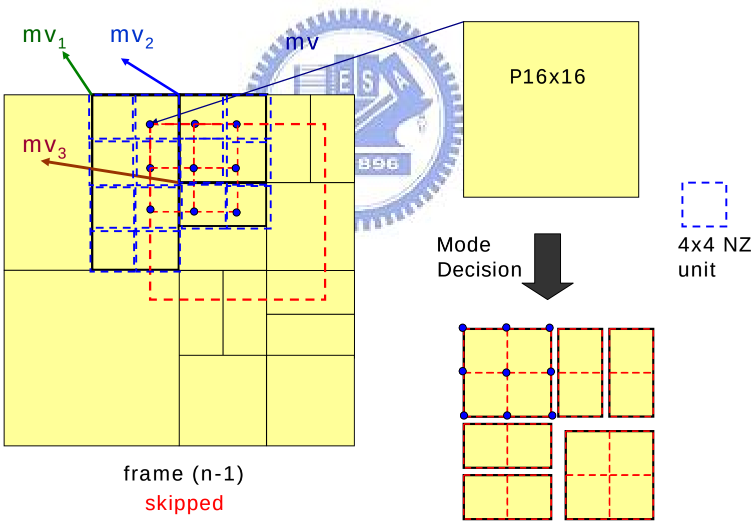
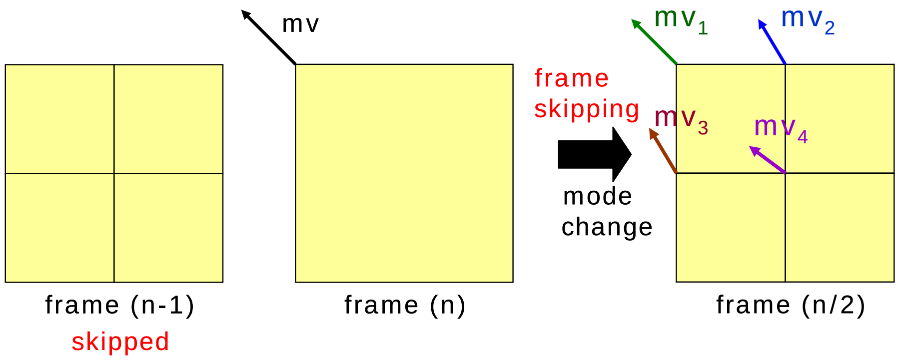


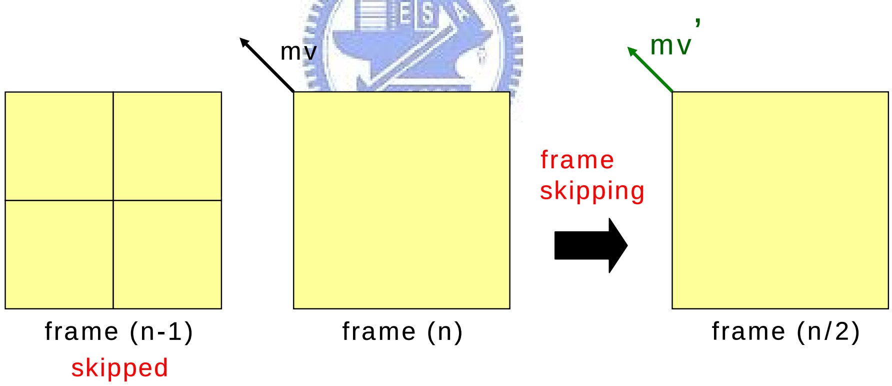
Fig. 3-12 Apply ADVS Example

3.4 MV Selections for Mode Change and No Mode Change

In this section, we probe the effectiveness of the mode change. For comparison, figure 3.13 (a) illustrates the case with mode change, while figure 3.13 (b) shows the one without mode change. Assume the current macroblock in frame (n) is a P16x16 and the co-located macroblock in the reference frame (n-1) is composed of four SMB8x8. After doing the proposed mode change method as well as enhanced FDVS or enhanced ADVS, the outcome would be four SMB8x8 block modes with different motion vectors. Oppositely, if we have the same block mode without using mode change, we would retain the block mode of non-skipped frame with a determined motion vector as illustrated in the figure 3.13 (b).



(a) mode change



(b) no mode change

Fig. 3-13 MV selections for (a) mode change and (b) no mode change

The experimental results of the mode change and no mode change will exhibit in the chapter 4.

3.5 Apply Motion Vector Composition

No matter enhanced FDVS or enhanced ADVS is adopt to obtain the dominant motion vectors, we have to add current motion vector and dominant motion vector up.

The typical strategy we use for motion vectors computation when a frame is skipped, is called motion vector composition (MVC) shown in figure 3.14. The goal of motion vector composition scheme is to compose the dominant motion vector in the skipped frame with the motion vector of the current frame in order to obtain a motion vector for the current frame that points to the previous non-skipped frame which is used as the new reference frame.

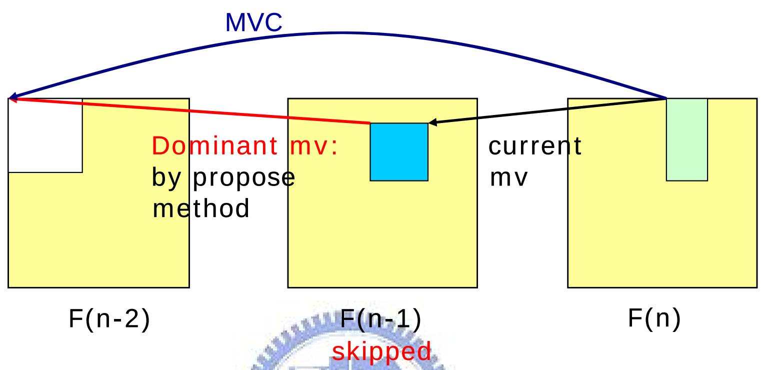


Fig. 3-14 Apply Motion Vector Composition

The benefit of MVC is that, to compute a motion vector for such macroblock is simpler because it effectively reuses the information from the encoded video stream.

Chapter 4 Experimental Results

In this chapter, we compare the proposed methods with the general FDVS [7], ADVS [6], and PADVS [8] algorithms, which speed up the motion vector composition, respectively. We also compare the proposed transcoder with the optimal frame skipping method proposed in H.264/AVC JM13.2 reference software. Various types of standard test sequences with CIF (352x288) format are tested.

The proposed transcoder is implemented by using the H.264/AVC JM13.2 reference software. The parameters of our experimental environments are set as following:

Hardware Parameters:

CPU: Intel Pentium Core 2 Due 1.83GHz, 1.83GHz

RAM: 2.00 GB

Software Parameters:

Test sequences: Foreman, Football, Tennis, Stefan, bus, Container, Hall

Frame Format: CIF (352x288 pixels)

Group of Picture (GOP): I P P P P …, and the period of I-frame is 30.

Frame Rate: 30 fps

Number of reference frame: 1

Motion Estimation: Search window size = 32, fast full search

R-D Optimization: High complexity mode

Inter Mode: All mode are enabled

Intra Mode: I16MB and I4MB enabled

We conducted experiments of different methods in this section. First, we applied FDVS, ADVS, and PADVS(n) to H.264/AVC video frame skipping transcoding which only use P16x16, PSKIP, and I16MB macroblock type. The reason is that all of three methods are used in MPEG-2 video coding standard originally.

Second, we separate our proposed method, mode decision and motion vector composition, into two cases. One is with motion vector composition with mode decision and the other is without mode decision. The destination is to observe the influence on mode decision.

Finally, we would compare our proposed method with JM 13.2 reference software, FDVS, ADVS, and PADVS(n).

4.1 FDVS, ADVS, and PADVS(n) Methods on Large Block Sizes

Several sequences tested in this section would show that the methods of FDVS, ADVS, and PADVS(n) save a lot of time of transcoding and motion estimation with acceptable degradation of video quality and slightly increase in bit-rate. The definition of large block size is block type of P16x16, PSKIP, and intra16x16MB. The test sequences are foreman, news, hall, football, and flower, where news and hall are classified as slow or smooth motion sequences, foreman and flower are median motion, and football is high motion. The parameter n in the PADVS(n) method is established as n=1, 3, 10, 36, and 49 that covered, where the non-zero quantized coefficients are selected in a zig-zag scan order from low frequency to high frequency. The numbers of frame sequences before and after frame skipping transcoding are 120 and 60, respectively. For the sequence, one frame is skipped for every two frames.

Table 4.1 describes the results of JM, FDVS, ADVS, and PADVS(n) methods applying to “foreman” on large block size. The experimental results show that comparing to reference software JM, the methods of FDVS, ADVS, and PADVS(n) decrease 0.35dB to 0.41dB in PSNR measurement while saving about 65% to 70% in total time and 81% to 87% in motion estimation time.

Item\Methods	JM	FDVS	ADVS	PADVS(n)				
				n=1	n=3	n=10	n=36	n=49
PSNR	37.24	36.89	36.83	36.84	36.84	36.84	36.84	36.83
△PSNR	0	-0.35	-0.41	-0.4	-0.4	-0.4	-0.4	-0.41
Decoding tim	41.886	61.781	44.143	42.274	41.553	42.789	45.881	46.535
Encoding tim	407.524	90.184	90.966	93.427	91.059	91.493	101.545	106.535
M.E. time	356.201	4.347	4.545	4.598	4.549	4.61	5.158	5.409
Transcoding time	449.41	151.965	135.109	135.701	132.612	134.282	147.426	153.07
△T. time(%)	0	-66.19%	-69.94%	-69.80%	-70.49%	-70.12%	-67.20%	-65.94%
△M.E.time(%	0	-81.44%	-86.33%	-86.84%	-87.06%	-86.69%	-85.67%	-85.42%
Total bits	1387056	2019680	2033344	2057504	2064304	2064304	2055560	2061000
Bit-rate	346.76	504.92	508.34	514.38	516.08	516.08	513.89	515.25

Table 4-1 Experimental results of FDVS, ADVS and PADVS(n) on foreman.cif

Here we define some terms such as $\Delta PSNR$, $\Delta T.time$, and $\Delta M.E.time$ as followings:

$$\Delta PSNR = \Delta PSNR\_method - \Delta PSNR\_JM$$

△PSNR means the degradation of PSNR compared with the full H.264/AVC re-encoder.

$\Delta T.time$: stands for the percentage of reduced processing time comparing with the H.264/AVC re-encoder. The formula is listed as below:

$$\Delta Total\_time = (Time\_method - Time\_JM)/Time\_JM$$

$\Delta M.E.time$: stands for the percentage of reduced motion estimation time comparing with the H.264/AVC re-encoder. M.E. is the abbreviation of motion estimation.

$$\Delta M.E.time = (M.E\_method - M.E.\_JM)/M.E.\_JM$$

where the "method" in above formula could be FDVS, ADVS, or PADVS (n). Notice that the definition of transcoding time is the summation of decoding time and encoding time. From Table 4.1, the experimental results show that the visual quality of FDVS, ADVS, and PADVS(n) are close to JM in PSNR measurement. However, due to only using large block size, some proportions of macroblocks are encoded as intra macroblocks since its RDcost increase if they encoded as P16x16 or PSKIP.

Therefore, the bit-rates increase when using FDVS, ADVS, and PADVS(n) methods. The phenomenon can be solved if we use all block modes to encode the macroblocks.

Figure 4.1 shows the PSNR measurement frame by frame in foreman sequence. The yellow curve is the result of conducting by JM while the blue and pink curves are representation of FDVS and ADVS.

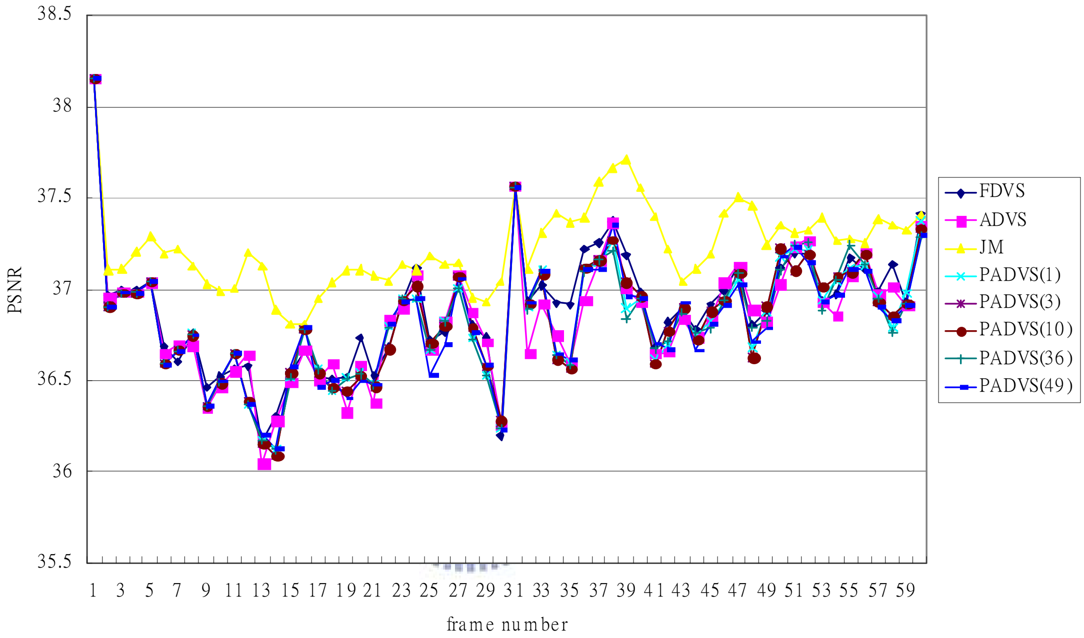


Fig. 4-1 Different Methods in PSNR Frame by Frame in Foreman

Figure 4.2 illustrates the comparison in encoding time and transcoding time in the same test sequence frame by frame. The definition of transcoding here means the summation of decode time and re-encoding time.

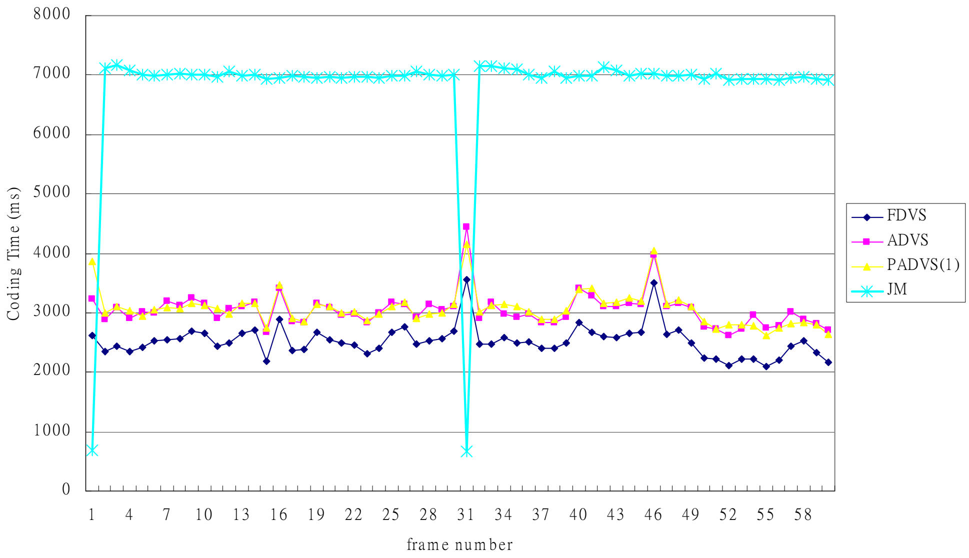


Fig. 4-2 Comparison Encoding Time with Transcoding Time Frame by Frame in Foreman

In figure 4.2, the intra periodic is set up as 30. Therefore, JM does not have to decide the macroblock is intra or inter when encoding each I-frame. The encoding time displays a period of declination every thirty frames. In our frame skipping transcoding methods, we do not consider about I-frame or P-frame from the video source but performing the mode change and motion re-estimation every two frames. Hence, the transcoding time rises every fifteen frames.

The sequence, foreman, represents the case of median to high motion one. In Appendix C, we will take other experimental sequences such as “news”, “hall”, “football”, and “flower” to show our experimental results.

4.2 Propose Methods on All Block Sizes

In this section, we use the same video test sequences as input mentioned in the section 4.3.1. Here, we focus on the experimental results of enhanced FDVS and apply ADVS on all block size that the methods including block mode decision and motion vector decision we proposed in the chapter 3. The term, all block sizes, means the block mode of PSKIP, P16x16, P16x8, P8x16, SMB8x8, SMB8x4, SMB4x8, SMB4x4, Intra16MB, and Intra4x4MB.

Table 4.2 to Table 4.4 illustrates the propose methods comparing to the reference software JM. The term, transcoding time stands for the summation of the decoding time and encoding time. The formulas of other terms are listed above in the section 4.3.1.

Item\Methods	JM	E-FDVS	E-ADVS
PSNR	37.37	37.28	37.24
△PSNR	0	-0.09	-0.13
Decoding tim	40.612	46.593	56.251
Encoding tim	667.942	287.41	287.41
M.E. time	466.319	167.27	171.3
Transcoding time	708.554	334.003	343.661
△T. time(%)	0	-52.86%	-51.50%
△M.E.time(%	0	-64.13%	-63.27%
Total bits	1110216	1122888	1145720
Bit-rate	277.55	280.72	286.43

Table 4-2 Propose Methods Comparing to H.264 (foreman)

Item\Methods	JM	E-FDVS	E-ADVS
PSNR	38.77	38.49	38.44
△PSNR	0	-0.28	-0.33
Decoding tim	35.88	39.36	42.28
Encoding tim	638.815	257.471	262.821
M.E. time	450.187	131.57	134.301
Transcoding time	674.695	296.831	305.101
△T. time(%)	0	-56.01%	-54.78%
△M.E.time(%	0	-62.03%	-60.78%
Total bits	715416	912328	925120
Bit-rate	178.25	228.08	231.28

Table 4-3 Propose Methods Comparing to H.264 (news)

Item\Methods	JM	E-FDVS	E-ADVS
PSNR	38.15	38	37.96
△PSNR	0	-0.15	-0.19
Decoding tim	35.409	39.532	41.88
Encoding tim	637.313	250.448	258.724
M.E. time	448.267	133.23	137.745
Transcoding time	672.722	289.98	300.604
△T. time(%)	0	-35.31%	-32.94%
△M.E.time(%	0	-61.46%	-59.93%
Total bits	741552	771536	787520
Bit-rate	185.39	192.88	196.88

Table 4-4 Propose Methods Comparing to H.264 (hall)

From Table 4.2 to Table 4.4, the experimental results of our enhanced FDVS method only decreases 0.09dB to 0.28dB in PSNR measurement while saving around 35% to 56% in total time and 61% to 64% in motion estimation time. Enhanced ADVS method decreases 0.19dB to 0.33dB in PSNR measurement while saving about 33% to 54% in total time and 60% to 63% in motion estimation time. The results improve 0.15dB and 0.2dB comparing to large block size when using FDVS and ADVS methods mentioned in the section 4.3.1. Table 4.5 shows the results of comparing to the terms in bit-rate.

	method\Item	PSNR	Total bits	Bit-rate
foreman	JM	37.37	1110216	277.55
	E-FDVS	37.28	1122888	280.72
	E-ADVS	37.24	1145720	286.43
news	JM	38.77	715416	178.25
	E-FDVS	38.49	912328	228.08
	E-ADVS	38.44	925120	231.28
hall	JM	38.15	741552	185.39
	E-FDVS	38.00	771536	192.88
	E-ADVS	37.96	787520	196.88
football	JM	35.32	4910904	1227.73
	E-FDVS	35.26	6259720	1564.23
	E-ADVS	35.18	6240010	1560.42

Table 4-5 Bit-rate of Propose Methods Comparing to H.264

Both of our propose methods, enhanced FDVS and enhanced ADVS, save a lot of bit-rate. This is because our propose methods do the operating of mode change and sub-division inter block to check whether the block need to be divided or not in aspect of RDcost. When we select the smaller inter block instead of choosing intra block, we have larger chance to save more bit-rate.

Figure 4.3 to figure 4.5 illustrate the bit-rate of different methods including JM on all modes, E-FDVS, E-ADVS, JM on large block size, FDVS, and ADVS in “foreman”, “news”, and “hall”. The figure shows that our propose methods are close to the reference software JM in terms of bit-rate.

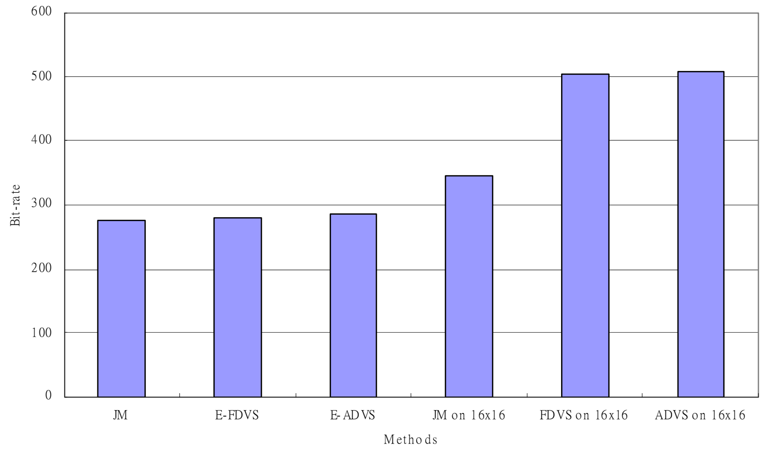


Fig. 4-3 Bit-rate of Different Methods in Foreman

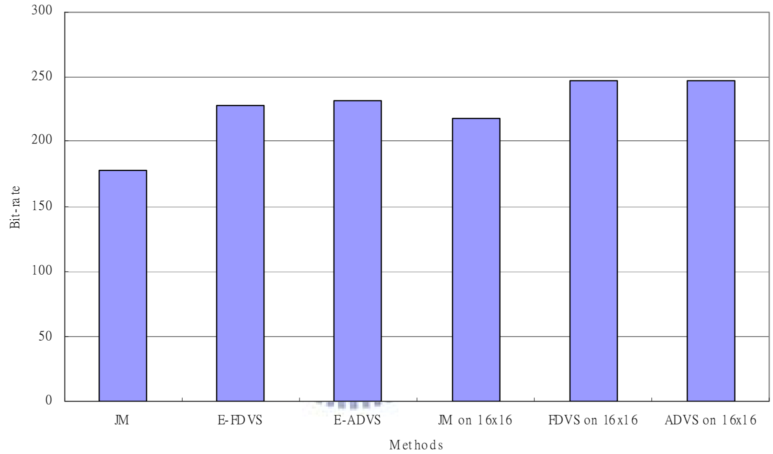


Fig. 4-4 Bit-rate of Different Methods in News

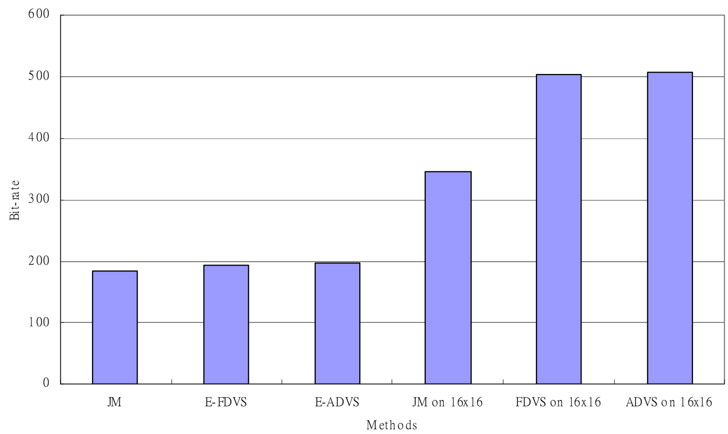


Fig. 4-5 Bit-rate of Different Methods in Hall

4.3 MV Selections for Mode Change and No Mode Change

In this thesis, we also curious about the effectiveness of the mode decision when we adopt the mode change in our propose mode decision flowchart or not. The quantity result of motion vector would change along with different block mode outcome. The procedure of how to do mode change and no mode change has brought up in the section 3.4.

Table 4.6 to Table 4.8 show the experimental results of mode change and no mode change.

Item \Methods	JM	E-FDVS	no mode change
PSNR	37.37	37.28	37.18
△PSNR	0	-0.09	-0.19
Decoding time	40.612	46.593	48.874
Encoding time	667.942	287.41	311.485
M.E. time	466.319	167.27	6.805
Transcoding time	708.554	334.003	360.359
△T. time(%)	0	-52.86%	-49.14%
△M.E.time(%)	0	-64.13%	-98.54%
Total bits	1110216	1122888	2535128
Bit-rate	277.55	280.72	633.78

Table 4-6 Comparing Mode Change with No Mode Change in foreman

Item\Methods	JM	E-FDVS	no mode change
PSNR	38.77	38.49	38.37
△PSNR	0	-0.28	-0.4
Decoding time	35.88	39.36	41.504
Encoding time	638.815	257.471	272.035
M.E. time	450.187	131.57	2.108
Transcoding time	674.695	296.831	313.539
△T. time(%)	0	-56.01%	-53.53%
△M.E.time(%)	0	-62.03%	-90.31%
Total bits	715416	912328	1256216
Bit-rate	178.25	228.08	314.05

Table 4-7 Comparing Mode Change with No Mode Change in news

Item\Methods	JM	E-FDVS	no mode chage
PSNR	38.15	38	37.91
△PSNR	0	-0.15	-0.24
Decoding time	35.409	39.532	42.421
Encoding time	637.313	250.448	265.067
M.E. time	448.267	133.23	4.089
Transcoding time	672.722	289.98	307.488
△T. time(%)	0	-35.31%	-31.41%
△M.E.time(%)	0	-61.46%	-89.62%
Total bits	741552	771536	985032
Bit-rate	185.39	192.88	246.26

Table 4-8 Comparing Mode Change with No Mode Change in hall

Although the method of no mode change saves more time, it also increases the bit-rate. The experimental results show that the effectiveness of mode change improves 0.09dB to 0.12dB in PSNR measurement when comparing to no mode change. Therefore, it is worthy of operating mode change to reduce bit-rate and improve the video quality.

Chapter 5 Conclusion

An efficient frame skipping transcoding from H.264/AVC to H.264/AVC including mode decision and motion vector decision methods had been proposed. In our propose methods, we obtain some information from the compressed video stream in H.264/AVC and then reuse them to decide the block mode types and motion vectors in the retained frame.

Our propose methods save more than 50% transcoding time and visual quality only reduced less than 0.2dB in most of the test sequences when comparing with H.264/AVC. Simulation results show that when comparing with all 16x16 mode, the propose methods improve the 0.2~0.3dB in PSNR measurement and reduce a lot of bit-rate. Besides, the experimental results also show that our propose methods improve about 0.1dB in average while comparing with no mode change. In future, we consider skipping not only one frame to make more decision about the block mode types and the length of motion vectors.

Reference

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Appendix A

Block Mode Type Observation

In this section, we observed about the block mode type relations between current frame and previous frame. Here, we abided by the relative macroblock location set up by the JM reference software—X, A, and B, as Fig. A.1 shows:

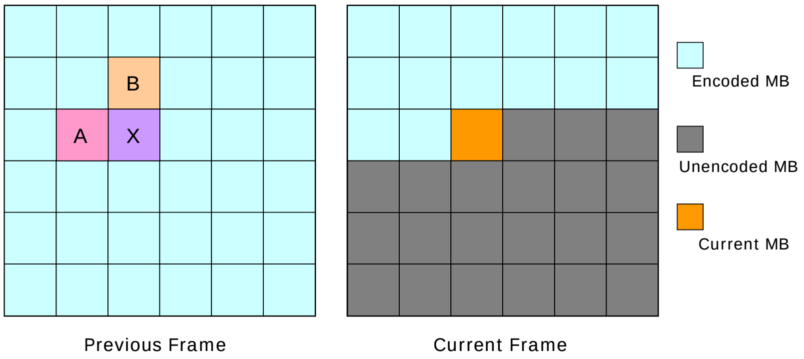
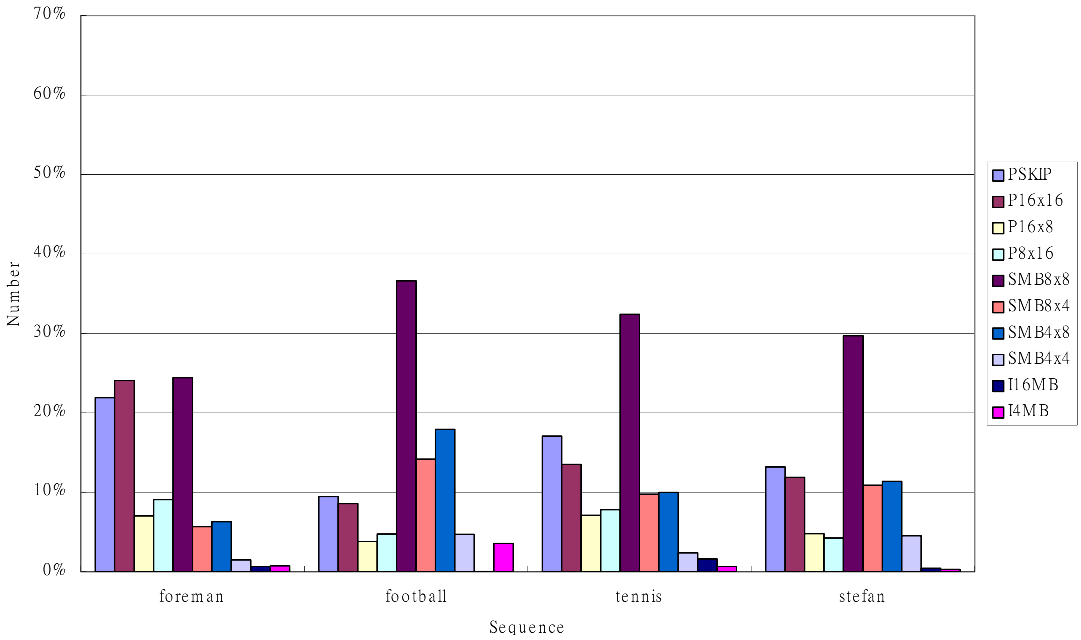


Fig. A.1 Macroblock relative location: X, A, and B

where X, A, and B represent the co-located, left, and up macroblock in the previous frame, respectively. Here we conducted different CIF sequences with 100 frame numbers per test sequence as inputs. The test sequences are Foreman, Football, Tennis, Stefan, Bus, Container, and Hall. Each kind of macroblock type, PSKIP, P16x16, P16x8, P8x16, SMB8x8, SMB8x4, SMB4x8, SMB4x4, Intra16x16, and Intra4x4, would be checked. Fig. A.2 exhibits each test sequence with 100 frames that contains the proportion of different kinds of macroblock type.



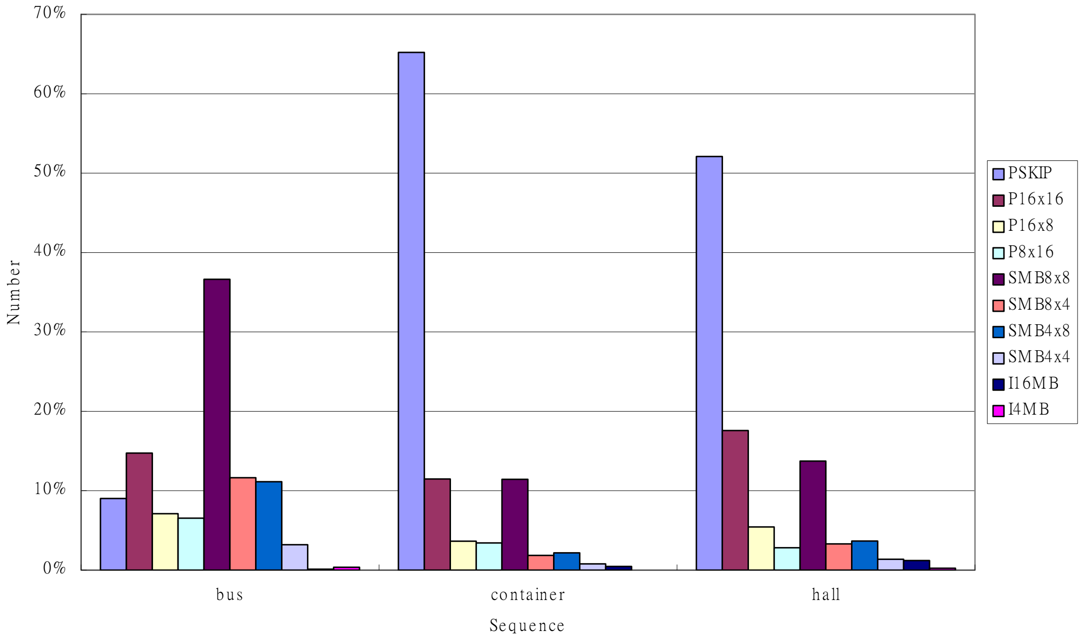


Fig. A.2 Statistic different MB types of each 100 test sequences in percentage (%)

Here, we divided different kinds of macroblock types into three parts. The first part is large macroblock type which includes PSKIP, P16x16, P16x8, and P8x16. The second part is called small macroblock type which contains from SMB8x8, SMB8x4, SMB4x8, and SMB4x4. The final part is intra macroblock type that comprises Intra4x4 and Intra16x16. The statistical data and the bar chart are shown as following in Table A.1 and figure A.3.

sequence	Large	Small	intra
football	25.65%	70.87%	3.47%
stefan	33.36%	55.24%	0.72%
bus	37.22%	62.31%	0.47%
tennis	44.48%	53.30%	2.22%
foreman	61.25%	37.38%	1.37%
hall	76.83%	21.76%	1.41%
container	83.36%	16.17%	0.47%

Table A.1 Catalog MB type in percentage

(Large: PSKIP~P8x16, Small: SMB8x8~SMB4x4)

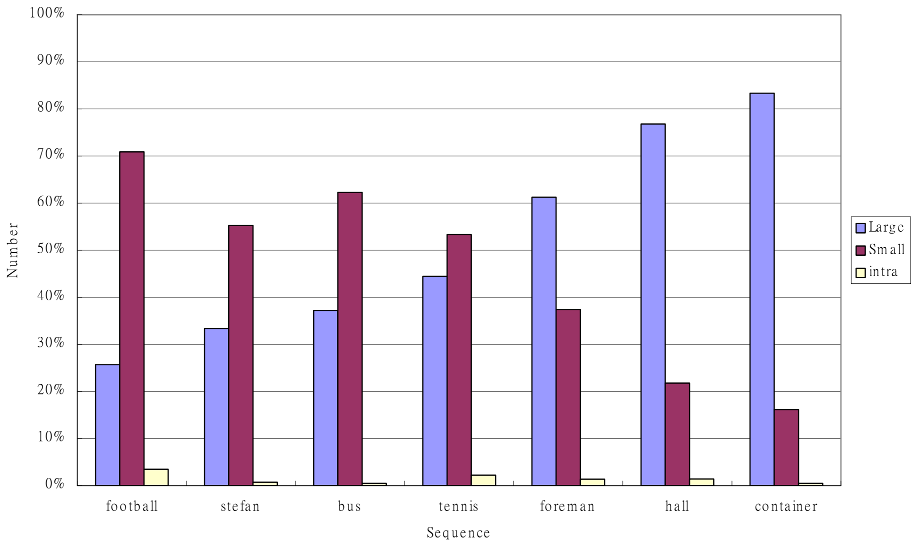


Fig. A.3 Catalog MB type in percentage

(Large: PSKIP~P8x16, Small: SMB8x8~SMB4x4)

Since the information mentioned above, we could conclude that higher percentage of larger macroblock obtained from test sequence means the test sequence is close to slow motion one. On the contrary, if the test sequence has higher percentage of small macroblock, it would be classified into high or fast motion sequence.

Table A.2 and Table A.3 illustrate the most and second frequent macroblock type appearance would be taken out and the statistical data would be revealed. Table A.1

shows the situation when current macroblock type is PSKIP.

sequence	PSKIP	P16x16	P16x8	P8x16	SMB8x8	SMB8x4	SMB4x8	SMB4x4	I16MB	I4MB
foreman	11777	12935	3773	4880	13132	3043	3392	797	350	398
football	7640	6919	3062	3849	29573	11454	14483	3802	34	2872
tennis	10899	8629	4535	4987	20691	6236	6374	1515	1028	422
stefan	8422	7587	3068	2715	18968	6963	7265	2884	283	189
bus	6609	10796	5200	4787	26828	8520	8159	2349	79	269
container	28960	5096	1609	1527	5079	823	969	345	205	3
hall	24064	8120	2515	1295	6349	1523	1693	631	559	102

Table A.2 Statistic different MB types of each 100 test sequences

sequence	PSKIP	P16x16	P16x8	P8x16	SMB8x8	SMB8x4	SMB4x8	SMB4x4	I16MB	I4MB
foreman	21.92%	24.07%	7.02%	9.08%	24.44%	5.66%	6.31%	1.48%	0.65%	0.74%
football	9.46%	8.57%	3.79%	4.76%	36.61%	14.18%	17.93%	4.71%	0.04%	3.56%
tennis	17.07%	13.51%	7.10%	7.81%	32.40%	9.76%	9.98%	2.37%	1.61%	0.66%
stefan	13.19%	11.88%	4.80%	4.25%	29.70%	10.90%	11.38%	4.52%	0.44%	0.30%
bus	9.02%	14.74%	7.10%	6.54%	36.63%	11.63%	11.14%	3.21%	0.11%	0.37%
container	65.21%	11.48%	3.62%	3.44%	11.44%	1.85%	2.18%	0.78%	0.46%	0.01%
hall	52.10%	17.58%	5.44%	2.80%	13.75%	3.30%	3.67%	1.37%	1.21%	0.22%

Table 5.3 Statistic different MB type in percentage

Appendix B

Motion Vector Observation

Observing and understanding the quantity of motion vector between different macroblock type and different test sequences is the goal of this experiment. In the experiments, we also examined different sequences including Foreman, Football, Tennis, Stefan, Bus, Container, and Hall. Table B.1 shows all kinds of inter macroblock with the rates of motion vector length of the sequence “Foreman”.

block\mv len.	0~1	2~4	5~8	9~15	16~30	31~50	51~100	101up
P16x16	22.72%	32.57%	20.64%	13.19%	7.75%	2.52%	0.55%	0.06%
P16x8	20.12%	27.46%	21.20%	14.55%	9.28%	5.17%	1.72%	0.50%
P8x16	23.57%	29.16%	22.42%	13.36%	8.03%	2.77%	0.57%	0.12%
SMB8x8	25.02%	28.65%	21.37%	12.79%	7.66%	3.72%	0.57%	0.22%
SMB8x4	24.88%	28.06%	20.97%	12.42%	8.61%	3.84%	0.95%	0.26%
SMB4x8	27.00%	27.86%	21.55%	12.85%	7.40%	2.62%	0.53%	0.18%
SMB4x4	28.86%	29.99%	23.71%	10.79%	4.14%	2.13%	0.25%	0.13%

Table B.1 All MB mode and its MV length in percentage (Foreman)

Notice that since the precision of motion vector can up to one-quarter pixel in H.264/AVC, the unit of the MV has multiplied by four.

Table B.2 to Table B.7 shows all kinds of inter macroblock with the rates of motion vector length of the sequence Football, Tennis, Stefan, Bus, Container, and Hall.

block\mv len.	0~1	2~4	5~8	9~15	16~30	31~50	51~100	101up
P16x16	44.33%	36.84%	7.72%	3.44%	4.83%	2.02%	0.79%	0.03%
P16x8	34.16%	26.62%	9.76%	8.88%	10.32%	5.78%	3.40%	1.08%
P8x16	35.46%	28.58%	10.73%	7.01%	9.43%	5.07%	2.88%	0.83%
SMB8x8	31.26%	25.78%	12.33%	10.82%	10.65%	5.29%	2.95%	0.92%
SMB8x4	27.81%	24.20%	14.05%	12.79%	11.53%	5.49%	2.97%	1.16%
SMB4x8	27.01%	27.06%	14.46%	12.31%	10.96%	4.86%	2.58%	0.76%
SMB4x4	28.46%	29.17%	15.97%	11.65%	8.44%	3.76%	1.76%	0.79%

Table B.2 All MB mode and its MV length in percentage (Football)

block\mv len.	0~1	2~4	5~8	9~15	16~30	31~50	51~100	101up
P16x16	28.15%	17.52%	16.93%	24.28%	8.61%	3.13%	1.08%	0.30%
P16x8	25.47%	16.67%	17.95%	22.27%	10.32%	4.61%	2.14%	0.57%
P8x16	22.80%	24.38%	19.71%	21.05%	7.98%	2.47%	1.32%	0.28%
SMB8x8	29.33%	21.60%	17.35%	17.97%	8.38%	3.51%	1.47%	0.40%
SMB8x4	31.03%	20.33%	16.31%	16.95%	8.32%	4.39%	2.05%	0.61%
SMB4x8	26.80%	22.11%	18.28%	18.34%	8.53%	4.31%	1.30%	0.33%
SMB4x4	34.65%	20.99%	13.53%	16.57%	8.38%	3.50%	1.91%	0.46%

Table B.3 All MB mode and its MV length in percentage (Tennis)

block\mv len.	0~1	2~4	5~8	9~15	16~30	31~50	51~100	101up
P16x16	19.20%	12.64%	7.75%	13.52%	26.52%	10.18%	8.61%	1.58%
P16x8	23.04%	10.37%	7.95%	13.43%	24.25%	10.07%	8.60%	2.28%
P8x16	19.56%	10.17%	8.88%	14.73%	25.34%	10.17%	9.54%	1.62%
SMB8x8	19.56%	10.17%	8.88%	14.73%	25.34%	10.17%	9.54%	1.62%
SMB8x4	16.37%	10.21%	7.77%	15.11%	27.03%	11.03%	9.72%	2.76%
SMB4x8	14.87%	9.51%	9.64%	16.30%	29.68%	9.69%	8.51%	1.82%
SMB4x4	17.16%	9.15%	8.04%	15.71%	27.88%	11.10%	9.29%	1.66%

Table B.4 All MB mode and its MV length in percentage (Stefan)

block\mv len.	0~1	2~4	5~8	9~15	16~30	31~50	51~100	101up
P16x16	2.92%	2.52%	5.05%	12.04%	50.03%	14.17%	10.85%	2.43%
P16x8	4.00%	4.63%	8.12%	13.81%	41.38%	14.15%	11.00%	2.90%
P8x16	3.01%	2.88%	5.49%	11.13%	44.52%	16.61%	14.10%	2.26%
SMB8x8	6.31%	5.36%	8.78%	12.27%	42.08%	12.80%	10.52%	1.87%
SMB8x4	12.17%	5.70%	9.98%	12.66%	37.59%	10.86%	9.32%	1.71%
SMB4x8	6.73%	6.73%	10.27%	12.92%	39.51%	11.31%	10.81%	1.72%
SMB4x4	9.92%	6.60%	11.92%	11.20%	38.78%	10.34%	9.75%	1.49%

Table B.5 All MB mode and its MV length in percentage (Bus)

block\mv len.	0~1	2~4	5~8	9~15	16~30	31~50	51~100	101up
P16x16	55.87%	40.70%	1.31%	0.67%	0.96%	0.16%	0.22%	0.12%
P16x8	57.18%	38.66%	1.43%	0.56%	0.68%	0.37%	0.75%	0.37%
P8x16	53.57%	41.52%	2.16%	0.52%	1.18%	0.39%	0.39%	0.26%
SMB8x8	67.18%	30.48%	1.40%	0.32%	0.47%	0.00%	0.16%	0.00%
SMB8x4	71.45%	25.76%	1.70%	0.12%	0.97%	0.00%	0.00%	0.00%
SMB4x8	69.25%	29.41%	1.14%	0.00%	0.21%	0.00%	0.00%	0.00%
SMB4x4	64.06%	32.17%	2.32%	0.87%	0.58%	0.00%	0.00%	0.00%

Table B.6 All MB mode and its MV length in percentage (Container)

block\mv len.	0~1	2~4	5~8	9~15	16~30	31~50	51~100	101up
P16x16	93.74%	2.54%	1.15%	1.42%	0.85%	0.25%	0.05%	0.01%
P16x8	92.41%	2.82%	1.43%	1.91%	1.11%	0.20%	0.12%	0.00%
P8x16	87.49%	3.86%	3.09%	3.01%	1.93%	0.54%	0.08%	0.00%
SMB8x8	79.79%	7.51%	4.90%	4.55%	2.35%	0.60%	0.25%	0.05%
SMB8x4	71.63%	11.29%	6.83%	6.37%	3.41%	0.07%	0.33%	0.07%
SMB4x8	59.30%	14.83%	10.63%	8.56%	4.61%	0.95%	1.12%	0.00%
SMB4x4	68.30%	13.95%	7.77%	6.50%	2.06%	0.79%	0.63%	0.00%

Table B.7 All MB mode and its MV length in percentage (Hall)

Appendix C

FDVS, ADVS, and PADVS(n) Methods on Large Block Size

Originally, all of the methods such as FDVS, ADVS, and PADVS(n) are used on MPEG-2 video standard. Unlike H.264/AVC, the macroblock modes of MPEG-2 are not as many as H.264/AVC. MPEG-2 video standard contains only four modes, SKIP mode, intra mode, inter mode with motion compensation, and inter mode with zero motion. For the sake of applying to our variable block size in H.264/AVC, we simulate the operation by closing some mode search in H.264/AVC. Hence, we close the following mode search parameters in reference software JM:

PSliceSearch16x8 = 0

PSliceSearch8x16 = 0

PSliceSearch8x8 = 0

PSliceSearch8x4 = 0

PSliceSearch4x8 = 0

PSliceSearch4x4 = 0

And then we reserve the mode search of P16x16, PSKIP, and intra16x16 which are all size of 16x16 block modes.

The meaning of FDVS method is to find out the dominant macroblock that has the largest overlapping area pointed by the current motion vector. However, due to the motion vector precision up to quarter-pixel in H.264/AVC, calculating the overlapping area is not a nice manner since it is a little redundant. So, we propose a better way to find out largest overlapping area instead. Figure C.1 illustrates the FDVS method on all 16x16 modes.

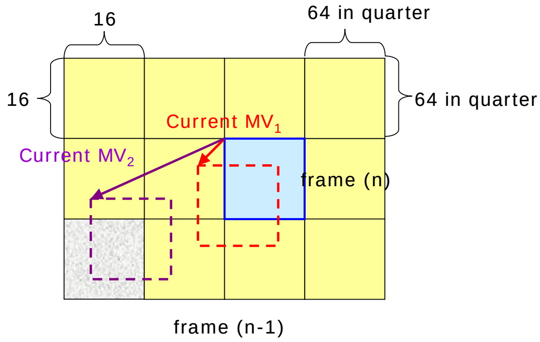


Fig. C.1 Illustrates the FDVS method on all 16x16 modes

There exist two current motion vectors, MV1 and MV2. The blue macroblock is the target one that we want to find its dominant motion vector in frame (n). Suppose we have two different quantities of current motion vectors as following,

```
currMB_mv_x = mv_x_info[img->number][(currMB->mbAddrX)/22][(currMB->mbAddrX)%22];
currMB_mv_y = mv_y_info[img->number][(currMB->mbAddrX)/22][(currMB->mbAddrX)%22];
```

And then we separate the motion vector by x and y direction. As shown in figure C.2.

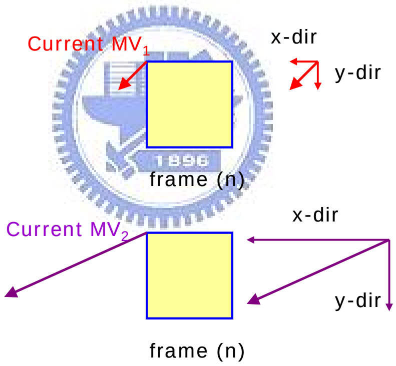


Fig. C.2 Separate the current MV in x and y direction

After separating the motion vector in the coordination of x and y, we use the following formula to find out the dominant macroblock.

$$Qx = (current\_mv\_x)/32$$

$$Qy = (current\_mv\_y)/32$$

Qx and Qy are quantities of the shift offset location in x and y direction. In out examples, current MV1 would occupy the blue macroblock which is the dominant macroblock while current MV2 would occupy the purple macroblock as dominant one. We can find out the dominant motion vector from the following array then.

```
Dominant_mv_x = mv_x_info[img->number - 1][(currMB->mbAddrX)/22 + Qy][(currMB->mbAddrX)%22 + Qx];
Dominant_mv_y = mv_y_info[img->number - 1][(currMB->mbAddrX)/22 + Qy][(currMB->mbAddrX)%22 + Qx];
```

Finally, we finish finding out the dominant motion vector by using FDVS method on all 16x16 block modes.

Like FDVS, ADVS method is also used in MPEG-2 video standard. To analyze the ADVS method, we nose out that ADVS is much complex than FDVS because we have to calculate the number of non-zero quantized coefficients that the area is covered by the macroblock. Figure C.3 and C.4 illustrate situations that the ADVS method covered on the 8x8 block.

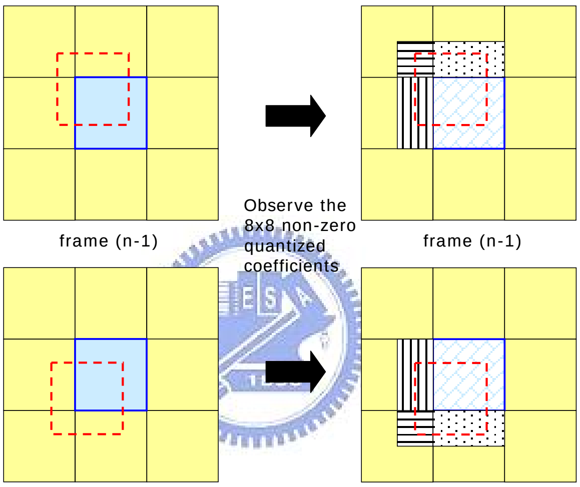


Fig. C.3 The first case of ADVS covering on all 16x16 block modes

In the first case shown in figure C.3, regardless of the quantities of current motion vector, the red dotted line represents the area of final result after adding current motion vector. What we care about is the direction of x and y, that is we want to know whether they are positive or negative. The upper one in the first case, except the center macroblock covered four 8x8 sub-blocks, we also need to calculate two 8x8 sub-blocks above and next to the center macroblock. Finally, still one 8x8 sub-block at the corner of the remaining covered macroblock is needed to be counted. So do the same operations in figure C.4.

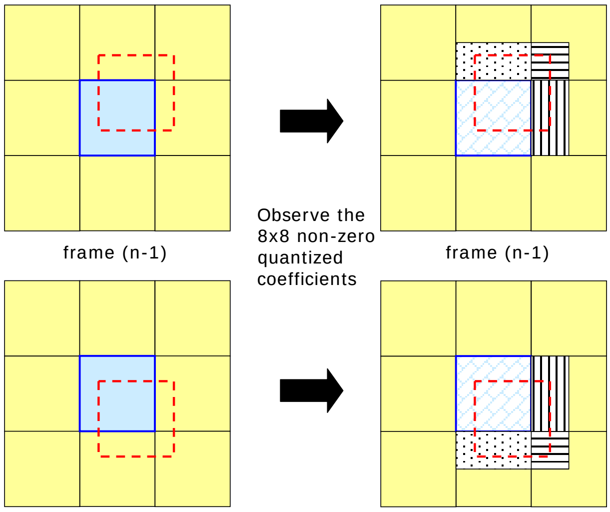


Fig. C.4 The second case of ADVS covering on all 16x16 block modes

We sum up the rules of ADVS as the followings:

If the location of the center macroblock is called (x, y), see in figure C.5.

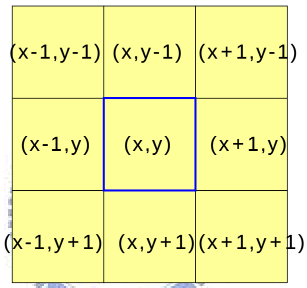


Fig. C.5 The representation of the ADVS location

Algorithm:

If x is *positive*, then calculate the *right part* of two 8x8 sub-blocks at (x-1, y)
    If y is *positive*, then calculate the *upper part* of two 8x8 sub-blocks at (x, y+1)
        and *upper-right part* of one 8x8 sub-block at (x-1, y+1)
    If y is *negative*, then calculate the *lower part* of two 8x8 sub-blocks at (x, y-1)
        and *lower-right part* of one 8x8 sub-block at (x-1, y-1)
If x is *negative*, then calculate the *left part* of two 8x8 sub-blocks at (x+1, y)
    If y is *positive*, then calculate the *upper part* of two 8x8 sub-blocks at (x, y+1)
        and *upper-left part* of one 8x8 sub-block at (x+1, y+1)
    If y is *negative*, then calculate the *lower part* of two 8x8 sub-blocks at (x, y-1)
        and *lower-left part* of one 8x8 sub-block at (x+1, y-1)

PADVS(n) method on all 16x16 block is similar with ADVS method. The only different between PADVS(n) and ADVS is the parameter n which n represents low frequency DCT coefficients in the estimation of activity. Besides, n is a set of DCT coefficients in the zigzag scan order. The set of is defined as follows,

$$n = \{1,3,6,10,15,21,28,36,43,49,54,58,61,63,64\}$$

Since a 8x8 DCT quantized coefficients has 64 coefficients, the opinion of PADVS(n) is that using all of the 64 DCT coefficients to select the dominant macroblock is a computationally expensive process. Study of the human visual system (HVS) reveal that high frequency DCT coefficients usually have little impact on the perception except showing finer details. Although activity estimation is seemingly unrelated to image perception, the inherent correlation leads to the obvious query whether the impact of the high frequency DCT coefficients is minimal compared to that by the low frequency components, including the DC.

An affirmative response to this query would lead to ignore the high frequency coefficients in selecting the dominant macroblock and thus reducing the overall computational complexity. This is an added benefit of ignoring the high frequency coefficients.

Table C.1 to Table C.4 are the experimental results of FDVS, ADVS, and PADVS(n) methods on large block size.

Item\Methods	JM	FDVS	ADVS	PADVS(n)				
				n=1	n=3	n=10	n=36	n=49
PSNR	38.58	38.26	38.24	38.24	38.25	38.24	38.25	38.25
△PSNR	0	-0.32	-0.34	-0.34	-0.33	-0.34	-0.33	-0.33
Decoding tim	0	52.371	35.153	35.026	33.784	33.767	34.064	33.768
Encoding tim	406.118	69.246	68.865	68.114	67.71	68.395	67.686	70.955
M.E. time	357.946	3.805	4.037	4.15	3.899	4.141	4.064	4.243
Total time	406.118							
Transcoding time		121.617	104.018	103.14	101.494	102.162	101.75	104.723
△T. time(%)	0	-70.05%	-74.39%	-74.60%	-75.01%	-74.84%	-74.95%	-74.21%
△M.E.time(%	0	-84.31%	-89.05%	-89.06%	-89.47%	-89.41%	-89.35%	-89.38%
Total bits	871368	988688	987720	994600	995000	994600	994000	994000
Bit-rate	217.84	247.17	246.93	248.65	248.75	248.65	248.5	248.5

Table C.1 Experimental results of FDVS, ADVS and PADVS(n) on news.cif

Item\Methods	JM	FDVS	ADVS	PADVS(n)				
				n=1	n=3	n=10	n=36	n=49
PSNR	37.99	37.85	37.85	37.85	37.85	37.85	37.85	37.85
△PSNR	0	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14
Decoding tim	0	53.521	35.803	35.579	34.881	35.015	35.55	34.941
Encoding tim	407.22	69.246	68.865	68.114	67.71	68.395	67.686	70.955
M.E. time	358.403	3.758	3.908	3.911	3.843	4.048	4.029	4.026
Total time	407.22							
Transcoding time		122.767	104.668	103.693	102.591	103.41	103.236	105.896
△T. time(%)	0	-69.85%	-74.30%	-74.54%	-74.81%	-74.61%	-74.65%	-74.00%
△M.E.time(%	0	-84.02%	-88.92%	-88.98%	-89.20%	-89.10%	-88.96%	-89.13%
Total bits	856472	991664	984448	993432	991904	991792	990880	991472
Bit-rate	214.12	247.92	246.11	248.36	247.98	247.95	247.72	247.87

Table C.2 Experimental results of FDVS, ADVS and PADVS(n) on hall.cif

Item\Methods	JM	FDVS	ADVS	PADVS(n)				
				n=1	n=3	n=10	n=36	n=49
PSNR	34.9	34.74	34.69	34.69	34.7	34.7	34.7	34.69
△PSNR	0	-0.16	-0.21	-0.21	-0.2	-0.2	-0.2	-0.21
Decoding tim	0	71.366	50.806	51.029	50.373	50.023	50.042	50.014
Encoding tim	422.698	152.031	149.034	149.586	148.849	149.355	149.147	151.744
M.E. time	361.711	4.187	4.148	4.306	4.247	4.249	4.139	4.247
Total time	422.698							
Transcoding time		223.397	199.84	200.615	199.222	199.378	199.189	201.758
△T. time(%)	0	-47.15%	-52.72%	-52.54%	-52.87%	-52.83%	-52.88%	-52.27%
△M.E.time(%	0	-79.11%	-84.81%	-84.70%	-84.90%	-85.00%	-85.02%	-85.00%
Total bits	5676504	5793464	5793280	5793280	5792768	5794584	5797456	5794504
Bit-rate	1419.13	1448.37	1448.32	1448.32	1448.19	1448.65	1449.36	1448.63

Table C.3 Experimental results of FDVS, ADVS and PADVS(n) on football.cif

Item\Methods	JM	FDVS	ADVS	PADVS(n)				
				n=1	n=3	n=10	n=36	n=49
PSNR	36.42	36.35	36.31	36.31	36.31	36.31	36.31	36.31
△PSNR	0	-0.07	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Decoding tim	0	71.191	45.925	44.935	45.158	44.565	44.259	45.15
Encoding tim	416.704	152.325	152.653	151.693	152.327	151.699	151.821	151.352
M.E. time	359.681	4.053	4.253	4.417	4.399	4.395	4.308	4.267
Total time	416.704							
Transcoding time		223.516	198.578	196.628	197.485	196.264	196.08	196.502
△T. time(%)	0	-46.36%	-52.35%	-52.81%	-52.61%	-52.90%	-52.95%	-52.84%
△M.E.time(%	0	-79.08%	-86.05%	-86.28%	-86.22%	-86.39%	-86.50%	-86.26%
Total bits	5257072	5646872	5638584	5600928	5592240	5596264	5596264	5596264
Bit-rate	1313.27	1411.72	1409.65	1400.23	1398.06	1399.07	1399.07	1399.07

Table C.4 Experimental results of FDVS, ADVS and PADVS(n) on flower.cif