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# Analysis of Fast Computing Algorithms Using Macro block Motion Decision in H.264

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***Abstract* - The latest video-coding standard H.264IAVC, which adopts rate distortion optimization (RDO), can achieve better coding efficiency. However, several techniques, such as inter mode and intra mode selection need to check all the prediction modes. So, it will greatly increase computational complexity. In this paper, a fast algorithm based on the macroblock motion decision was proposed to reduce the computational complexity of the motion estimation process in H.264. The results show that this fast algorithm can reduces computing time .The optimal coding mode for each macroblock (MB) is selected by exhaustively searching all MB modes in the multiple reference frames motion estimation. The exhaustive mode search has a very high computational complexity. This paper proposes two different approaches along with their combination to reduce the complexity of the rate-distortion optimized mode decision process in H.264. These approaches are based on temporal correlation in video sequences. Experimental results demonstrate that the proposed methods achieve improvement in average speedup with good prediction quality.**

***Keywords*: motion estimation (ME), macroblock, variable block size, computational complexity, speedup**

## I. INTRODUCTION

The H.264/AVC is the state-of-the-art video compression standard recently developed by the ITU-T/ISO/IEC Joint Video Team [1]. Compared to previous standards, this new video coding standard can deliver significantly improved compression efficiency, which makes it possible to transmit high quality video over lower bit rate channels. In addition, the increased flexibility of H.264 encoding and transmission caters to a broad spectrum of video applications enabling new video services over cable, satellite and mobile networks. However, these performance gains of H.264 come at a cost of increased computational complexity [2]. The decoding complexity increases by a factor of four, whereas the encoding complexity may be as high as nine times over MPEG-2. This huge increase in encoder complexity is mainly due to Rate-Distortion Optimization (RDO) of the Motion Estimation (ME) and Mode decision (MD) processes in H.264.

Fig. 1 shows the different Macroblock(MB) modes used in H.264. An MB with large partition size requires a single motion vector to represent its motion information. However, a single motion vector may not be able to accurately represent the motion information of the entire MB resulting in a large residual error and hence a large number of bits for encoding the transformed residual error. Small MB size reduces the residual error but increase the computational complexity.

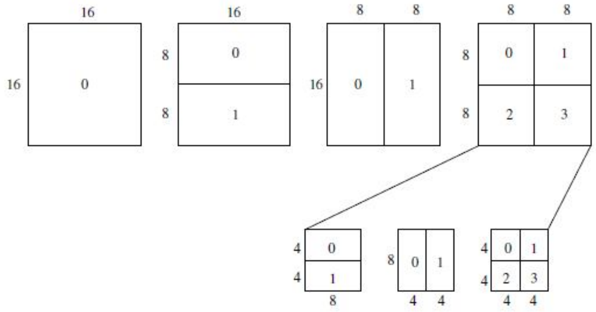

Fig. 1 Variable Block Sizes in H.264 Motion Compensation

## II. FAST RATE DISTORTION OPTIMIZATION IN H.264

Rate-distortion optimization techniques have been widely applied to video encoders [3]. The RDO techniques result in substantial improvement in compression efficiency. In RDO, the Lagrangian minimization method is used to find the best MB mode among the modes of {INTER16X16, INTER16X8, INTER8X16, INTER8X8, INTER8X4, INTER4X8, INTER4X4, SKIP}. For each MB in an inter-frame, the RDO is first used to obtain the optimal motion vector by minimizing the cost function,

$$J\mathrm{motiom}(mv, \lambda) = D(s, c(mv)) + \lambda R(mv - pmv) \qquad (1)$$

where, *mv* is the motion vector obtained by motion estimation, *pmv* is the predicted motion vector and $\lambda$ is the Lagrange multiplier. *R(mv-pmv)* represents the motion information and *D(s,c(mv))* is the sum of absolute differences (SAD) between the original video signal *s* and the coded video signal *c*. To take the full advantage of these modes, the H.264 encoder can select the best mode by using the rate-distortion optimization (RDO) calculations. The specific process is described as follows: First, given the encoded frame and quantitative parameters, we can get Lagrange multipliers with the following formula:

(2)

The SAD (Sum of Absolute Differences) is computed

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

as:

$$SAD(s,\ c(\mathbf{m})) = \sum_{x=1,\ y=1}^{B,\ B} \left| s[x, y] - c[x - m_x, y - m_y] \right|$$

(3)

### A. Skip Prediction based Fast RDO

The H.264/AVC JM encoder [1] identifies certain MBs as skipped during encoding. The MB whose motion vectors are zero is called skip MB.The encoding of these MBs are skipped by the encoder. In the decoder, the skipped MB is reconstructed by motion-compensated prediction from the current reference picture using a motion vector predicted from previously decoded motion vectors. The SKIP mode has the lowest RD cost (*J*) among all MB encoding modes. Moreover, checking of SKIP mode involves the lowest complexity. Thus, a SKIP decision at the start of the mode decision process can substantially lower the entire encoder complexity. However, incorrect skip decisions may increase the bit rate and may also result in a loss of picture quality.

### B. Reference Frame Selection

In H.264 motion estimation, the encoder searches for MVs in multiple reference frames (max 16, as per JM10.2 reference implementation) to obtain the best mode decision. For each reference frame, the motion estimation algorithm is executed for all possible modes of an MB. This essentially increases the motion estimation time in multiples of the number of reference frames used. Our proposed algorithm selects a reference frame from previous four frames, based on an initial estimate of the Rate-Distortion (RD) cost for the reference frame. Then the selected reference frame is used to find the best mode for the MB. Based on the temporal correlation, a predicted motion vector (which is also used for SKIP cost calculation) is used as the center of the motion vector search region. This idea has been extended to predict the minimum RD cost for the best mode of the MB, for a particular reference frame .SKIP RD Cost of an MB is defined as the RD Cost, assuming SKIP mode for the MB, for a particular reference frame.

For a moving object in a video frame, if the particular MB is part of the same object as its neighboring MBs, the motion vector and reference frame for the current MB will be similar to its neighboring ones. Since in SKIP mode, the motion vector predicted from neighboring MBs is used, this SKIP RD cost for this MB will be minimum among all reference frames. However, if MB is not a part of the same object in motion, the SKIP RD cost will be high. So, the reference frame, which gives minimum SKIP RD Cost, will also give the minimum RD cost among all modes.

## III PROPOSED MB MODES PREDICTION ALGORITHMS

Success of the proposed fast mode selection algorithm for interface coding is achieved by intrinsic complexity of the macroblock and the mode knowledge of the previously encoded frame(s) .Intuitively, a mode having a smaller partition size may be beneficial for detailed areas during motion estimation process, whereas a larger partition size is more suitable for homogeneous areas. Therefore the primary goal is to apply a complexity measurement to each macroblock.

**Basic Measurement**

H.264 video coding standard uses variable block size motion estimation. One macroblock is divided as several different kinds of partition types: 16×16(mode 1), 16×8(mode 2), 8×16(mode 3), 8×8 (mode 4).Under 8×8 (mode 4). Each 8×8 block is divided as 8×4(mode 5), 4×8(mode 6), 4×4 (mode 7), as shown in Fig. 2

The algorithm for mode decision MD16, MD8 and MD4 can be listed as follows:

***MD16* category algorithm** (apply to homogeneous macroblock) is summarized as follows:

*(i)*. Obtain a motion vector for a 16X16 macroblock by using the full search algorithm with search range of ±8 pixels.

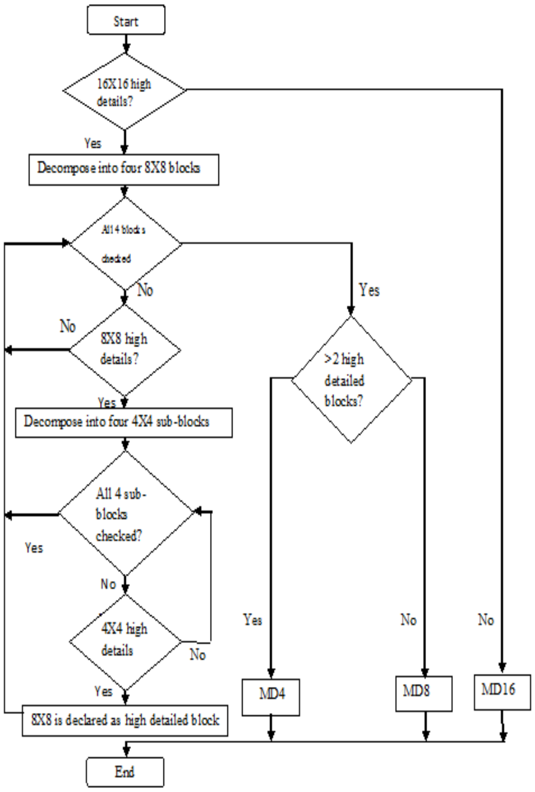

Fig.2: Flowchart For Microblock and Sub-macroblock Decision

*(ii)*. Compute the Lagrangian costs of *SKIP* to find a final mode decision for the current macroblock.

***MD8* category algorithm** (apply to medium-detailed macroblock):

*(i)*. Obtain a motion vector for each of the four 8X8 blocks in a macroblock by using the full search algorithm with search range of ±8 pixels.

*(ii)*. Continue to search for motion vector(s) for the 8X16 blocks, 16X8 blocks, and 16X16 macroblock by referring only to the 4 search points, i.e., the motion vectors of the four 8X8 blocks.

*(iii)*. Perform step A2 to find the final mode decision for the current macroblock.

***MD4* category algorithm** (apply to high-detailed macroblock):

*(i)*. Obtain a motion vectors for each of the sixteen 4X4 blocks in a macroblock by using the full search algorithm with search range of ±8 pixels.

*(ii)*. Continue to search for motion vector(s) for 8X4 blocks, 4X8 blocks, and 8X8 blocks by referring only to the 16 search points, i.e., the motion vectors of the sixteen 4X4 blocks.

*(iii)*. Perform steps B2 to B3 to find the final mode decision for current macroblock.

## IV. RESULTS

Experiments were performed on the MATLAB (R2009) Windows7 platform. The results for performance analysis were collected for by keeping the Quantization Parameter (QP) as 28. The simulations have been performed on the luminance as well as chrominance component of the popular video sequences listed in Table 1. These sequences consist of different degrees and types of motion and are in QCIF (176×144); CIF (352×288) formats. The first three sequences, namely, *Akiyo*, *Suzie* and *Clarie* are in QCIF format. The next three sequences are *Coastguard*, Flower and *Bus* in CIF format. Among these sequences, *Akiyo* ,*Suzie and Clarie* has gentle, smooth and low motion change and consists mainly of stationary and quasi- stationary blocks. *Coastguard, Flower* and *Bus* has moderately complex motion and hence is categorized as "medium" motion content sequences. Image sequences are always IPPPPP and no B frames were used.

**Table 1 Test sequences used in Analysis**

| **Name** | **Format** | **Frames** | **Motion** |
|---|---|---|---|
| Claire | QCIF (176x144) | 494 | Low |
| Akiyo | QCIF (176x144) | 300 | Low |
| Suzie | QCIF (176x144) | 150 | Low |
| Coastguard | CIF (352x288) | 300 | Medium |
| bus | CIF (352x288) | 150 | Medium |
| flower | CIF (352x288) | 250 | Medium |

Fig.3 PSNR for variable block sizes for CIF Bus sequence shows that for macroblock size 16x16 PSNR drops which increases for reduced block size (4x4).

Fig.4 indicates increase in computational complexity with reduction in block size. When block size is 16x16 computational complexity is less which increases when the block size is reduced towards 4x4. The proposed schemes, tested on the sequences given in the Fig. 4 Computation for Variable Block Sizes for Bus Fig.5 Skip Block Count in CIF Bus Table 1. Fig.5 shows Skip Block count in CIF Bus which is based on motion vector calculation. If the motion vector of macroblock predicted is zero that is a good approximation for SKIP prediction. Table 2 shows average PSNR of 100 successive frames. Figs 6-11 shows PSNR for 16x16 block size with single reference frame(FS 16x16) , PSNR for variable block size with single reference frame(FS Variable Block Size) PSNR for 16x16 block size with multiple reference frame(FS MultiRef 16x16) ,PSNR for Variable block size with multiple reference frame for luma component (FS MultiRef Multi-mode_Y). PSNR for Variable block size with multiple reference frame for chroma(red) (FS MultiRefMultimode_U), PSNR for Variable block size with multiple reference frame for chroma(blue)(FS_MultiRefMultimode_V).

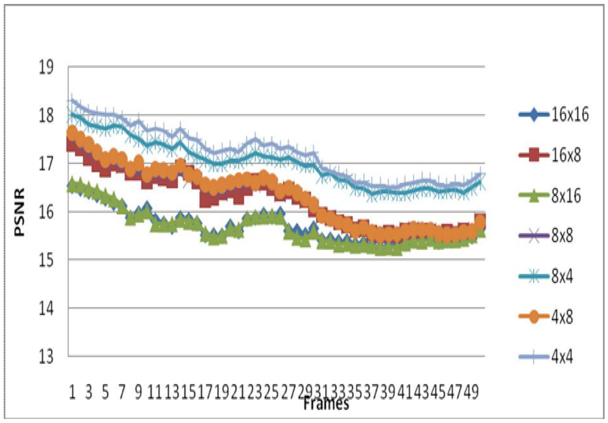

Fig. 3 PSNR for Variable Block Sizes for Bus

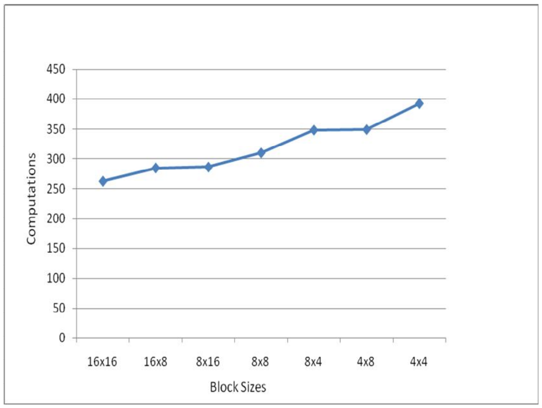

Fig. 4 Computations for Variable Block Sizes CIF Bus

First three graphs show slow motion in video sequence with approximate same PSNR is obtained for variable block size and variable block size with multiple reference frame. Similar results are obtained for next three sequences which have medium motion.Fig.12 shows percentage speedup in different video sequence.

Table 2 Average PSNR of 100 Successive Frames

| **Name of the Video** | **ES_16x16** | **ES_Variable Block Size** | **ES_16x16 Multiref** | **ES_ Variable Block Size Multiref_Y** | **ES_ Variable Block Size Multiref_U** | **ES_ Variable Block Size Multiref_V** |
|---|---|---|---|---|---|---|
| Claire | 41.33 | 41.48 | 41.75 | 42.08 | 50.24 | 51.08 |
| Akiyo | 42.26 | 42.79 | 42.8 | 43.44 | 55.11 | 55.54 |
| Suzie | 33.57 | 34.6 | 34.44 | 35.41 | 51.05 | 50.57 |
| Coastguard | 28.02 | 29.11 | 28.38 | 29.43 | 48.14 | 49.9 |
| bus | 23.25 | 24.92 | 23.84 | 25.4 | 43.59 | 45.8 |
| flower | 24.9 | 25.24 | 25.61 | 25.95 | 37.72 | 43.26 |

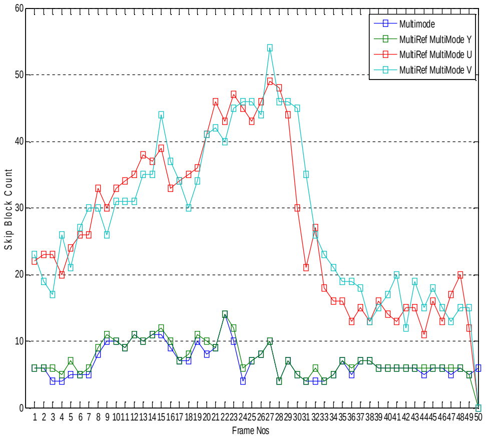

Fig. 5 Skip Block Count in CIF Bus

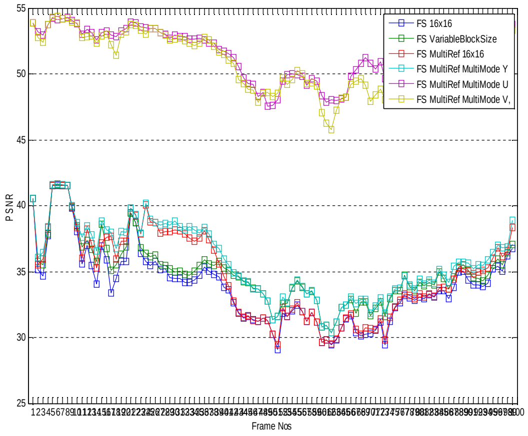

Fig.7 PSNR QCIF Suzie for 100 frames

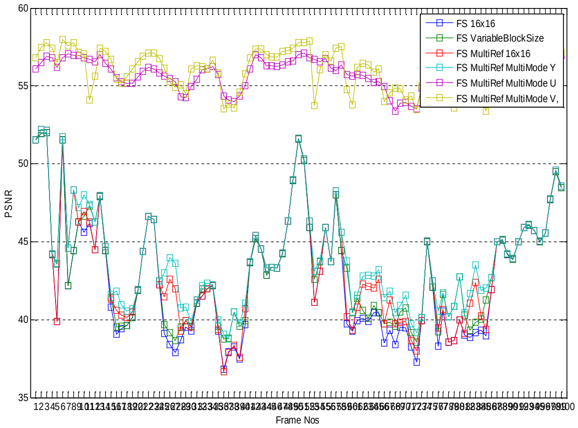

Fig.6 PSNR QCIF Akiyo for 100 frames

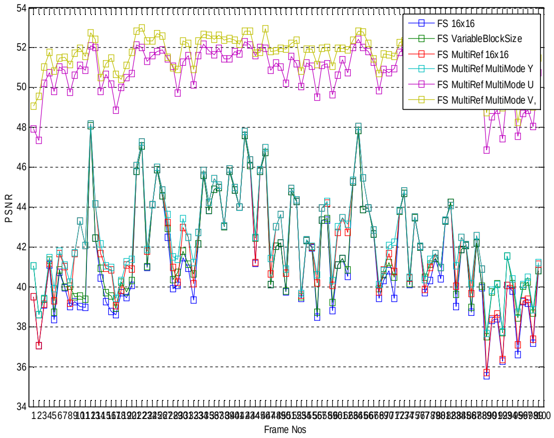

Fig.8 PSNR QCIF Claire for 100 frames

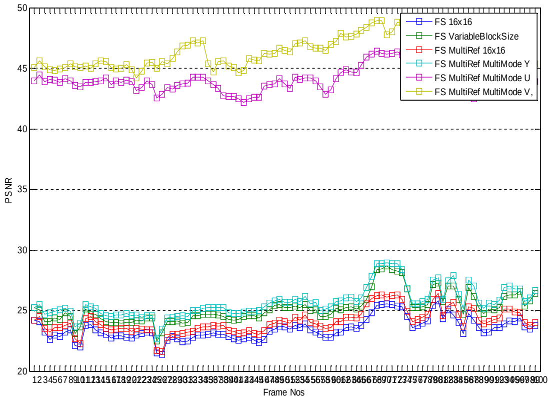

Fig.9 PSNR CIF Bus for 100 frames

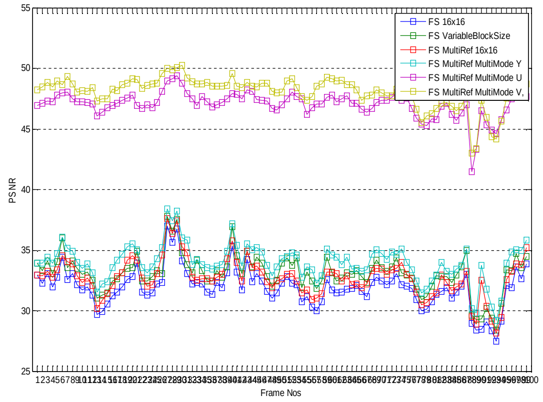

Fig.10 PSNR CIF Flower for 100 frames

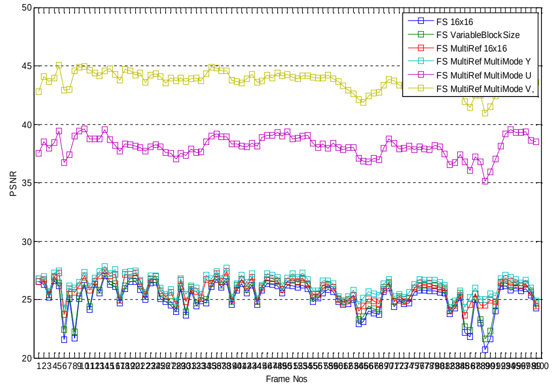

Fig.11 PSNR CIF Coastguard for 50 frames

**Table 2 Speed up analysis**

| Name | Format | Total Frames | Speedup for 50 frames |
|---|---|---|---|
| Claire | QCIF (176x144) | 494 | 90 % |
| Akiyo | QCIF (176x144) | 300 | 95% |
| Suzie | QCIF (176x144) | 150 | 89% |
| Coastguard | CIF (352x288) | 300 | 32% |
| bus | CIF (352x288) | 150 | 35% |
| flower | CIF (352x288) | 250 | 30% |

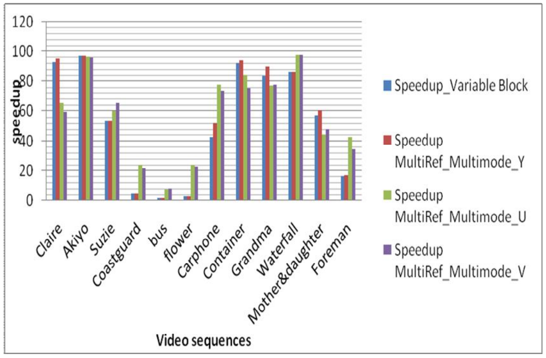

Fig.12 Percentage Speedup in Video Sequences

## V. CONCLUSION

The paper has presented a scheme for SKIP prediction based fast motion estimation with applications in H.264. Two different approaches were proposed. The first approach utilizes the SKIP MB mode which was predicted based on this zero motion vector value. The second approach uses temporal correlation among the collocated MBs in the same frame as well as the previous frame forms the basis of the next approach. The second approach uses temporal correlation among the collocated MBs in the same frame as well as the previous frame forms the basis of the next approach. Finally, the multiple numbers of reference frames, on which the mode search is performed, were reduced based on an initial low-complexity matching cost. It was observed that, each of the proposed approaches individually exhibited the best performance in terms of either prediction quality or compression efficiency or coding efficiency. Subsequently, two approaches were merged to generate the combined results. The experimental results on standard test sequences demonstrate substantially high speed up.

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