2008 Second International Conference on Future Generation Communication and Networking Symposia

# Efficient Selection of Candidates for Fast Inter Mode Decision in H.264

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## Abstract

*In the H.264/AVC video codec, a rate-distortion optimization method for mode decision provides high coding efficiency. However, it increases encoding time significantly due to its high complexity. In this paper, we propose a fast algorithm for inter mode decision using motion cost during motion estimation to reduce the number of candidate modes. The proposed approach makes early 16×16 mode decision and early inactive P8 × 8 mode decision. Its encoding performance is similar to that of the fast inter mode decision in the H.264/AVC JM reference software; however, its encoding time is reduced by 30.95% on average. Especially, when quantization parameter (QP) is larger, we obtained better results.*

## 1. Introduction

H.264/AVC is a video coding standard made jointly by ITU-T and ISO/IEC [1]. H.264/AVC supports five inter modes and two intra modes to obtain high coding performance [2]. Intra modes have Intra 4×4 with nine prediction directions, and Intra 16 × 16 with four prediction directions. Inter modes consist of SKIP, 16×16, 16×8, 8×16, and P8×8; these are used for a macroblock encoding through motion prediction. P8×8 mode can be divided into 8×8, 8×4, 4×8, and 4×4 in each 8×8 block.

Figure 1 represents inter modes used in H.264/AVC. Among them, the mode which has the least rate-distortion value is selected as the best prediction mode. This approach improves coding efficiency significantly; however, it increases the encoder complexity. The main reason for the increased complexity is that it employs a rate-distortion method that requires a large amount of computation.

In this paper, we propose a fast algorithm for inter mode decision considering motion cost and SKIP conditions during motion estimation. We implement early 16×16 mode decision and early inactive P8×8 mode decision to reduce the time for determining the best prediction mode.

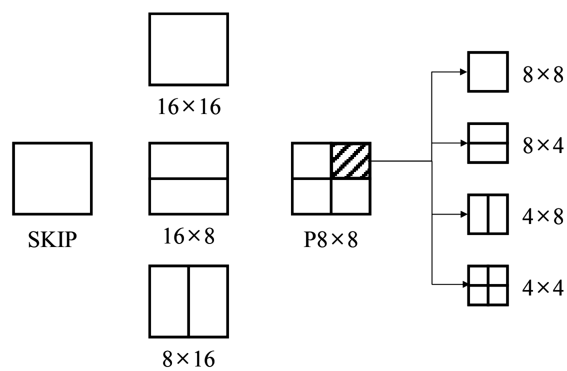


**Figure 1. Inter modes in H.264/AVC**

## 2. Mode decision of H.264/AVC

### 2.1. Rate-distortion optimization

For each macroblock, to determine which mode is the best mode is one of the cores of H.264/AVC encoder. H.264/AVC considers the distortion and bit rate to determine the best mode among several modes. In the inter mode, we should select motion vector and reference frame before calculating the distortion and bit rate. Motion vector and reference frame for variable blocks are determined by

$$J_{motion}(MV, REF|\lambda_{motion}) = SAD(s,r(MV, REF)) + \lambda_{motion} \cdot (MV, REF) \quad (1)$$

where *MV* is the motion vector, *REF* denotes the reference picture and $\lambda_{motion}$ is the Lagrangian multiplier which depends on quantization parameter. *R(MV, REF)* represents the bits used for coding motion vector and the reference picture. *s* and *r* indicate the current and reference blocks, respectively. *SAD* represents the sum of absolute difference between the original and reference blocks.

978-0-7695-3546-3/08 $25.00 © 2008 IEEE
DOI 10.1109/FGCNS.2008.43

The decision of the sub-block mode for P8× 8, the prediction mode in the intra mode, and the best mode for macroblock is carried by

$$J_{mode}(s, r, M|\ \lambda_{mode}) = SSD(s, r, M) + \lambda_{mode} \cdot R(s, r, M) \quad (2)$$

where $\lambda_{mode}$ is $(\lambda_{motion})^2$, $M$ is macroblock mode, $R(s, r, M)$ is the number of bits associated with choosing M including the bits for the macroblock header, motion vectors, and all discrete cosine transform (DCT) coefficients. *SSD* represents the sum of square differences between the original and reference blocks.

### 2.2. Mode decision procedure of H.264/AVC

First, the motion vector and the reference frame which have minimum $J_{motion}$ value in Eq. (1) are stored for 16×16, 16×8, and 8×16. Sub-block mode decision for P8×8 consists of two parts. One part is determining motion vectors and reference frames for 8×8, 8×4, 4×8, and 4×4. Other part is determining the best mode using Eq. (2). After finding SKIP motion vector, the best mode is selected by using Eq. (2). In this process, intra mode is included and the mode which has minimum $J_{mode}$ value in Eq. (2) value becomes the best mode.

### 2.3. Fast inter mode decision algorithm of JM reference software

Fast inter mode decision is implemented in H.264/AVC JM reference software [3]. In this implementation, we can omit unnecessary calculations using early skip mode decision. Figure 2 represents fast inter mode decision of JM reference software. As described above, the original H.264/AVC mode decision process finds SKIP motion vector and calculates rate-distortion after determining sub-block for P8×8. However, in the fast inter mode of JM, after obtaining motion vector and reference frame of 16×16, $J_{mode}$ is determined for 16×16 mode.

The conditions for SKIP mode are checked from the result of $J_{mode}$ for 16×16. If the set of conditions is satisfied, the best mode becomes SKIP mode and the remaining mode decision processes are omitted. The conditions of SKIP mode are as follows:

(1) The motion compensation block size is 16×16.
(2) The reference frame is the previous frame.
(3) The SKIP motion vector is equal to 16 × 16 motion vector.
(4) Coded block pattern (CBP) which reflects the number of quantized DCT coefficients is equal to zero

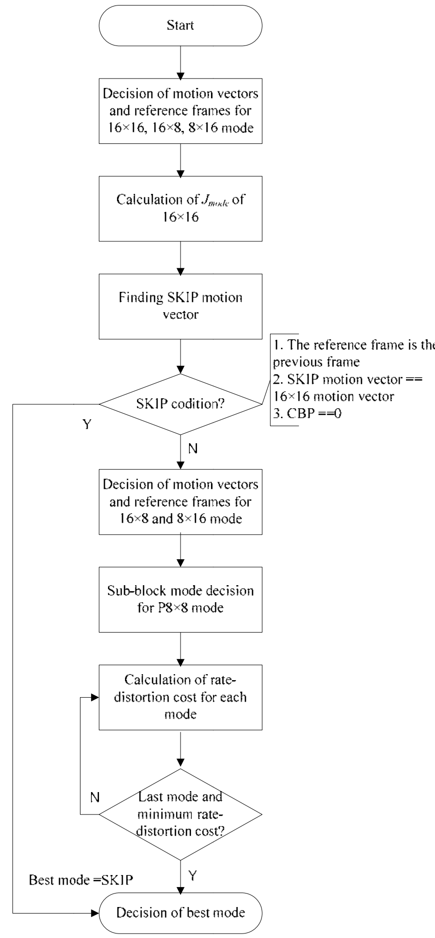


**Figure 2. Fast inter mode decision of JM reference software**

## 3. Proposed algorithm using $J_{motion}$ and SKIP conditions

### 3.1. Motivation

Figure 3 shows the run-time percentage of major function module in the H.264/AVC encoder [4]. From Fig. 3, we can know that motion prediction and mode decision take the largest portion of computational complexity. Thus, in order to reduce the complexity of H.264/AVC encoder, it is necessary to develop the fast inter mode decision.

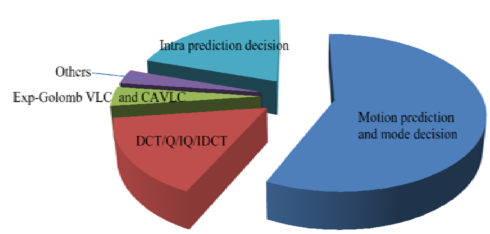


**Figure 3. Run-time proportion of major function module in H.264/AVC encoder**

### 3.2. Selection of the candidate mode using $J_{motion}$

We can reduce the complexity from predicting candidate mode which has high possibility for best mode. To decide the best mode, H.264/AVC finds motion vector and reference frame corresponding to each mode from Eq. (1). Generally, if $J_{motion}$ in Eq. (1) is small, $J_{mode}$ in Eq. (2) is small. Thus we can predict best mode by using Eq. (1). The result of the mode decision based on Eq. (1) is worse than that of the rate-distortion method using Eq. (2) in terms of PSNR and bit rates since it does not count the actual coding bits. However, the mode decision which uses Eq. (1) gives us a good candidate to determine rate-distortion the best mode.

Figure 4 shows the correlation between the mode decision by Eq.(1) and the mode decision by Eq.(2) in case that selected mode by Eq.(1) is 16×16 mode. In the experiment, 30 frames for Akiyo sequence are used with QP 32. From Fig. 4, the mode decision method by $J_{motion}$ offers candidate mode to decide the best mode. That is, when the best mode by $J_{motion}$ is 16×16, the best mode by $J_{mode}$ is likely to be 16×16.

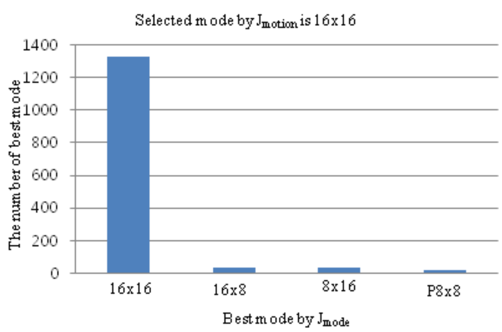


**Figure 4. The correlation between $J_{motion}$ and $J_{mode}$ for Akiyo sequence**

### 3.3. Obtainment of hint related to fast mode decision from SKIP conditions

We presented SKIP conditions in 2.3. In the proposed algorithm, we implement fast mode decision by using SKIP conditions. To determine SKIP mode, all SKIP conditions should be satisfied. However, even if SKIP conditions are not all satisfied, it gives us hint to develop fast mode decision. If SKIP motion vector is equal to 16×16 motion vector, it has high possibility that the best mode is 16×16. If CBP value of 16×16 is '0', we assume that the current macroblock is in the smooth region of the image or in part of the object moving the same direction. Thus we can make P8×8 inactive.

### 3.4. Flowchart of the proposed algorithm

Figure 5 shows the flowchart of the proposed algorithm. At first, we determine motion vector and reference frame for 16×16. We then calculate $J_{mode}$ of 16×16, find SKIP motion vector. After that, we check the SKIP conditions. If conditions are satisfied, the best mode is determined as SKIP and other mode decision process are terminated. Even if not, if best mode by $J_{motion}$ is 16×16 and SKIP motion vector is equal to 16×16 motion vector, we can make 16×8, 8 × 16, and P8 × 8 inactive. Then, we check the conditions which the best mode by $J_{motion}$ is 16×16 and CBP of 16×16 is zero. If these conditions are satisfied, we can make P8×8 inactive.

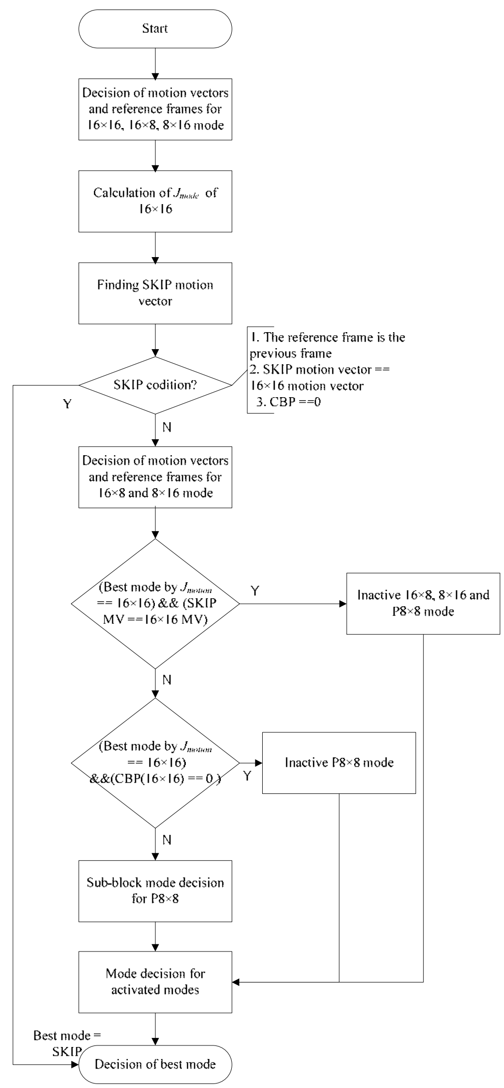


**Figure 5. Flowchart of the proposed algorithm**

## 4. Experimental results

In our experiments, we use eleven test sequences in CIF (352 × 288): Akiyo, Coastguard, Container, Flowergarden, Foreman, Hall_monitor, Mobile, Mother and daughter, News, Paris, and Stefan. We have used the H.264/AVC reference software JM 13.2. Main parameters for coding are shown in Table 1.

**Table 1. Experimental condition**

| Profile | Baseline |
|---|---|
| RDOptimization mode | Fast high complexity |
| Number of frames | 100 frames |
| Frame sequence | IPPPPP….. |
| Search range | ±16 |
| Reference frames | 5 |
| Quantization parameters | 28, 32, 36, 40 |
| Fast motion estimation | UMHexagonS |

To compare coding performance between the proposed method and fast inter mode decision of the H.264/AVC JM reference software, we check PSNR and bit rate [5]. For encoding time, ΔT is defined by

$$\Delta T = \frac{\text{time(proposed method)} - \text{time(H.264 fast mode)}}{\text{time(proposed method)}} \times 100[\%] \quad (5)$$

Table 2 represents performance comparison between the proposed mode decision and fast inter mode decision of the H.264/AVC JM reference software. All values represent average values of eleven sequences.

**Table 2. Performance comparison**

| | QP | ΔPSNR (dB) | ΔBit Rate (%) | ΔT (%) |
|---|---|---|---|---|
| Average | 28 | -0.032 | 1.68 | -27.66 |
| | 32 | -0.026 | 1.23 | -29.08 |
| | 36 | -0.010 | 1.01 | -31.73 |
| | 40 | -0.015 | 0.80 | -35.34 |

From these results, we can observe that the proposed fast inter mode algorithm can reduce the considerable encoding time compared with H.264/AVC fast inter mode. PSNR and bit rate have little difference in both cases. As QP increases, encoding time is much reduced because the probability that the best mode becomes SKIP mode or 16×16 mode increases.

Figure 6 represents rate-distortion curve which has the worst case in coding performance. From Fig. 6, we can know that the proposed fast inter mode algorithm does not have more distortion compared with H.264/AVC fast inter mode.

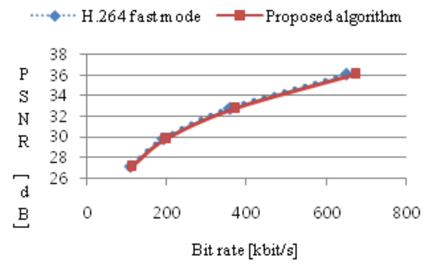


**Figure 6. Rate-distortion curve for Paris sequence**

## 5. Conclusion

In this paper, we have proposed a fast inter mode decision considering efficient candidate mode selection. In the proposed algorithm, we reduce the encoding time by decreasing the number of candidate mode through $J_{motion}$ value and SKIP conditions. From the experimental result, the proposed algorithm doesn't have large change in PSNR and bit rate compared with and fast inter mode decision of the H.264/AVC JM reference software. However, it reduces the encoding time by 30.95% on average. Especially, when the QP is larger, encoding time is much reduced.

## Acknowledgement

This work was supported in part by ITRC through RBRC at GIST (IITA-2008-C1090-0801-0017).

## References

[1] T. Wiegand, G. J. Sullivan, G. Bjontegaard, and A. Luthra, "Overview of the H.264/AVC Video Coding Standard," IEEE Transactions on Circuits and Systems for Video Technology, Vol. 13, No.7, July 2003.

[2] J. Ostermann, J. Bormans, P. List, D. Marpe, M. Narroschke, F. Pereira, T. Stockhammer, and T. Wedi, "Video coding with H.264/AVC: Tools, Performance, and Complexity," IEEE Circuits and Systems Magazine, first quarter 2004.

[3] JVT reference software version 13.2, http://iphome.hhi.de/suehring/tml/download/old_jm/jm13.2.zip.

[4] G. Y. Kim, B. Y. Yoon, and Y. S. Ho, "A Fast Inter Mode Decision Algorithm in H.264/AVC for IPTV Broadcasting Services," SPIE Visual Communication and Image Processing, Vol. 6508, 2007

[5] I. E. G. Richardson "H.264 and MPEG-4 Video Compression," John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England, 2003.