International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:3, No:1, 2009

# Bitrate Reduction Using FMO for Video Streaming over Packet Networks

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***Abstract*—**Flexible macroblock ordering (FMO), adopted in the H.264 standard, allows to partition all macroblocks (MBs) in a frame into separate groups of MBs called Slice Groups (SGs). FMO can not only support error-resilience, but also control the size of video packets for different network types. However, it is well-known that the number of bits required for encoding the frame is increased by adopting FMO. In this paper, we propose a novel algorithm that can reduce the bitrate overhead caused by utilizing FMO. In the proposed algorithm, all MBs are grouped in SGs based on the similarity of the transform coefficients. Experimental results show that our algorithm can reduce the bitrate as compared with conventional FMO.

***Keywords*—**Data Partition, Entropy Coding, Greedy Algorithm, H.264/AVC, Slice Group.

## I. INTRODUCTION

THE packet loss probability increases as the packet size large since the probability of a bit error is higher than that of shorter one. This lost probability obstructs the transmission of high definition video over packet-oriented networks to achieve high video quality. H.264/AVC [1] adopts data partitioning and FMO to address this problem. While data partitioning enables unequal error protection to video packets, the FMO has advantages of efficient error-concealment for MBs in missing packets [2]. Although a large packet can be sliced to smaller ones which are easier to be transmitted over networks, the bitrate increment due to FMO has to be addressed.

FMO defines SGs for a frame, each MB in the frame is assigned to a SG. FMO consists of seven different types. Fig. 1 shows interleaved and dispersed FMO type configurations which have two slice groups: white and gray ones. All MBs in a SG are independently encoded and encapsulated in a NALU. Thus, the lost of one NALU does not affect to the decoding process of others. Among the types, the explicit type freely assigns MBs to any SG and each SG contains an arbitrary number of MBs. This explicit type allows us to group appropriate MBs into SGs to minimize the bitrate of NALUs of the frame.

Several approaches to reduce the packet size, known as coding efficiency tools, have been invented. At waveform coding, motion vector of current block is predicted from those of previously coded blocks since motion vectors of the neighboring blocks are highly correlated. Intra prediction uses previously encoded pixels in blocks to the left and/or above the current block to predict the pixels of current block. At entropy coding, the context-adaptive variable length coding (CAVLC) specifies the coding table for the current symbol in a block by examining the values of the left and upper symbols. The context-based adaptive binary arithmetic coding (CABAC) achieves high coding efficiency by defining hundreds of context models. The context model used for the current symbol is derived from previous coded symbols.

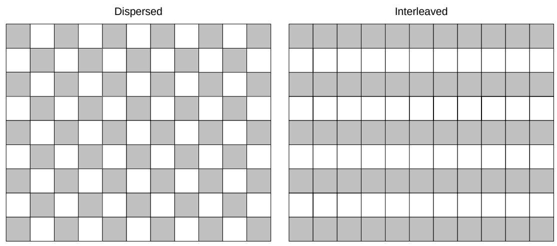


Fig. 1 FMO types

In this paper, we introduce an efficient algorithm which can classify MBs with similar transform coefficient distributions. The proposed FMO method groups similar MBs in the same SG based on their similarity. The bitrate of our algorithm is lower than that of conventional FMOs while video packet division is still guaranteed.

The paper is organized in five main sections. Section II describes the classifying algorithm in detail. Implementation in reference software is presented in section III. Experiments on several video sequences and their results are presented in section IV. Finally conclusion is given in section V.

## II. PROPOSED METHOD

### A. Proposed FMO Algorithm

The purpose of our proposed algorithm is to partition MBs of a frame into SGs. For the simplicity of the explanation, we assume that a frame is divided into two SGs with the same number of MBs. MBs in an SG are encoded independently from those in the other. We assume that the more similar the coefficient distribution of MBs in an SG is, the more

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compression rate it achieves. The algorithm is designed to classify all MBs in a frame to the two SGs such that the total compression rate is optimal.

First, we define a similarity measure of coefficient distribution between two MBs by considering the Bhattacharyya distance as follows:

$$D(MB_1, MB_2) = 1 - \sum \sqrt{P_{X_{MB_1}}(x) P_{X_{MB_2}}(x)}, \qquad (1)$$

where $X_{MB_i}$ is the random variable (RV) which represents the levels of coefficients in $MB_i$ for $i$ = 1, 2 and $P_X(x)$ is the probability mass functions (PMFs) of $X$. This measure grows to 1 to express a difference between the two PMFs, and decreases to 0 when the distributions remain similar.

$$H(S) = \max\left(D(MB_1, MB_2) \mid MB_1, MB_2 \in S\right). \qquad (2)$$

Then the Coefficient Distribution Homogeneity (CDH) measure of a set $S$ of MBs is defined as in (2). This CDH measure is the largest difference between two MBs of the set $S$ and indicates the similarity among all MBs in the set $S$ in term of coefficient distribution. Given a pair of MBs ($MB_1$,$MB_2$) in set $S$, we call it partition pair of set $S$ if $D(MB_1,MB_2)=H(S)$.

The partition problem required to minimize the CDH measures of both subsets $S_1$ and $S_2$ is defined as follows:

$$\begin{aligned} &\text{minimize} \quad \max\left(H(S_1), H(S_2)\right) \\ &\text{subject to} \quad S_1 \cup S_2 = S, S_1 \cap S_2 = \varnothing, \|S_1\| \simeq \|S_2\|, \end{aligned} \qquad (3)$$

where $S$ is the set of all MBs in a frame. $S$ should be partitioned into two subsets $S_1$ and $S_2$ such that the numbers of elements of these subsets are approximately equal, and the CDH measures of these two subsets are minimized. The proposed algorithm to solve this problem consists of partition and optimization procedures.

The partition procedure consists of three steps partitions a set of MBs $S$ into two subsets $S_1$ and $S_2$ by selecting a pair of MBs at each iteration. The requirement which the CDH measure of a subset should be minimized suggests that the two MBs of partition pair of set $S$ should not be in a same subset. Step 1, the partition pair ($MB_1$,$MB_2$) is calculated; $MB_i$ is assigned subset $S_i$ and excluded from the set $S$, for $i$ = 1,2. Step 2, for each partition pair ($MB_1$,$MB_2$) found in $S$, let $a$, $b$, $c$ and $d$ be the CDH measure of $S_1 \cup \{MB_1\}$, $S_2 \cup \{MB_1\}$, $S_1 \cup \{MB_2\}$ and $S_2 \cup \{MB_2\}$; $MB_1$ is assigned to $S_1$ and $MB_2$ is assigned to $S_2$ if $\max(a, d) \le \max(b, c)$ otherwise $MB_1$ is assigned to $S_2$ and $MB_2$ is assigned to $S_1$; then $MB_1$ and $MB_2$ are excluded from $S$. In other words, $MB_1$ or $MB_2$ is assigned to $S_1$ or $S_2$ if maximum CDH measure yielded is minimum. Repeat the step 2 until there is no MB pair in $S$. There are always two MBs excluded from $S$ at each iteration of the step 2. If the number of MBs in $S$ at initiation is odd, there must be an MB left for step 3 in which the last MB is assigned to the subset $S_i$ whose CDH yielded is minimum.

The optimization procedure tries to reduce the CDH measure of the two subsets $S_1$ and $S_2$ by exchanging two MBs. The CDH measures of subset $S_1$ and $S_2$ called $max_1$ and $max_2$ corresponding to partition pairs ($MB_1$,$MB_2$) and ($MB_3$,$MB_4$) are calculated. Let $e$ and $f$ be the CDH measures of $S_2 \cup \{MB_1\}$ and $S_1 \cup \{MB_3\}$ respectively. $MB_1$ and $MB_3$ are exchanged between the two subsets if $e<max_2$ and $f<max_1$. In other words, $MB_1$ and $MB_3$ are exchanged if the final maximum CDH measure yielded is smaller than before exchange. The pairs ($MB_1$,$MB_4$), ($MB_2$,$MB_3$) and ($MB_2$,$MB_4$) are carried out in the same manner with ($MB_1$,$MB_3$). This procedure is repeated until there is no pair to be exchanged.

*B. Implementation*

Our algorithm is implemented on reference software JM 13.0 [2]. We make the encoder read FMO mapping every frame from file by setting the parameter slice_group_map_type = 6. FMO mapping is signaled to the decoder by a Picture Parameter Set (PPS). Setting the parameter ResendPPS = 1 enables retransmission a PPS for each frame to the decoder.

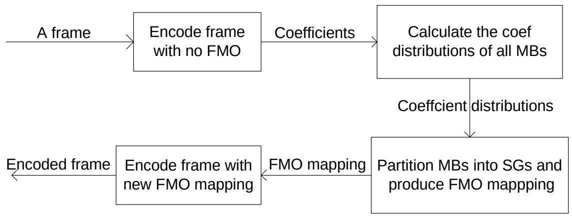


Fig. 2 Encode one frame

Fig. 2 depicts the encoding process of the proposed algorithm. A frame is encoded with no FMO, or one SG mode; Right before entropy encoding procedure, all coefficients are stored to calculate the MBs' coefficient distributions; These coefficient distributions are feed to the partitioning algorithm to produce FMO mapping; The FMO mapping is then used to encode the frame again.

## III. Experimental Results

The sequences we use in our experiments consists only I-frames. All intra predictions are disabled to avoid their side effects to our partitioning algorithms. Our algorithm is examined with CABAC [3] and CAVLC [4] entropy encoding modes. We use the same quantization parameter (QP) for all frames of experimented sequences to control the bitrate. Several QCIF sequences are experimented at frame rate 30fps by the proposed algorithm, dispersed and interleaved FMO mappings. Average bitrates and the average peak signal to noise ratio (PSNR) of all frames in each sequence are recorded.

Fig. 3 and Fig. 4 depict the bitrate reduction in percent comparison of the *carphone* and *hallmonitor* sequences with CABAC entropy coding. The proposed algorithm is not better at very high bitrate, QP<10, but it outperforms the dispersed and interleaved at low bitrate, QP>10. TABLE I. shows the average bitrate increase and average bitrate increase in percent of several QCIF sequences encoded by proposed, dispersed and interleaved methods cooperating with CABAC and CAVLC entropy encodings. At CABAC entropy coding mode, our algorithm save more bitrate than dispersed and interleaved FMOs.

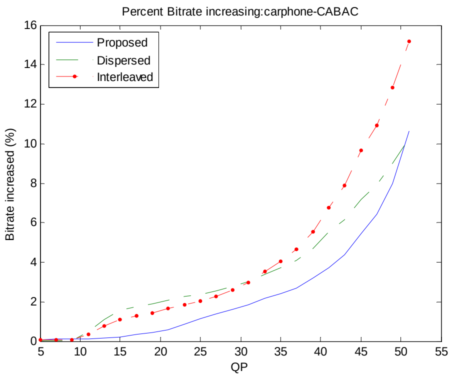


Fig. 3 Bitrate Increase Comparison of carphone sequence

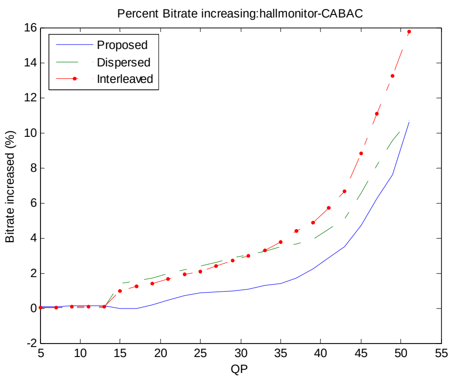


Fig. 4 Bitrate Increase Comparison of hallmonitor sequence

TABLE I
AVERAGE BITRATE INCREASE

| Seq. | FMO | Inc. of CABAC | | Inc. of CAVLC | |
|---|---|---|---|---|---|
| | | *Bits* | *%* | *Bits* | *%* |
| | Pros. | 12 323 | 2.13 | 12 789 | 0.89 |
| Foreman | Disp. | 19 032 | 2.97 | 28 422 | 1.30 |
| | Inte. | 21 990 | 3.62 | 10 382 | 0.81 |
| | Pros. | 11 379 | 1.89 | 10 520 | 0.64 |
| Stefan | Disp. | 19 536 | 2.74 | 42 745 | 1.49 |
| | Inte. | 20 171 | 3.10 | 10 072 | 0.61 |
| | Pros. | 10 119 | 2.42 | 10 275 | 0.86 |
| Carphone | Disp. | 20 622 | 3.50 | 25 439 | 1.27 |
| | Inte. | 19 698 | 4.15 | 10 726 | 0.90 |
| | Pros. | 7 675 | 1.99 | 11 396 | 0.88 |
| Hallmonitor | Disp. | 18 741 | 3.28 | 28 050 | 1.41 |
| | Inte. | 18 972 | 3.97 | 9 503 | 0.80 |

## IV. CONCLUSION

We defined the measure of coefficient distribution distance between two MBs and the CDH measure for a set of MBs. The proposed algorithm minimizes the CDH measure of the set of MBs in each SGs to reduce the bitrate of the frame subject to the number of MBs in the SGs are equally the same. Experiments show that the bitrate of our proposed algorithm is lower than that of conventional FMOs.

## ACKNOWLEDGEMENT

This research was supported by Seoul Future Contents Convergence (SFCC) Cluster established by Seoul R&BD Program.

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