# Adaptive Error Resilient Coding Based on FMO in Wireless Video Transmission

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***Abstract*—H.264/AVC is the latest video coding standard from ITU-T and ISO/IEC. Not only the compression performance is enhanced but also the robustness of video bit streams to errors is better. FMO (Flexible Macro-block Ordering) is a new error resilient tool adopted by H.264/AVC and it has a good performance of error resilience. In this paper, a novel FMO algorithm is proposed, and an adaptive coding scheme based on this new FMO algorithm is introduced. Experiment results show that the proposed FMO algorithm could achieve almost the same PSNR as the FMO Type 1, but has better robustness in wireless transmission, and the adaptive coding scheme can still guarantee a high PSNR in the case of high packet loss rate.**

***Keywords*—Error resilient coding, H.264/AVC, FMO, Redundant slices, Adaptive.**

## I. INTRODUCTION

H.264/AVC video coding standard is developed by ITU-T Video Coding Experts Group (VCEG) and ISO/IEC Moving Pictures Experts Group (MPEG). The main goals of the new standard are enhanced compression performance and provision of the "network-friendly" video transmission.

With the development of multimedia and the third-general (3G) wireless cellular systems, there has been an increasing demand for transmitting compressed video streams over wireless channel, such as video telephony, video on demand service and so on. However, Video quality suffers significant degradation when transmitted over error-prone wireless channel, due to packet loss and bit error. Fig.1 shows that there are serious regional blur and block phenomenon in the frame. It sets a higher requirement for the development of wireless mobile communication and multimedia and the integration of these two technologies.

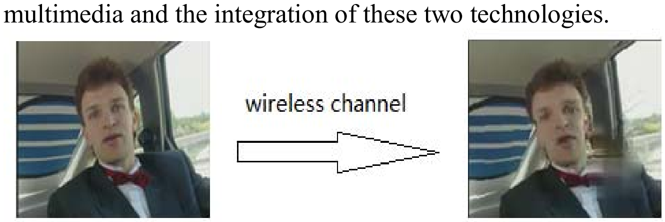


Fig.1. Video transmission over wireless error-prone channels.

The newest video coding standard-H.264/AVC has introduced some new error-resilient tools to enable reliable video communication. Two of those tools are FMO (Flexible Macro-block Ordering) [1] and RS (Redundant Slices). FMO allows great flexibility to define the coding order of MBs within a picture, and obtains impressive performance of error resilience. RS places one or more coded representations of a MB into the bit stream to protect the particular MB.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 |
| 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 |
| 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 |
| 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 |
| 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 |
| 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 |
| 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 |
| 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 |
| 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 |

Fig.2. FMO Type 1 (176*144, 4 slice groups).

There are 7 FMO Types in H.264/AVC in total, which define different types of MBAmap (Macro-block Allocation map) and different coding orders of MBs. FMO Type 0 to Type 5 are fixed patterns, for example, Type 0 distributes MBs to slice groups in raster scan order within a picture and each slice group has a maximum number of MBs that it can contain, while in case of Type 1, MBs in a slice group are separated from each other as far as possible, so that FMO Type 1 is also known as the Chessboard pattern. An example of MBAmap generated by FMO Type 1 is shown in Fig.2, and "0" to "3" denotes the number of slice group which the MB belongs to. FMO Type 6 is called Explicit, and it is the most flexible Type of all. Usually, Type 1 has the greatest performance in PSNR among Type 0 to Type 5 because this pattern is helpful for error concealment at the decoder side. While using FMO Type 6, the entire MBAmap should be transmitted to the decoder in PPS (Picture Parameter Set), which may decrease the coding efficiency.

In [2], the authors combine FMO Type 2 with Redundant Slices. The central region of a frame is thought to be the foreground, and it is defined as a ROI (Region of Interest). The rest of the frame is background. Every ROI is protected by a redundant slice in case that the ROI is lost during transmission. In [3][4][5], the importance of each MB is first defined, and then the MBAmap is generated according to the order of importance. This method ignores the position of a MB, so the neighboring MBs may be allocated to the same slice group, which is detrimental to error concealment. There are several choices for the protection of important MBs, such as Forward Error Correction code (FEC) [6][7], RS and so on. FEC is aimed at correcting bit error so that it doesn't work well in packet loss situation, while RS could ensure a relatively high PSNR in packet loss or high bit error environment.

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In this paper, we will propose an adaptive error resilient coding scheme based on RS and a new FMO algorithm. The redundant slice is generated according to the situation of wireless channel, and the new FMO algorithm will consider both the importance and position information of the MB.

The rest of this paper is organized as follows. Section II describes the proposed FMO algorithm. An adaptive error resilient coding scheme based on this new FMO algorithm and RS is presented in Section III. Section IV shows the experiment results, and a brief conclusion based on these results is given in Section V.

## II. PROPOSED FMO ALGORITHM

The proposed FMO algorithm has two main goals:

a) Separate important MBs from the unimportant ones, so that the encoder could take an unequal protection.
b) Allocate the neighboring MBs to different slice groups, which is helpful for error resilient.

In order to achieve the two goals, we should take both the importance and the position of a MB into consideration. The algorithm is as follows:

1. Calculate the gradient image of a frame using templates in Fig.3.

| | | |
|---|---|---|
| 0 | 1 | 0 |
| 1 | -4 | 1 |
| 0 | 1 | 0 |

(a)

| | | |
|---|---|---|
| 1 | 1 | 1 |
| 1 | -8 | 1 |
| 1 | 1 | 1 |

(b)

| | | |
|---|---|---|
| 0 | -1 | 0 |
| -1 | 4 | -1 |
| 0 | -1 | 0 |

(c)

| | | |
|---|---|---|
| -1 | -1 | -1 |
| -1 | 8 | -1 |
| -1 | -1 | -1 |

(d)

Fig.3. Templates for gradient calculation.

2. Calculate the average gradient value of every MB: *mb_ave_grad*, and the average gradient of the whole frame:*fra_ave_grad*. If *mb_ave_grad*>*fra_ave_grad*, the MB is thought to be important, otherwise it is an unimportant one.
3. Allocate the MBs into 4 slice groups using the following formula [1]:

$$K = ((i \bmod \mathrm{W}) + ((i / \mathrm{W}) * n) / 2) \bmod n \qquad (1)$$

Where, $i$ denotes the number of a MB, W is the width of the frame in terms of MB, and $n$ is the number of slice groups.

4. For MBs in slice group 0 and 2, the unimportant MB is moved to slice group 5 and 7, and the important MB in slice group 1 and 3 is moved to slice group 4 and 6, as Fig.4 shows.

In Fig.4, "0" to "7" represents the numbers of slice groups. It is obvious that slice group 0, 2, 4, 6 are important, while the others are not so important. Fig.4 shows that important slice groups are dispersed, so that it can avoid consecutive loss of important packets.

Step 3 is actually the algorithm of FMO Type 1. This algorithm can enhance the performance of error concealment at the decoder side, and that's why we take it into our new FMO algorithm.

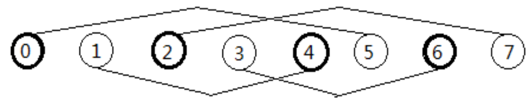


Fig.4. Step 4 of the proposed FMO algorithm.

An example of MBAmap using the proposed FMO algorithm is shown in Fig.5, and '0' to '7' denotes the number of slice group which the MB belongs to.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 7 | 3 | 5 | 1 | 7 | 3 | 0 | 1 | 7 |
| 7 | 3 | 5 | 1 | 7 | 3 | 5 | 1 | 2 | 3 | 5 |
| 0 | 1 | 7 | 3 | 5 | 1 | 2 | 3 | 0 | 4 | 7 |
| 2 | 6 | 0 | 4 | 7 | 3 | 0 | 1 | 2 | 6 | 5 |
| 0 | 4 | 2 | 6 | 5 | 1 | 2 | 3 | 0 | 4 | 2 |
| 2 | 6 | 0 | 4 | 7 | 3 | 5 | 4 | 2 | 6 | 5 |
| 0 | 4 | 2 | 6 | 0 | 4 | 2 | 6 | 5 | 1 | 2 |
| 2 | 3 | 0 | 1 | 7 | 3 | 0 | 1 | 7 | 3 | 5 |
| 5 | 1 | 7 | 3 | 5 | 1 | 7 | 6 | 5 | 1 | 7 |

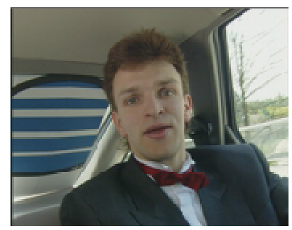

Fig.5. MBAmap generated by the proposed FMO algorithm.

## III. PROPOSED ADAPTIVE ERROR RESILIENT CODING SCHEME

The error resilient effect of FMO is limited because it just changes the coding order of MBs and the packaging strategy of coded bits stream. Since we have classified MBs into important and unimportant ones, we can take an unequal protection for different slice groups using Redundant Slices. Though the wireless channel is error-prone, the quality of video transmission is acceptable in most of the time. So, we can encode redundant slices just when the channel situation is terrible.

### A. Simulation of wireless channels

We use the Two-State Markov Model [8] to simulate the wireless channel in this paper.

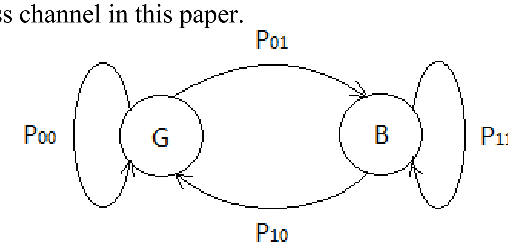


Fig.6. Two-State Markov model.

Fig.6 shows the Markov model, which can be uniquely specified by average burst length (BL) and packet loss rate (PLR).

$$p_{10} = 1 / \mathrm{BL} \qquad (2)$$

$$p_{01} = p_{10} \times \mathrm{PLR} / (1 - \mathrm{PLR}) \qquad (3)$$

We change PLR during our experiments to simulate different channels and test the performance of error resilience of the proposed scheme.

The Two-State Markov Model has only two states, “Good” or “Bad”, so it is naturally to code a redundant slice should into the bit stream when the channel state is “Bad”. After coding an original slice, the encoder will check the channel state, and then determine if the redundancy coding will be conducted adaptively.

### B. *Redundant slices*

It’s important to note that the redundant slice is not a simple copy of the original one. Indeed, a redundant slice is usually coded using different settings, for example, a high QP (low quality). In this paper, we choose a high QP when coding a redundant slice for important slice groups, while the other redundancy is coded with a higher QP.

The position of redundant slices in bit stream is also a problem worth considering. If the redundant slice is too close to the original one, the two packets may be lost at the same time in a burst packet loss. To handle this problem, we can encode the redundant slices of a frame only when all the original slices are coded, as shown in Fig.7.

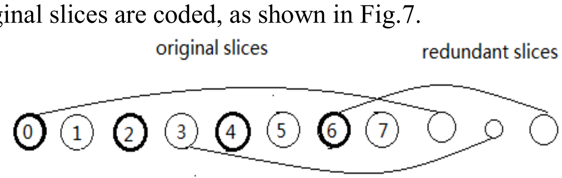


Fig.7. Position of redundant slices.

In Fig.7, “0” to “7” are the original slices of the same frame, and the redundant slices of slice 0, 3, 6 come after all the original ones.

## IV. EXPERIMENT RESULTS

### A. *Experiment settings*

The experiments are conducted based on the Joint Model (JM) version 8.6 of H.264/AVC. We compare the performance among FMO Type 1, the proposed FMO algorithm and the proposed adaptive error resilient coding scheme. Each frame is divided into 8 slice groups while using FMO Type 1.

Five video sequences are tested, and 60 frames of each sequence are encoded, as the Table 1 shows.

Table 1 video sequence for test

| | video sequence | size |
|---|---|---|
| 1 | Foreman | 176*144 |
| 2 | mobile | 176*144 |
| 3 | news | 352*288 |
| 4 | coastguard | 352*288 |
| 5 | mobile_cif | 352*288 |

The frame GOP structure is set as IPPPP..., thus only the first frame is intra-frame and the others are all inter-frame. The original slices are encoded with QP=28, while the redundant slices of important slice groups are encoded using QP=34. The QP for other redundancy is 40.

As for the Two-State Markov Model, average burst length (BL) is set to be 2, and packet loss rate (PLR) ranges from 5% to 30%, with an interval of 5%.

### B. *Experiment results*

The experiment result is shown in Table 2~Table 5 and Fig.8, in which “a” denotes FMO Type 1 with 8 slice groups, “b” is the proposed FMO algorithm and “c” is the proposed adaptive error resilient coding scheme.

Table 2 PSNR of “foreman” (a: FMO Type 1, b: proposed FMO algorithm, c: proposed adaptive error resilient coding scheme)

| PLR | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|
| a | 30.81 | 28.37 | 0 | 0 | 0 | 0 |
| b | 31.01 | 27.98 | 27.63 | 25.77 | 23.97 | 23.33 |
| c | 35.02 | 34.06 | 33.36 | 30.58 | 30.37 | 28.69 |

Table 3 PSNR of “mobile” (a: FMO Type 1, b: proposed FMO algorithm, c: proposed adaptive error resilient coding scheme)

| PLR | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|
| a | 27.85 | 0 | 0 | 0 | 0 | 0 |
| b | 27.85 | 24.77 | 24.16 | 22.32 | 20.39 | 19.55 |
| c | 31.20 | 29.19 | 29.06 | 25.85 | 24.71 | 23.66 |

Table 4 PSNR of “coastguard” (a: FMO Type 1, b: proposed FMO algorithm, c: proposed adaptive error resilient coding scheme)

| PLR | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|
| a | 29.49 | 0 | 0 | 0 | 0 | 0 |
| b | 30.02 | 26.67 | 26.20 | 24.61 | 22.80 | 0 |
| c | 32.72 | 30.14 | 29.48 | 27.57 | 25.86 | 25.88 |

Table 5 PSNR of “mobile_cif” (a: FMO Type 1, b: proposed FMO algorithm, c: proposed adaptive error resilient coding scheme)

| PLR | 5% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|
| a | 27.61 | 0 | 0 | 0 | 0 | 0 |
| b | 27.44 | 23.98 | 23.37 | 21.46 | 19.66 | 18.80 |
| c | 31.36 | 29.69 | 28.96 | 25.38 | 24.38 | 23.11 |

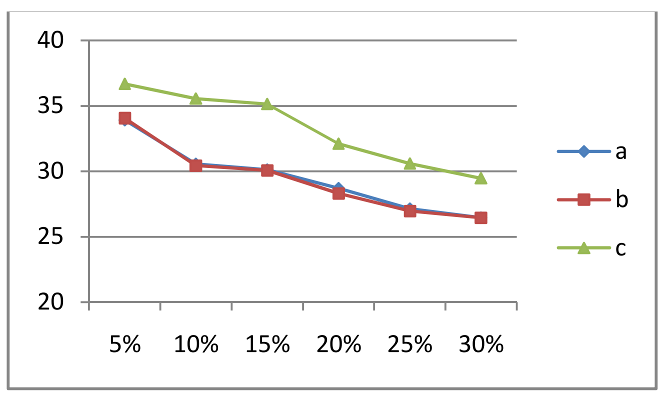


Fig.8. PSNR of “news” (a: FMO Type 1, b: proposed FMO algorithm, c: proposed adaptive error resilient coding scheme)

As we can see in Table 2~Table 5 and Fig.8, the proposed FMO algorithm can achieve almost the same PSNR as FMO Type 1, but the robustness is greatly enhanced. Four of the five test video sequences cannot be entirely decoded (PSNR=0) in high packet loss rate when decoded using FMO Type 1, while the same phenomenon occurs only once in the proposed FMO algorithm (“coastguard”, PLR=30%).

The proposed adaptive error resilient coding scheme has the greatest performance of error resilience of the three methods, and the PSNR is usually 2 to 6 dB higher than method a and b. Fig.8 shows that the visual quality of method c is obviously better than the other two.


Fig.9. The 40th frame of "foreman" with PLR=20%, (1) no error frame, (2) FMO Type 1 with 8 slice groups, (3) the proposed FMO algorithm, (4) the proposed adaptive error resilient coding scheme.

Fig.9 are the 40th frames of "foreman" with PLR=20% using different error resilient techniques. It shows that the proposed adaptive error resilient coding scheme could achieve the best visual quality, while FMO Type 1 and the proposed FMO algorithm are almost the same.

The total bits of the coded video sequences are presented in Table 6. It's easy to know that the average increase in bits from method a to b is 1.55%, and that from a to c is 3.91%. Considering the great enhanced performance of error resilience, such increase in bits is just acceptable.

Table 6 Total bits of the coded video sequences, (a) FMO Type 1with 8 slice groups, (3) the proposed FMO algorithm, (4) the proposed adaptive coding scheme with PLR=15%

| | a | b | c |
|---|---|---|---|
| Foreman | 250528 | 262896 | 275608 |
| Mobile | 859904 | 874384 | 896512 |
| News | 441704 | 474336 | 487944 |
| Coastguard | 2909504 | 2938920 | 2998720 |
| Mobile_cif | 3390616 | 3423248 | 3500608 |
| Total | 7852256 | 7973784 | 8159392 |

## V. CONCLUSION

In this paper, we first introduce a novel FMO algorithm, which takes both the importance and position information of MBs into consideration. Then, an adaptive error resilient coding scheme based on this new FMO algorithm is proposed. In this coding scheme, redundant slices are generated according to the channel states. Experiment results show that the proposed FMO algorithm can achieve almost the same PSNR as FMO Type 1, but the robustness is much better. In these three methods, the proposed adaptive error resilient coding scheme achieves the greatest performance of error resilience, by introducing an acceptable increase of video bit stream size.

## ACKNOWLEDGMENT

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