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| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  13th Meeting: Incheon, KR, 18–26 Apr. 2013 | Document: JCTVC-M0257 |

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| *Title:* | **Intra Frame Rate Control Based on SATD** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

In this contribution, an R-λ model based rate control scheme for intra frame/slice is proposed for HEVC. The proposed rate control algorithm is implemented on HM-10.0. Compared with the existing rate control algorithm in HM-10.0, it is asserted that the proposed algorithm provides more accurate matching of target rate while maintaining similar coding efficiency.

# Introduction

The goal of rate control is to find for each frame values of syntax elements such that the mean-squared-error (MSE) distortion *D* between the prediction error *E(x,y)* and the reconstructed version of the prediction error  is minimized subject to a constraint in the rate *R* for coding the syntax elements:

|  |  |  |
| --- | --- | --- |
|  |  | (1) |

The rate-constrained problem (1) can be solved by being converted to an equivalent unconstrained problem by “merging” rate and distortion through the Lagrange multiplier . The unconstrained problem becomes the determination (for a fixed ) of values of syntax elements, which results in the minimum total Lagrangian Cost defined as

|  |  |  |
| --- | --- | --- |
|  | = | (2) |

The Lagrange multiplier can be viewed as a trade-off between rate and distortion. A low value of favors minimizing distortion over rate, and a high value of favors minimizing rate over distortion. The challenge of rate control in video encoding is to determine appropriate value of to achieve the best video quality within the buffer size constraint.

The rate control scheme proposed in [2] was adopted in HEVC Test Model (HM-10.0). In this scheme, rate control λ is calculated using only target rate [2] of the current frame (CTU). Such a scheme works well for inter-coded frame but not so well for intra-coded frame. In this proposal, we propose to extend the current rate control model in HM to determine λ for an intra frame.

# Proposed scheme

To better control rate allocation in an intra-coded frame, a complexity measure of the current frame (CTU) is additionally taken into consideration in the R-λ model as follows:

|  |  |  |
| --- | --- | --- |
|  |  | (3) |

The model parameters α and β are calculated by fitting the model to statistic of a number of natural images. The QP value is calculated using λ value, as proposed in [1]:

|  |  |  |
| --- | --- | --- |
|  |  | (4) |

We introduce two different modes of operation for intra frames rate control:

1. Constant λ for the whole frame is used. Parameters α and β can be updated after each frame is encoded.
2. Parameters α and β remain constant for the entire frame however bits are allocated per CTU depending on the number of remaining bits allocated to this frame. Value of λ is calculated for each CTU using Eq. (3).

Currently in HM only first mode is used for intra frames.

## Complexity Measure

Complexity measure is based on Sum of Absolute Transformed Differences (SATD). SATDis sum of absolute values of coefficients obtained after applying Hadamard transform to the original 8x8 block:

|  |  |  |
| --- | --- | --- |
|  |  | (5) |

To take into account usage of intra prediction two modified measures are introduced:

|  |  |  |
| --- | --- | --- |
|  |  | (6) |

and

|  |  |  |
| --- | --- | --- |
|  |  | (7) |

It was observed that the best results are obtained when both and are calculated and is used when values is larger than a certain threshold. However only small drop in performance was noticed when is used for 720p resolutions and above and is used otherwise. Complexity measure for frame (CTU) is defined as sum of or calculated for all 8x8 blocks within this frame (CTU).

In HM complexity of each CTU is used to allocate its bit budget. The complexity is measured by Mean Absolute Difference (MAD) of the CTU at the same location in the previous frame. The proposed algorithm requires preprocessing to compute the frame complexity of each frame in advance. However in case of intra frame in many application we may expect that correlation intra coded framed will be smaller than the correlation between inter coded frames since intra frames will be placed in larger temporal distance from each other or used at scene cuts.

## Parameter Adaptation

In all modes after encoding a picture, we use the values of the obtained (actual) bits to update the values of *α* and *β*:

|  |  |  |
| --- | --- | --- |
|  |  | (8) |
|  |  | (9) |

where

|  |  |  |
| --- | --- | --- |
|  |  | (10) |

and is a scaling parameter which reduces the speed of changes, in our simulations set to 0.25.

## Bit Allocation

In mode 2 the bits allocated to *i*th CTU are derived as follows:

|  |  |  |
| --- | --- | --- |
|  |  | (13) |

Weight is a ratio of complexity of the *i*th CTU to the complexity of all the CTUs which are still to be coded:

|  |  |  |
| --- | --- | --- |
|  |  | (12) |

where is the number of the CTUs is the coded frame. Since parameters *α* and *β* are notbeing adaptedwithin the frame we can expect that if their initial values are not matching statistic of the frame there will be a mismatch between allocated bits and the bits obtained during the encoding. To compensate for that, modified remaining bits are used to obtain the number of bits allocated to code *i*th CTU:

|  |  |  |
| --- | --- | --- |
|  |  | (14) |

where denotes total remaining bits available to code the frame, is the initial bit target allocated to each CTU

|  |  |  |
| --- | --- | --- |
|  |  | (15) |

and W is the size of a window, which is used to make the bitrate change smoother. The *W* used in our simulations is 4. The term denotes the number of bits allocated to code the frame.

# Experimental results

When rate control is used, constant number of bits is assigned to each frame. Four different rate points are used per sequence. The bits assigned to the frame are the average of the bits obtained when HM is run in intra only mode for a given QP. Used QPs, corresponding to 4 rate points, are 22, 27, 32 and 37.

In the first set of experiments values of parameters *α* and *β* are reset at the beginning of each frame to their initial value, to simulate scene cuts. Table 1 summarizes results on rate control accuracy and Table 2 shows the R-D performance. The resulting average target rate deviation for HM rate control is 93%, and 18% and 4% respectively for Mode 1 and Mode 2 of the proposed method. In the second set of results values of parameters *α* and *β* are updated after encoding of each frame both in HM rate control and in the proposed method. Table 3 summarizes results on rate control accuracy and Table 4 shows the R-D performance. The average target rate deviation for HM rate control and Mode 1 and Mode 2 of the proposed method is 14%, 2% and 1%, respectively.

Table 1:Rate control target rate deviation of the HM rate control and the proposed rate control (Mode 1 and Mode 2) when values of parameters *α* and *β* are reset at the beginning of each frame.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **HM** | **Mode 1** | **Mode 2** |
| Class A | 94.46% | 29.17% | 6.5% |
| Class B | 71.67% | 18.23% | 1.63% |
| Class C | 124.13% | 14.42% | 2.17% |
| Class D | 154.76% | 15.25% | 2.29% |
| Class E | 24.37% | 11.57% | 1.85% |
| Class F | 74.68% | 16.12% | 6.75% |
| **Overall:** | **92.59%** | **17.74%** | **3.52%** |

Table 2:R-D performance of the HM rate control and the proposed rate control (Mode 1 and Mode 2) when values of parameters *α* and *β* are reset at the beginning of each frame.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **HM** | **Mode 1** | **Mode 2** |
| Class A | 0.0% | 0.1% | 0.9% |
| Class B | 0.0% | -0.8% | 3.2% |
| Class C | 0.3% | -1.0% | 0.4% |
| Class D | -0.1% | -0.5% | 0.4% |
| Class E | 0.3% | 0.3% | 3.8% |
| **Overall:** | **0.1%** | **-0.5%** | **1.8%** |
| Class F | 0.6% | -2.9% | -1.9% |

Table 3:Rate control target rate deviation of the HM rate control and the proposed rate control (Mode 1 and Mode 2) when values of parameters *α* and *β* are updated after encoding of each frame.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **HM** | **Mode 1** | **Mode 2** |
| Class A | 8.48% | 1.8% | 0.43% |
| Class B | 4.1% | 1.5% | 0.38% |
| Class C | 23.47% | 1.35% | 0.56% |
| Class D | 26.86% | 1.39% | 0.46% |
| Class E | 1.33% | 1.07% | 0.31% |
| Class F | 16.1% | 3.39% | 2.29% |
| **Overall:** | **13.5%** | **1.77%** | **0.74%** |

Table 4:R-D performance of the HM rate control and the proposed rate control (Mode 1 and Mode 2) when values of parameters *α* and *β* are updated after encoding of each frame.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **HM** | **Mode 1** | **Mode 2** |
| Class A | 0.8% | 0.4% | 1.7% |
| Class B | 0.3% | 0.2% | 3.1% |
| Class C | -0.4% | -0.8% | 0.5% |
| Class D | -0.2% | -0.6% | 0.3% |
| Class E | 0.6% | 0.5% | 3.8% |
| **Overall:** | **0.1%** | **-0.1%** | **1.9%** |
| Class F | 0.0% | -4.1% | -2.5% |

# Conclusion

In this contribution, the proposed rate control scheme for intra frame works significantly better than the current scheme in HM10.0. It provides more accurate target rate matching and at the same time preserves coding efficiency. We proposed such a rate control scheme be adopted into HM for intra frame coding.

# References

1. JCTVC-I0426, “QP determination by lambda value,” Geneva, CH, 27 April – 7 May 2012.
2. JCTVC-K0103, “Rate control by R-lambda model for HEVC,”Shanghai, CN, 10–19 Oct. 2012.

# Patent rights declaration(s)

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