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Title: **Improved Chroma Spatial Prediction for Intra Coding**

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1 Abstract

Subjective tests have shown that chroma blockiness can be present in JM 2.0 coded video material, particularly in the presence of highly saturated chroma. In this document, we propose an improved method of chroma prediction that increases subjective quality. The modification requires one minor syntax change. We propose adoption of the new mode into all profiles. No Intellectual Property Rights are claimed.

2 Introduction

The images in this section exemplify the issue we address in this proposal. We compared JM 2.0 to a commercially available MPEG-2 encoder at equal luma PSNR. The source sequence was a composite from a Hollywood movie, taken from a SuperBit DVD. All three images are 143x80 size regions taken from D-1 resolution progressively scanned images and pixel-replicated by a factor of 3 for display purposes. Table 1 explains the images.

Table 1: Explanation of Images in Figures 1-3

Figure	Source	Luma PSNR	Bitrate
1	Original	N/A	N/A
2	JVT 2.0	40.7 dB	1.02 Mbps
3	MPEG-2	40.7 dB	1.87 Mbps

The chroma blockiness in the JVT image region is clearly more pronounced than that in the MPEG-2 image region.

In the course of this work, we discovered that the primary reason for this blockiness is the encoder trick that eliminates isolated chroma coefficients. Nonetheless, our efforts to improve chroma prediction did result in what we think are worthwhile gains at a reasonable cost in terms of increased complexity.

Figure 1: Original image region

Figure 2: Image region from JM 2.0 coded intra-picture

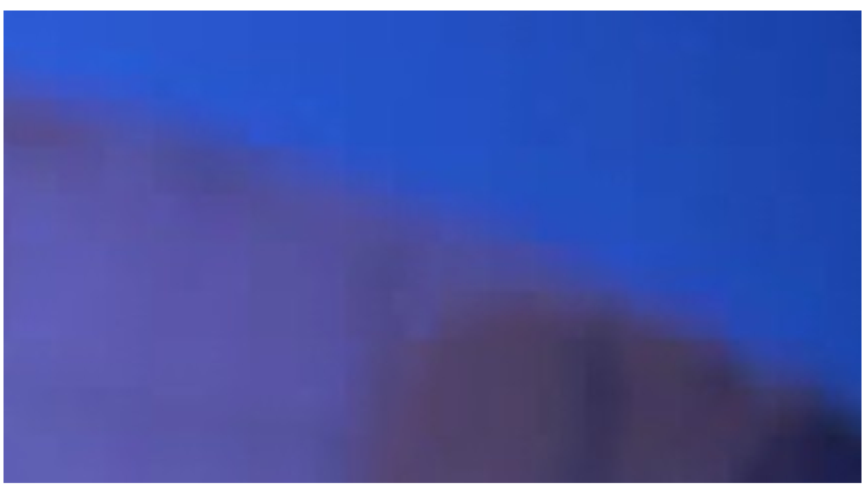


Figure 3: Image region from MPEG-2 coded intra-picture

3 Chroma Spatial Prediction in JM 2.0

There are many spatial prediction modes for luma spatial prediction in intra-coded macroblocks. In 4x4 macroblock mode, luma spatial prediction can be DC or in one of eight spatial directions. The prediction data for a given 4x4 block is taken from the 4x4 blocks above and to the left (if they exist[1]), which in many cases is inside the same macroblock. In 16x16 mode, four prediction choices exist (DC, Horizontal, Vertical and Plane), all using data from *outside* the macroblock.

In contrast to the luma prediction, chroma can *only* be predicted in DC mode, and *only* using data from outside the macroblock. This means that the chroma prediction mode does not have to be signaled.

The DC prediction mode used in chroma differs from those used in luma. Each 4x4 block is predicted with a separate DC prediction.

The 8x8 block of chroma pixels is predicted as follows. Consider the following figure, which is simply a copy of Figure 8.5 from the JVT Working Draft.

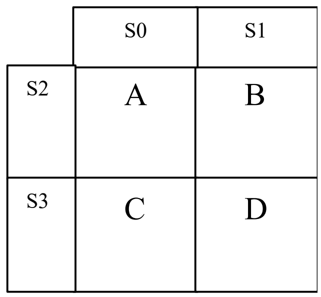


Figure 4: Chroma 4x4 blocks A, B, C and D; and predictors S0-S3.

In this figure, each of S0-S3 represents the sum of the four pixels bordering the macroblock at the location indicated in the figure. Given this, the predictions for all pixels within a block (A, B, C or D) are dependent upon the presence of the pixels used to compute S0-S3, and can be summarized in Table 2. Note that S0-S3 can be unavailable by being outside the picture or slice or because constrained intra prediction is in use and the neighboring blocks are not intra coded.

Table 2: DC Chroma Predictions

Block	S0-S3 available	S0-S1 available	S2-S3 available	None available
A	(S0 + S2 + 4)/8	(S0 + 2)/4	(S2 + 2)/4	128
B	(S1 + 2)/4	(S1 + 2)/4	(S2 + 2)/4	128
C	(S3 + 2)/4	(S0 + 2)/4	(S3 + 2)/4	128
D	(S1 + S3 + 4)/8	(S1 + 2)/4	(S3 + 2)/4	128

4 Proposed Chroma Spatial Prediction

We modify the chroma prediction by allowing adding several new prediction modes similar to modes used in luma processing – horizontal, vertical and plane. The prediction is still done on the entire 8x8 macroblock. To signal the chroma mode, we transmit an **`intra_chroma_pred_mode`** syntax element before the **`cbp`** element location, with the semantics listed in Table 3. The same prediction mode is applied to all intra U and V blocks within a macroblock. The syntax element is only transmitted when at least one chroma block is intra coded. We have only implemented this new syntax element using UVLC and are working on a CABAC implementation. The encoder implementation performs rate-distortion optimized mode decision.

Table 3: Coding of Chroma Prediction Mode

Codeword	Prediction Mode
0	DC
1	Horizontal
2	Vertical

[1] If Constrained Intra Prediction is used, then the neighbors must also be intra blocks.

3	Plane

For the horizontal and vertical filters, the prediction is filtered using a {1,2,1}/4 filter. For the plane mode, we adapt the luma 16x16 plane mode coefficients to an 8x8 block, as follows:

Pred(i,j) = clip1((a + b·(i-3) + c·(j-3) +16) >> 5), i,j=0,…,7
where:

- a = 16·(P(-1,7) + P(7,-1))
- b = (17*H+16)>>5)
- c = (17*V+16)>>5)

and H and V are defined as:

$$H = \sum_{i=1}^{4} i \cdot (P(3+i,-1) - P(3-i,-1))$$

$$V = \sum_{j=1}^{4} j \cdot (P(-1,3+j) - P(-1,3-j))$$

5 CABAC Context Modeling

The coding of **`intra_chroma_pred_mode`** of a given block C is conditioned on the intra chroma prediction mode of the previous block A to the left of C. If there is no block to the left of C, the conditioning context of 0 is used. There are four difference prediction modes, and for each mode, two different models are supplied: one for the most significant bit of **`intra_chroma_pred_mode`** and the other for the least significant bit. In total, eight context models are used.

6 Reduction of Chroma Blockiness

In the JM20 reference encoder, there is an encoder optimization in which the quantized transform coefficients are discarded if the "cost" of the coefficients are determined to be less than a threshold. We have found that this "chroma trick" is the root cause for the blockiness in Figure 2.

7 Results

We tested the proposed change under several different conditions. First, since this is a change to the intra coding, we conducted a test on the all the sequences in the Coding Efficiency Common Conditions document, but under intra coding. The JM20 code was modified to remove the "chroma trick." Because of its length, we sub-sampled Paris temporally by a factor of 5. Otherwise all sequences were coded in their entirety. The average Bjøntegaard-Delta results are 0.12 dB and 3.2% (Table 4). Testing of another NTSC-D1 progressively scanned sequence showed much better results (Table 5).

Next, we tested the actual common conditions for the baseline profile. As intra coding is not used much there, we expected the performance changes to be minimal under these conditions. However, the improvement was actually a substantial fraction of the intra improvement (0.066 dB and 2.3%; Table 6).

In a third test, we tested with the common conditions for higher profile proposals. One deviation from the common conditions document (in accordance with more recent sentiment regarding higher profiles) is that ¼-pel motion-compensation was used. Additionally, we selected the intra period to be 15, in order to simulate conditions of typical entertainment profiles in use today. Data is still being collected.

7.1 Coding Efficiency Common Conditions Sequences (I-frame only)

7.1.1 BΔ Data

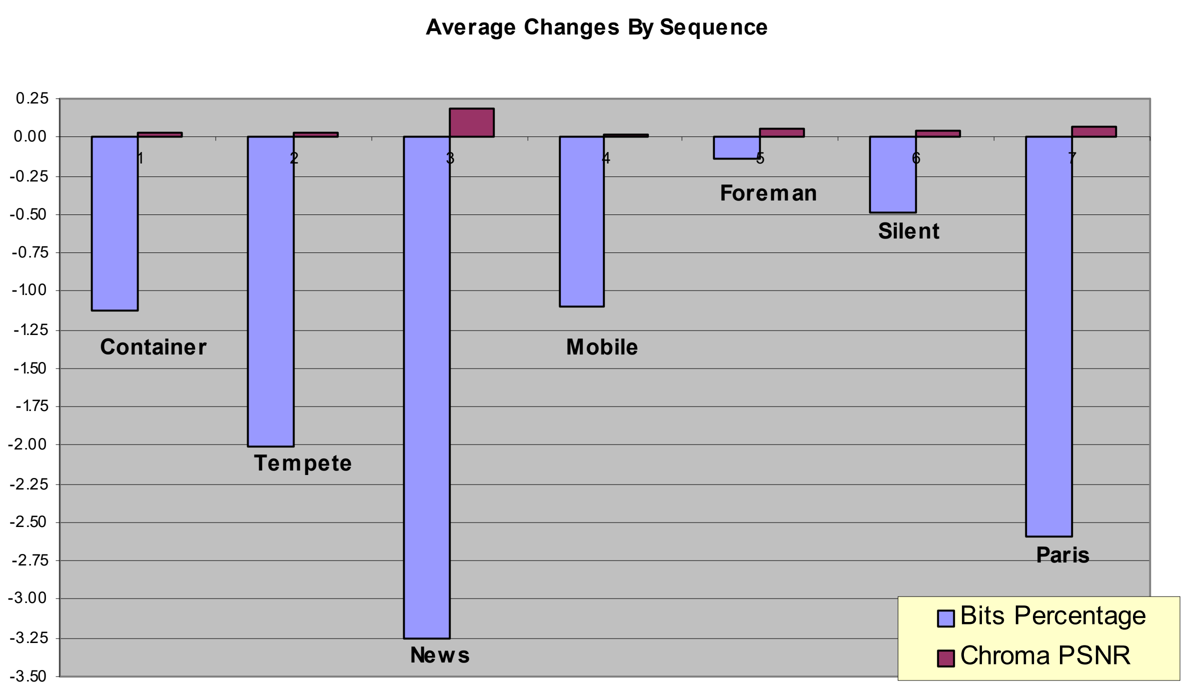
This table is updated with new results since a bug was found in revision 1 of this document.

Table 4: Proposal versus Modified JM20 (without "chroma trick"), Common Conditions, I Only, UVLC

Res.	Hz.	Sequence	BΔ-PSNR (chroma)	BΔ-Bits
QCIF	30	Container	0.087 dB	-2.14%
QCIF	30	News	0.409 dB	-9.57%
QCIF	30	Foreman	0.082 dB	-2.76%
QCIF	30	Silent	0.040 dB	-1.35%
CIF	6	Paris	Unavailable	Unavail.
CIF	30	Mobile	0.060 dB	-1.35%
CIF	30	Tempete	0.098 dB	-3.10%
		AVG	**0.120 dB**	**-3.22 %**
		MAX	**0.409 dB**	**-9.57 %**
		MIN	**0.040 dB**	**-1.35 %**

7.1.2 Average Changes in PSNR and Bits

The following graph shows the average % change in bit-rate and average change in PSNR across the common conditions QP range for each sequence. This may help reader to understand the actual effect of the change, in light of the fact that the other results presented here are with respect to chroma PSNR, while JVT participants are accustomed to thinking of luma PSNR.



7.2 Another Sequence

The example sequence shown in Section 2 shows much more promising results than the Common Conditions test set. This is probably because of the saturated chroma. These results are presented here. These results have not been updated since revision 1, and we expect them to improve.

Table 5: Proposal versus Modified JM20 (without "chroma trick"), Other Sequences, I Only

Res.	Hz.	Sequence	BΔ-PSNR (chroma)	BΔ-Bits
NTSC-D1	30	Secretary	0.432 dB	-9.06%

7.3 Coding Efficiency Common Conditions Baseline Profile (IPPPP w/ UVLC)

Table 6: Proposal versus Modified JM20 (without "chroma trick"), Common Conditions, I/P, UVLC

Res.	Hz.	Sequence	BΔ-PSNR (chroma)	BΔ-Bits
QCIF	10	Container	0.074 dB	-3.02%
QCIF	10	News	0.228 dB	-6.66%
QCIF	10	Foreman	0.030 dB	-1.26%
QCIF	15	Silent	0.032 dB	-1.26%
CIF	15	Paris	0.063 dB	-2.22%
CIF	30	Mobile	0.007 dB	-0.29%
CIF	30	Tempete	0.026 dB	-1.27%
		AVG	**0.066 dB**	**-2.28%**
		MAX	**0.228 dB**	**-6.66%**
		MIN	**0.007 dB**	**-0.29%**

7.4 Coding Efficiency Common Conditions Higher Profile (IPB w/ CABAC)

Table 7: Proposal versus Modified JM20 (without "chroma trick"), Common Conditions, I/P/B, CABAC

Res.	Hz.	Sequence	BΔ-PSNR (chroma)	BΔ-Bits
QCIF	10	Container	X	X
QCIF	10	News	X	X
QCIF	10	Foreman	X	X
QCIF	15	Silent	X	X
CIF	15	Paris	X	X
CIF	30	Mobile	X	X
CIF	30	Tempete	X	X
		AVG		
		MAX		
		MIN		

7.4.1 JVT Patent Disclosure Form

International Telecommunication Union Telecommunication Standardization Sector	International Organization for Standardization	International Electrotechnical Commission

Joint Video Coding Experts Group - *Patent Disclosure Form*

(Typically one per contribution and one per Standard | Recommendation)

Please send to:

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Place and date of submission	3rd JVT meeting May 6 – 11, Fairfax

Relevant Recommendation | Standard and, if applicable, Contribution:

Name (ex: "JVT")	**JVT**
Title	**Improved Chroma Spatial Prediction for Intra Coding**
Contribution number	**JVT-C118**

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