CCITT SGXV
Working Party XV/1
Specialists Group on Coding for Visual Telephony

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Title : INTRA overload
Source: Japan

1. Introduction

When the value of the quantization step size is four or six, coefficient level overloads may occur especially in INTRA macroblocks, because of the +/- 127 level limitation of TCOEFF VLC table (see Appendix 2). In this document the picture quality in the overload case is investigated.

2. Summary of Simulation Results

Simulations are carried out based on the Reference Model 8 under conditions shown in Table 1.

Table 1. Simulation conditions

Frame rate	: 30 F/s
Bit rate	: q = infinite
Q step size	: g = 4 (fixed)
Cyclic refresh	: If the sum of the frame number and the macroblock number, from one to 396, is a multiple of 132, the macroblock is coded as INTRA.

In the "CLAIRE" decoded sequence, the overload cases are observed at her jacket collars and cause noticeable block-shaped distortion. (One method to escape from overloads is shown in Appendix 1. The method is coder optional.)

Considering INTRA overload, forced update should be carried out with the step size more than or equal to eight. The produced bit amount at the first frame is shown in Table 2 when the step size is equal to eight.

Table 2. Produced bit amount at the first frame for g = 8

	Produced bit amount	SNR for Y
'Claire'	70 kbits	43.7 dB
'Miss America'	67	40.9
'Salesman'	164	37.7
'Swing'	221	37.7
'Blue Jacket'	103	40.1

3. Conclusion

Overload causes noticeable block-shaped distortion. This document proposes that the following note must be written in the final recommendation.

> "Note: When g is under eight, overloads may occur especially at INTRA macroblocks and cause noticeable block-shaped distortion."

4. Appendices

Appendix 1: INTRA overload escape method.
Appendix 2: Value range of 8 x 8 DCT data.

5. Reference

[1] UK,Document #430,"Bits per INTRA Coded picture".

END.

Appendix 1 to Doc. #509

INTRA overload escape method

One method to escape from the overloads is limiting the step size to more than or equal to eight for INTRA macroblocks. The overloads do not occur because quantized data will be in the range from -127 to +127 by limiting the step size to more than or equal to eight. Nevertheless, if the step size is changed temporarily, the changed step size value must be transmitted. This operation can be optional on the coder side. The summary of the procedure is:

If g = 4 or 6:

1. At INTRA macroblocks, g is changed to 8. The g value must be transmitted, so that the TYPE3 becomes "INTRA + Q".
2. From the next macroblock which is not INTRA, macroblocks are coded using the original g value. At the next first transmitted macroblock, the g value must be transmitted, so that the TYPE3 becomes "Coded + Q" or "MC coded + Q".
3. Subsequent macroblocks are coded ordinarily till the next INTRA macroblock appears.

Otherwise:

All macroblocks are coded ordinarily.

The additional code amount by changing the g value is 17 bits for every INTRA macroblock: at the INTRA macroblock, 5 bits for QUANT2 code and additional 3 bits for changing the TYPE3 from "INTRA" to "INTRA + Q", and at the next first coded macroblock, 5 bits for QUANT2 code and additional 4 bits for changing the TYPE3 from "Coded" to "Coded + Q" or from "MC coded" to "MC coded + Q". The total additional code amount is 51 bits for every coded frame because of three INTRA macroblocks in every coded frame for cyclic refresh. 51 bits per coded frame are not substantial for the total bit amount.

Tables 3 and 4 show the simulation results, and numerically there is almost no difference between RM8 and the proposed method. Subjectively, the block-shaped distortion mentioned above is removed by the proposed method. In some scenes, however, some very slight mosquito noises may be observed at INTRA macroblocks because of being encoded with coarser step size, g = 8, than surrounding macroblocks.

Table 3. INTRA overload simulation result "Claire"

STATISTICS : RM8 INSTITUTE : NEC
SEQUENCE : CLAIRE DATE : June 2,1989
MODIFICATION : Step size g = 4 fixed BIT RATE : Free
Cyclic refresh 3 MB / F FRAME RATE : 30Hz

Mean value 1/493			RM8	INTRA : g = 8
1. RMS	Y		1.32	1.32
	U		1.34	1.35
	V		1.08	1.10
2. SNR	Y		45.73	45.71
	U		45.60	45.49
	V		47.47	47.33
3. Quantization step size			4.00	4.03
4. Num. of non-zero coeffs			4.10	4.09
5. Num. of zero coeffs			8.85	8.90
6. Block type of MACRO	FIXED		96.2	96.7
	CODED MC		20.9	20.9
	FIXED MC		0.0	0.0
	CODED		276.0	275.4
	INTRA		3.0	3.0
7. Block type of Y	FIXED		996.2	993.8
	CODED MC		79.5	79.6
	FIXED MC		4.0	3.9
	CODED		492.3	494.7
	INTRA		12.0	12.0
8. Block type of UV	FIXED		553.8	554.8
	CODED MC		35.0	35.1
	FIXED MC		6.7	6.7
	CODED		190.4	189.4
	INTRA		6.0	6.0
9. Number of bits	Macro attribs		2481.1	2525.4
	INTRA MB mean val.	Y	96.1	96.1
		UV	48.0	48.0
	End of block		1630.4	1633.6
	Motion vectors		65.4	92.6
	Coeffs	Y	17096.8	17004.4
		U	1784.4	1775.5
		V	800.5	790.8
		Total	19681.8	19570.6
	Total		24002.8	23966.3

RM8 : Overloads occur sometimes in INTRA macroblocks.

Table 4. INTRA overload simulation result "Salesman"

STATISTICS : RM8 INSTITUTE : NEC
SEQUENCE : Salesman DATE : June 2,1989
MODIFICATION : Step size g = 4 fixed BIT RATE : Free
Cyclic refresh 3 MB / F FRAME RATE : 30Hz

Mean value 1/448			RM8	INTRA : g = 8
1. RMS	Y		2.15	2.17
	U		1.43	1.44
	V		1.29	1.31
2. SNR	Y		41.50	41.39
	U		45.03	44.94
	V		45.92	45.78
3. Quantization step size			4.00	4.03
4. Num. of non-zero coeffs			6.54	6.52
5. Num. of zero coeffs			39.96	39.98
6. Block type of MACRO	FIXED		2.5	2.6
	CODED MC		62.0	61.7
	FIXED MC		0.0	0.0
	CODED		328.4	328.5
	INTRA		3.1	3.1
7. Block type of Y	FIXED		160.6	156.5
	CODED MC		247.1	246.1
	FIXED MC		0.9	0.8
	CODED		1162.9	1168.1
	INTRA		12.4	12.5
8. Block type of UV	FIXED		477.8	478.4
	CODED MC		62.4	61.7
	FIXED MC		61.6	61.8
	CODED		183.9	183.9
	INTRA		6.2	6.2
9. Number of bits	Macro attribs		2688.7	2728.9
	INTRA MB mean val.	Y	99.5	99.6
		UV	49.8	49.8
	End of block		3350.1	3357.1
	Motion vectors		212.0	305.6
	Coeffs	Y	97464.4	97002.4
		U	3118.5	3090.2
		V	1244.9	1224.9
		Total	101827.9	101317.5
	Total		108227.9	107858.6

RM8 : No overload occurs.

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Value range of 8 x 8 DCT data

The 2-D DCT is defined as Equation (1). B(u,v) takes its maximum value when b(x,y) takes its maximum value for a positive c(u,x)·c(v,y) value and b(x,y) takes its minimum value for a negative c(u,x)·c(v,y) value. B(u,v) takes its minimum value when b(x,y) takes its minimum value for a positive c(u,x)·c(v,y) value and b(x,y) takes its maximum value for a negative c(u,x)·c(v,y) value.

When b(x,y) has a value within the range from 0 to 255, the maximum and the minimum values of B(u,v) are shown in Table 5. Except B(0,0), the highest maximum value is 1020 and the lowest minimum value is -1020. Therefore, when the quantization step size is smaller than eight, the range of quantized value is wider than the range from -127 to +127.

When b(x,y) has a value within the range from -255 to 255, the maximum and the minimum values of B(u,v) are shown in Table 6. Including B(0,0), the highest maximum value is 2040 and the lowest minimum value is -2040.

$$B(u,v) = \sum_{x=0}^{7} \sum_{y=0}^{7} b(x,y)\, c(u,x)\, c(v,y) \qquad u,v = 0,1,2,\cdots,7 \tag{1.a}$$

$$c(u,x) = \frac{C(u)}{2} \cos \frac{\pi u (2x+1)}{16} \tag{1.b}$$

$$C(u) = \begin{cases} 1/\sqrt{2} & \text{for } u = 0 \\ 1 & \text{otherwise} \end{cases} \tag{1.c}$$

Table 5. Value range of B(u, v) when $0 \leqq b(x, y) \leqq 255$

u = 0	1	2	3	4	5	6	7	
2040 0	924 -924	942 -942	924 -924	1020 -1020	924 -924	942 -942	924 -924	0 = v
	837 -837	854 -854	837 -837	924 -924	837 -837	854 -854	837 -837	1
		871 -871	854 -854	942 -942	854 -854	871 -871	854 -854	2
			837 -837	924 -924	837 -837	854 -854	837 -837	3
				1020 -1020	924 -924	942 -942	924 -924	4
					837 -837	854 -854	837 -837	5
						871 -871	854 -854	6
MAX MIN							837 -837	7

Table 6. Value range of B(u, v) when $-255 \leqq b(x, y) \leqq 255$

u = 0	1	2	3	4	5	6	7	
2040 -2040	1849 -1849	1885 -1885	1849 -1849	2040 -2040	1849 -1849	1885 -1885	1849 -1849	0 = v
	1675 -1675	1708 -1708	1675 -1675	1849 -1849	1675 -1675	1708 -1708	1675 -1675	1
		1741 -1741	1708 -1708	1885 -1885	1708 -1708	1741 -1741	1708 -1708	2
			1675 -1675	1849 -1849	1675 -1675	1708 -1708	1675 -1675	3
				2040 -2040	1849 -1849	1885 -1885	1849 -1849	4
					1675 -1675	1708 -1708	1675 -1675	5
						1741 -1741	1708 -1708	6
MAX MIN							1675 -1675	7