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

Document #107

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SOURCE: NTT, KDD, NEC and FUJITSU
TITLE : REFERENCE MODEL SIMULATION

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1. Introduction

A reference model was agreed upon to further investigate quantization and coding strategies at the last Tokyo meeting. The specifications were described in Document #104. The model has been implemented and improved in the computer simulation system so that it gives reasonable performance and can be used for algorithm comparison purpose.

This contribution describes some problems encountered in the course and improvements made. The improved results will be demonstrated at the meeting.

2. Five Steps Simulated

First the reference model was implemented according to Document #104 (MOD10). Since the obtained performance was not good, several elements were improved step by step in four steps (MOD11 - MOD14). Parameters for each step are shown in Table 1 and numerical results are shown in Annex.

3. Redundancy Removal for Block Attributes (MOD11)

As the bit consumption data for MOD10 shows, the original reference model according to document #104 uses 30% or more of the total bits for transmitting 'Block Type' and 'Quantizer Step'. To save some of them, the following improvements are justifiable.

- For chrominance blocks, no motion compensation is applied. Hence the attribute 'MC/No MC' is redundant. This will reduce the Block Type information to 1.4 bits per chrominance block instead of 2 bits per block. To simulate more correctly, the following VLC was assumed.

Luminance Block Type	Word length
Inter/No MC/No coded	1 bit
Inter/MC/Coded	2
Inter/No MC/Coded	3
Inter/MC/No coded	4
Intra	4

Chrominance Block Type	Word length
Inter/No coded	1 bit
Inter/Coded	2
Intra	2

- For a scene cut, all the blocks are coded with intra mode. Hence Block Type for the frame can be moved to Picture Attribute, negating block basis bit consumption.

- Since the quantizer step size control of the reference model seems equivalent to GOB basis control, the 'Quantizer Step' Attribute can be moved to GOB Attribute, negating block basis bit consumption.

All of these measures make additional 3000 bits usable for 'Quantizer Index' per frame to improve SNR by 0.3 - 0.5 dB.

In addition to that, temporal pre-filter having characteristics described in Figure 3/Document #60 was introduced to cope with noisy test sequences. It should be noted that definition of SNR is changed to (signal) to (difference between coded Output and pre-filter output) when pre-filter is used.

4. Introduction of Adaptive Filter in the Coding Loop (MOD12)

An adaptive filter having the following characteristics was inserted before the frame memory inside the coding loop;

- Median type
- Operated only if the difference between the filter output and input is not greater than 6

It improves SNR by 0.3 - 1.0 dB. Reduction of MC vector information is observed. For further discussion of this filter, see the companion Document #110.

5. Modification of Intra/inter Identification (MOD13)

For Split-Trevor sequence, a considerable number of blocks are coded by intra mode in MOD10 - MOD12. This is due to that if the input block has levels around 128, the mode selection criterion specified in Annex 3 to Document #104 gives intra mode even when prediction errors are small. Hence, an additional criterion to always select inter mode if the squared sum of the prediction error is less than 100.

This prevents the use of less efficient intra mode when it is not appropriate.

6. Modification of Quantizer Control and VLC (MOD14)

6.1 Quantizer Control

Observation of processed pictures for MOD13 revealed, however, that there was a tendency of good pictures at the middle of the frame but bad pictures at the bottom. This phenomenon was obvious for Checked Jacket in particular.

This was considered to be due to GOB basis control. Hence, picture basis control was tried to assign distortion equally over the picture. This can be realized either by feed forward method, where information

generation for the picture to be coded is estimated by some feature of each block, or by feed back method, where information generation is estimated from the data quantity of the previously coded picture stored in the transmission buffer. For further discussion, see the companion Document #111. For the simulation purpose, the first approach was taken because of relatively short test sequences.

First, average word length for non-zero coefficients and average number of zero coefficients before the last non-zero coefficient are set as functions of the quantizer step size from training data. Next, for a picture to be coded, its number of non-zero coefficients and its number of significant blocks are estimated to determine an appropriate quantizer step size from histograms of transform coefficient amplitudes and assigned quantity of bits for the picture.

6.2 VLC

Large amplitude of coefficients are occasionally generated, in which case a lot of coded bits are necessary with the code set defined in Annex 2 to Document #104. Hence, the alternative code set as shown in Figure 1 was introduced. This code set limits the code length at 11 bits.

6.3 Motion Vector Suppression

To suppress generation of motion vectors in the still background, motion vectors are forced to zero if the sum of absolute prediction errors in a block is less than 64 x 3 (Item 21/Document #104). There was observed, however, 'sticking noise' in the uncovered background part in Miss America. An additional use of absolute sum of pure frame difference as shown in Figure 2 was introduced to cope with this 'sticking noise'.

6.4 Improvements

SNR has improved by 0.3 - 0.8 dB compared to MOD13 as intended.

7. Observations on Simulation Results

1) Information for chrominance signals

The data in Annex shows the percentage for chrominance information is about 25% for Miss America and about 10% for other test sequences. Further subsampling may be unnecessary.

2) Occurrence frequency for each Block Type

The data in Annex shows the use of VLC with word length of Section 3 is almost reasonable. Code assignments for 'Inter/MC/Coded' and 'Inter/No MC/Coded' should better be interchanged.

8. Conclusion

Efforts have been made to obtain the best possible pictures within the reference model, in order to compare with it the proposal described in the companion Document #108. Processed pictures for MOD14 will be presented with VTR.

Table 1 Reference Model Simulation Parameters

Item		MOD 10 (Document # 104)	MOD 11	MOD 12	MOD 13	MOD 14
1) Significant / insignificant identification		After quantization	→	→	→	→
2) Intra / inter identification		Squared sum comparison between input block and prediction error block	→	→	Minimum power for intra selection restricted (§5)	→
3) Scene cut	Detection	Squared sum comparison between input frame and prediction error frame	(not implemented) Note			
	Number of bits / frame	2 × normal frame (40k, 60k)	→	→	→	→
4) Quantizer	Intra DC	9 bit linear				
	Inter DC AC	Linear with dead zone (Dead zone = 1.5 × step size)	→	→	→	→
	Y/C	Same				
5) Quantizer control		Block basis	GOB basis (§3)	→	→	Frame basis (§6.1)
6) Determination of transmitted coeff.		According to zig-zag scan	→	→	→	→
7) Classification		None (but EOB)	→	→	→	→
8) VLC		① One for coefficients ② One for EOB	→	→	→	Shortened for large amplitude (§6.2)
9) Table for coding		None	→	→	→	→
10) MC	Detection	① 3 step block matching ② Forced to off with $\overline{\text{IFDI}}$	→	→	→	$\overline{\text{IDFDI}}$ is also compared (§6.3)
	Vector	Integer	→	→	→	→
	Chrominance	Without MC				
	Tracking range	±7 pels × ±7 lines				
	Coding	Absolute vector, FLC (8 bit)				
11) Filter inside the coding loop		None	→	Adaptive median filter (§4)	→	→
12) Pre-filter		None	Temporal filter (§3)	→	→	→
13) Block attribute		Block type : 2 bit / block Q. step : 3 bit / block MC : 8 bit / block	① Y/C Block type → VLC ② Q. step → GOB attribute ③ Block type for scene cut → Picture attr. (§3)	→	→	→

Note : A priori method used.

Fig. 1

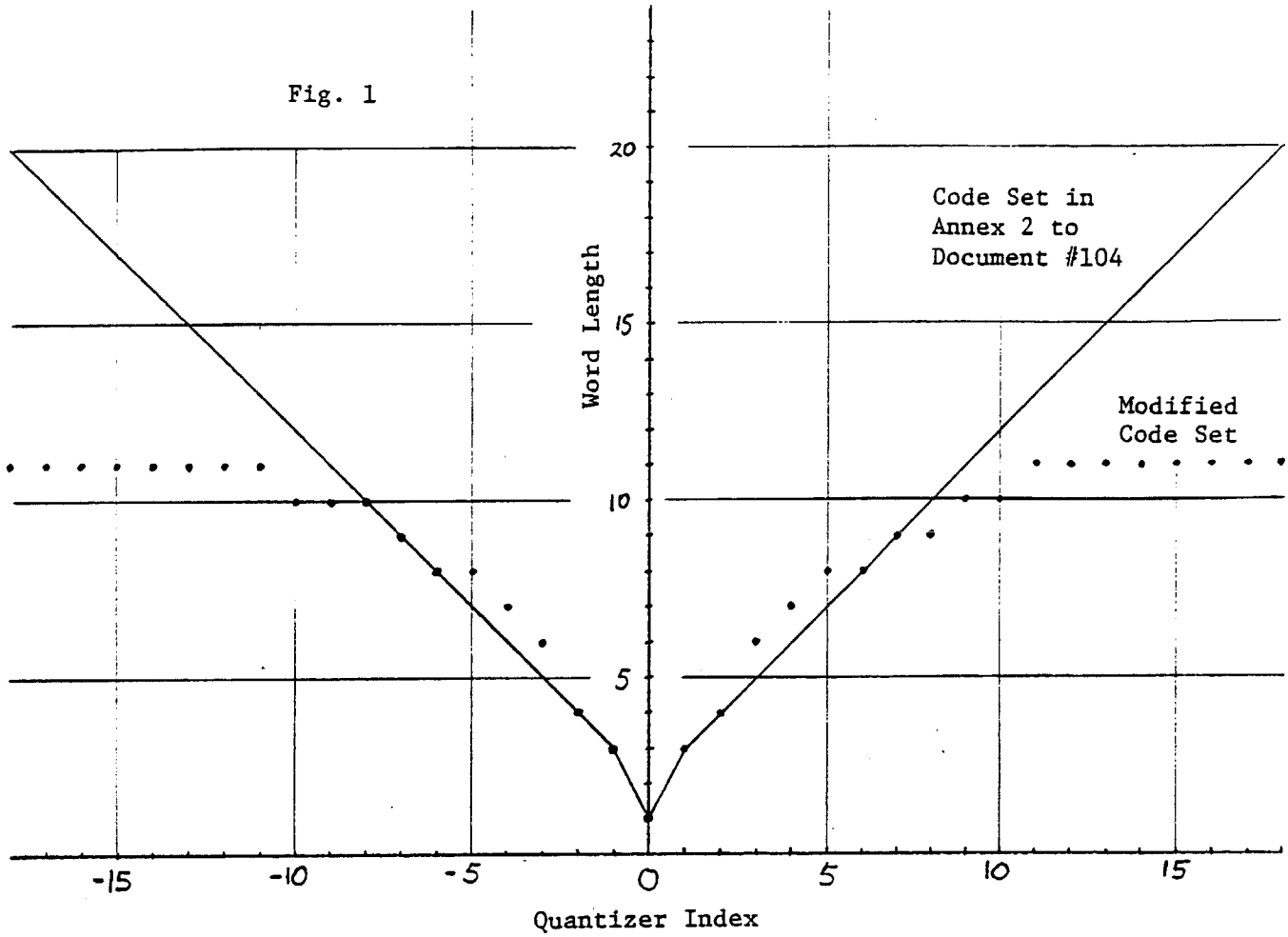
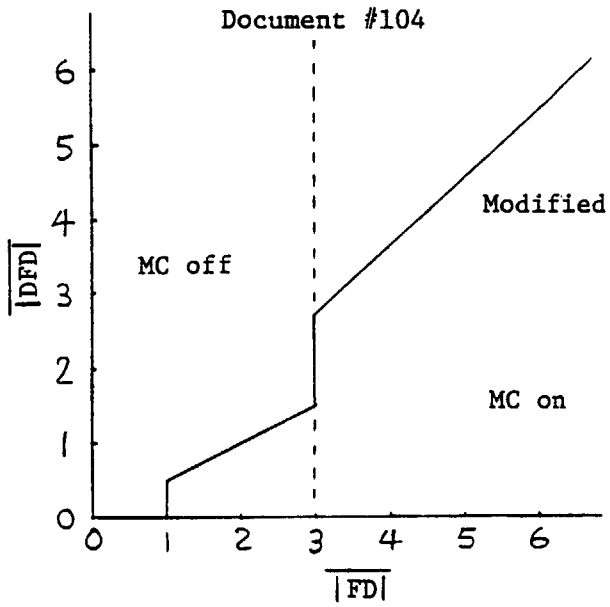

Code Set in
Annex 2 to
Document #104
Modified
Code Set
Word Length
20
15
10
5
-15
-10
-5
0
5
10
15
Quantizer Index

Fig. 2


Document #104
Modified
MC off
MC on
|DFD|
|FD|
0
1
2
3
4
5
6

Annex to Document #107

Simulation Results

Key

STEP VALUE	Step size g averaged over all the transmitted frames
THRESHOLD VALUE	Threshold to determine significant coefficients (= 1.5 g)
SIGNIFICANT COEFFICIENTS	Average number of significant coefficients per significant block
SENT COEFFICIENTS	Average number of transmitted coefficients per significant block
ATTRIBUTE	Average number of attribute bits per transmitted frame
MC VECTOR	Average number of MC vector bits per transmitted frame
BIT EOB	Average number of EOB bits per transmitted frame
SQ	Average number of quantizer index bits per transmitted frame
LUMINANCE	Percentage of luminance information to the total
CHROMINANCE	Percentage of chrominance information to the total
SIGNIFICANT BLOCK	Average number of coded blocks per transmitted frame
INTRA BLOCK	Average number of intra mode coded blocks per coded frame except scene-cut frame(s)
SNR	Signal (=255) to root mean square error between coder output and input

Information Generation and SNR

Miss America	MOD 10	MOD 11	MOD 12	MOD 13	MOD 14
STEP VALUE	9.5	7.7	6.9	6.9	6.8
THRESHOLD VALUE	14.3	11.6	10.4	10.4	10.2
SIGNIFICANT COEFFICIETS	2.5	3.0	3.0	3.0	3.0
SENT COEFFICIENTS	12.3	13.4	11.4	11.7	12.2
ATTRIBUTE	6373	3421	3462	3456	3469
MC VECTOR	2831	2237	1923	1926	1932
BIT EOB/CLASS	1319	1808	1996	1994	1965
SQ	9837	12866	12944	12958	13214
LUMINANCE	70.7	75.6	74.9	75.2	74.7
CHROMINANCE	29.3	24.4	25.2	24.8	25.3
SIGNIFICANT BLOCK	540	621	682	675	664
INTRA BLOCK	14	12	11	0	0
SN RATIO	38.79	40.61	41.74	41.73	42.00

Checked Jacket	MOD 10	MOD 11	MOD 12	MOD 13	MOD 14
STEP VALUE	10.4	8.7	8.3	8.2	8.2
THRESHOLD VALUE	15.6	13.1	12.5	12.3	12.3
SIGNIFICANT COEFFICIETS	2.9	3.8	3.7	3.7	3.7
SENT COEFFICIENTS	16.6	20.3	18.5	18.8	21.3
ATTRIBUTE	6265	3113	3167	3157	3137
MC VECTOR	1798	1472	1425	1412	1046
BIT EOB/CLASS	1405	1844	1906	1918	1915
SQ	11382	14436	14361	14360	15281
LUMINANCE	86.3	90.7	90.6	91.2	92.6
CHROMINANCE	13.7	9.3	9.4	8.8	7.4
SIGNIFICANT BLOCK	504	510	538	535	546
INTRA BLOCK	26	16	15	0	0
SN RATIO	37.45	38.33	38.64	38.69	39.48

Split-Trevor	MOD 10	MOD 11	MOD 12	MOD 13	MOD 14
STEP VALUE	14.6	12.6	11.9	10.5	10.7
THRESHOLD VALUE	21.9	18.9	17.9	15.8	16.1
SIGNIFICANT COEFFICIETS	2.5	2.9	2.9	4.0	4.1
SENT COEFFICIENTS	8.7	10.1	9.5	14.0	14.0
ATTRIBUTE	7562	4136	4126	3514	3482
MC VECTOR	4862	4630	4485	4436	4017
BIT EOB/CLASS	2374	2842	2915	3103	3190
SQ	16679	19883	19936	20401	21010
LUMINANCE	84.9	88.6	88.4	91.5	91.2
CHROMINANCE	15.1	11.4	11.6	8.5	8.8
SIGNIFICANT BLOCK	937	977	999	794	791
INTRA BLOCK	333	329	327	14	15
SN RATIO	35.62	36.48	37.34	37.86	38.20

Graphics	MOD 10	MOD 11	MOD 12	MOD 13	MOD 14
STEP VALUE					21.4
THRESHOLD VALUE					32.1
SIGNIFICANT COEFFICIETS					2.2
SENT COEFFICIENTS					28.4
ATTRIBUTE					3287
MC VECTOR					147
BIT EOB/CLASS					2348
SQ					27956
LUMINANCE					90.8
CHROMINANCE					9.2
SIGNIFICANT BLOCK					791
INTRA BLOCK					0
SN RATIO					30.68

Occurrence Frequency of Block Type (MOD 14)

in %

Luminance Block Type	MA	CJ	ST	Average
Inter/No MC/No coded	69.7	72.0	55.6	65.8
Inter/MC/Coded	5.6	6.7	25.8	12.7
Inter/No MC/Coded	14.8	19.3	10.5	14.9
Inter/MC/No coded	9.8	1.8	7.2	6.3
Intra	0.0	0.0	0.7	0.2

in %

Chrominance Block Type	MA	CJ	ST	Average
Inter/No coded	68.6	91.5	83.1	81.1
Inter/Coded	31.3	8.3	16.4	18.7
Intra	0.0	0.0	0.4	0.1