CCITT Study Group XV **Draft Document #122**
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Specialists Group on Coding for Visual Telephony

Source: UK, Sweden, France

Title: VLC set proposal for nx384kbits/s

Introduction

Working party members in Holland have produced statistical data using the Split-Screen and Miss America sequences through the simulation reference codec (see appendix 1 and 2). This paper uses this statistical data to derive a VLC code set for the video multiplex.

Statistical data

Examining the data for Miss America (Appendix 1) it can be seen that the End of Block (EOB) word occurs very frequently when compared to the occurrences of the quantisation data, being second in probability only to quantisation level zero. This implies that an efficient method of coding the block length is to use a VLC coded EOB word at the end of the quantisation data. For the purposes of VLC code book calculation therefore the EOB occurrences are considered as part of the quantisation statistical data.

For simplicity of comparison and documentation in this paper only the first 16 most frequently occurring terms are considered from the tables in appendix 1 and 2. This simplification will not significantly impact on the results as approximately 99.8% of the data occurrences are included in the 16 most frequent levels.

Rank-ordering the statistical data for split screen and calculating the Minimum-Redundancy Code Table (Huffman code ref.1) the following results are obtained:-

Data Type	Occurrences	Huffman Code	Length
Quantisation level 0	119142	1	1
End Of Block Code	13203	011	3
Quantisation level 2	12775	010	3
Quantisation level -2	12250	001	3
Quantisation level -3	2251	00011	5
Quantisation level 3	2086	00010	5
Quantisation level -4	672	000011	6
Quantisation level 4	663	000010	6
Quantisation level 5	298	0000010	7
Quantisation level -5	287	0000001	7
Quantisation level 6	169	00000110	8
Quantisation level -6	156	00000001	8
Quantisation level 7	90	000001111	9
Quantisation level -7	85	000001110	9
Quantisation level -8	58	000000001	9
Quantisation level 8	52	000000000	9

Table 1

Performing the exact same set of operations on the data for Split-Screen results in the following table:-

Data Type	Occurrences	Huffman Code	Length
Quantisation level 0	138405	1	1
Quantisation level 2	16929	011	3
Quantisation level -2	16196	010	3
End Of Block Code	15267	001	3
Quantisation level -3	4180	00011	5
Quantisation level 3	3975	00010	5
Quantisation level -4	1656	000010	6
Quantisation level 4	1518	000001	6
Quantisation level 5	858	0000110	7
Quantisation level -5	738	0000001	7
Quantisation level 6	459	00001110	8
Quantisation level -6	381	00000001	8
Quantisation level 7	244	000011111	9
Quantisation level -7	233	000011110	9
Quantisation level -8	184	000000001	9
Quantisation level 8	167	000000000	9

<u>Table 2</u>

Note: The code word lengths resulting for split-screen are identical to that for Miss America. The code word tables are therefore optimally matched to both sets of data.

Calculating the number of bits required for the above data sets and comparing the result with a simple comma code of lengths 1,2,3,4,5... etc results in the following table:

	Huffman	Comma	Saving using Huffman
Miss America	272781 bits	279997bits	2.6%
Split-Screen	368744 bits	390887bits	6%

<u>Table 3</u>

NB. The above results have been derived by using the code set derived for Miss America on the Split Screen data without re-ordering for maximum efficiency (ie derived without cheating).

<u>Discussion</u>

A comma code has advantages in simplicity of implementation and error recovery. A 6% loss in coding performance is unfortunately a fairly high price to pay. If we consider the use of VLC coding for the relative addressing of coded blocks, comma codes have a distinct disadvantge. In a group of blocks, if we assume the worst case condition of the first Y block coded and the CB block on the far right of the picture also coded, then a relative distance of 131 must be transmitted in the addressing scheme. A simple comma code of the type mentioned above would require a word length of 131 bits which is unacceptable from an efficiency and hardware point of view. A huffman code would also result in unacceptable code word lengths with such a large data set. It is therefore proposed that a threshold "Lukacs" code is used similar to that described in ref 2. A possible code set is shown in table 4 below:

Number	Code	Length
1	1	1
2	001	3
3	010	3
4	011	3
5	00010	5
6	00011	5
7	000010	6
8	000011	6
9	0000010	7
10	0000011	7
11	00000010	8
12	00000011	8
13	000000010	9
14	000000011	9
15	0000000010000001	16
16	0000000010000010	16
17	0000000010000011	16
18	0000000010000100	16
19	0000000010000101	16
20	0000000010000110	16
21	0000000010000111	16
22	0000000010001000	16
.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
138	0000000001111100	16
139	0000000001111101	16
140	0000000001111110	16

<u>Table 4</u>

This table has a number of significant advantages:

i) The efficiency of the code set for the quatisation data is near optimal

ii) The maximum code length is 16

iii) No words or combination of words contain more than 14 zeros in a row

iv) Re-sychronisation (after a tracking loss due to errors) is highly likely if simple rules are applied such as "if two ones in row are found then assume the next bit is the start of a code word". Other valid rules are also possible.

If we use 16 zeros for the Group of Block Start Codes (GBSC) as well as for the Picture Start Code (PSC) and make the PSC simply a GBSC with the block line number set to zero (ie. a special case of GBSC)' then reasonable performance will be obtained under retracking and error conditions.

It is thought that the code set in table 4 will be reasonably matched to the statistics of relative addressing of the moving blocks of typical scenes although a formal analysis has not been performed. It should be remembered that there is only one relative address per coded block and a number of coded coefficients so relative address efficiency is not as critical as coefficient coding.

The exact detail of the Huffman Code propsed in Table 4 is not important at this stage since the statistics are likey to change with algorithm improvements. From a hardware point of view though it is necessary to put some restriction on the length and number of codes used.

Summary of Proposal

1). Intially the code table in table 1 above should be adopted for all variable length coded data in the codec.

2). A GBSC should consist of 16 zeros followed by Line of Block Number and Type information.

3) A PSC should be as the GBSC above except with the Line of Block Number set to zero.

4) The detail of the VLC set should be programmable for all code words within the constraint of a maximum code word length of 16.

Conclusion

The above proposal attempts to make a sensible compromise between efficiency, error performance and implementation difficulties. The code table proposed will be well matched to the quantisation data provided by Holland for both Split-Screen and the Miss-America sequences.

References:

Ref 1 D.A.Huffman, " A Method for the construction of Minimum-Redundancy Codes", Proceeding of the IRE #40, Sept 1952.

Ref 2. M.E.Lukacs, "Variable Word Length Coding for a High Data Rate DPCM Video Coder", 1986 Picture Coding Symposium, Tokyo, Japan.

MISS AMERICA CODING STATISTICS : first 20 frames
frame frequency : 15 Hz
modified CIF

MODES FOR LUMINANCE :

INTRA UNCODED (EXC. DC)	:	1009
INTRA CODED	:	579
INTER UNCODED NO DISP	:	23439
INTER CODED NO DISP	:	3189
INTER UNCODED DISP	:	1124
INTER CODED DISP	:	3926

MODES FOR U_SIGNAL :

INTER UNCODED	:	4853
INTER CODED	:	3463

MODES FOR U_SIGNAL :

INTER UNCODED	:	6270
INTER CODED	:	2046

BITS FOR Y_COEFF.	:	0
BITS FOR U_COEFF.	:	0
BITS FOR V_COEFF.	:	0
BITS FOR EOB_WORD	:	32176
BITS FOR Y_ATTR	:	87873
BITS FOR U_ATTR	:	18705
BITS FOR V_ATTR	:	14454

QUANTIZATION LEVEL 0 OCCURS : 119142 TIMES.

LEVEL 1 OCCURS	0 TIMES	LEVEL -1 OCCURS	0 TIMES.
LEVEL 2 OCCURS	12250 TIMES	LEVEL -2 OCCURS	12775 TIMES.
LEVEL 3 OCCURS	2086 TIMES	LEVEL -3 OCCURS	2251 TIMES.
LEVEL 4 OCCURS	663 TIMES	LEVEL -4 OCCURS	672 TIMES.
LEVEL 5 OCCURS	298 TIMES	LEVEL -5 OCCURS	287 TIMES.
LEVEL 6 OCCURS	169 TIMES	LEVEL -6 OCCURS	156 TIMES.
LEVEL 7 OCCURS	90 TIMES	LEVEL -7 OCCURS	85 TIMES.
LEVEL 8 OCCURS	52 TIMES	LEVEL -8 OCCURS	58 TIMES.
LEVEL 9 OCCURS	29 TIMES	LEVEL -9 OCCURS	40 TIMES.
LEVEL 10 OCCURS	21 TIMES	LEVEL -10 OCCURS	30 TIMES.
LEVEL 11 OCCURS	21 TIMES	LEVEL -11 OCCURS	17 TIMES.
LEVEL 12 OCCURS	10 TIMES	LEVEL -12 OCCURS	21 TIMES.
LEVEL 13 OCCURS	11 TIMES	LEVEL -13 OCCURS	7 TIMES.
LEVEL 14 OCCURS	6 TIMES	LEVEL -14 OCCURS	7 TIMES.
LEVEL 15 OCCURS	2 TIMES	LEVEL -15 OCCURS	7 TIMES.
LEVEL 16 OCCURS	1 TIMES	LEVEL -16 OCCURS	3 TIMES.
LEVEL 17 OCCURS	5 TIMES	LEVEL -17 OCCURS	5 TIMES.
LEVEL 18 OCCURS	3 TIMES	LEVEL -18 OCCURS	8 TIMES.
LEVEL 19 OCCURS	2 TIMES	LEVEL -19 OCCURS	3 TIMES.
LEVEL 20 OCCURS	1 TIMES	LEVEL -20 OCCURS	5 TIMES.
LEVEL 21 OCCURS	2 TIMES	LEVEL -21 OCCURS	0 TIMES.
LEVEL 22 OCCURS	3 TIMES	LEVEL -22 OCCURS	1 TIMES.
LEVEL 23 OCCURS	0 TIMES	LEVEL -23 OCCURS	0 TIMES.
LEVEL 24 OCCURS	3 TIMES	LEVEL -24 OCCURS	1 TIMES.
LEVEL 25 OCCURS	1 TIMES	LEVEL -25 OCCURS	0 TIMES.
LEVEL 26 OCCURS	0 TIMES	LEVEL -26 OCCURS	0 TIMES.
LEVEL 27 OCCURS	0 TIMES	LEVEL -27 OCCURS	1 TIMES.
LEVEL 28 OCCURS	0 TIMES	LEVEL -28 OCCURS	0 TIMES.
LEVEL 29 OCCURS	0 TIMES	LEVEL -29 OCCURS	1 TIMES.
LEVEL 30 OCCURS	0 TIMES	LEVEL -30 OCCURS	2 TIMES.
LEVEL 31 OCCURS	0 TIMES	LEVEL -31 OCCURS	2 TIMES.

EOB_STATISTICS :

6762	2858	269	189	19	18	0	1
1325	413	150	42	18	2	0	0
706	112	41	19	2	1	0	0
88	49	8	5	0	0	0	0
81	6	1	0	0	0	0	0
3	8	0	0	0	0	0	0
7	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

EOB IS 13203 TIMES USED.

[illegible] 20. frames
frame frequency : 10 Hz
modified CIF

MODES FOR LUMINANCE :

INTRA UNCODED (EXC. DC)	:	1557
INTRA CODED	:	1187
INTER UNCODED NO DISP	:	11596
INTER CODED NO DISP	:	233
INTER UNCODED DISP	:	8961
INTER CODED DISP	:	10310

MODES FOR U_SIGNAL :

INTER UNCODED	:	6703
INTER CODED	:	1613

MODES FOR U_SIGNAL :

INTER UNCODED	:	6392
INTER CODED	:	1924

BITS FOR Y_COEFF.	:	0
BITS FOR U_COEFF.	:	0
BITS FOR V_COEFF.	:	0
BITS FOR EOB_WORD	:	49085
BITS FOR Y_ATTR	:	98157
BITS FOR U_ATTR	:	13155
BITS FOR V_ATTR	:	14088

QUANTIZATION LEVEL 0 OCCURS : 138405 TIMES.

LEVEL 1 OCCURS	0 TIMES	LEVEL -1 OCCURS	0 TIMES.
LEVEL 2 OCCURS	16196 TIMES	LEVEL -2 OCCURS	16929 TIMES.
LEVEL 3 OCCURS	3975 TIMES	LEVEL -3 OCCURS	4180 TIMES.
LEVEL 4 OCCURS	1518 TIMES	LEVEL -4 OCCURS	1656 TIMES.
LEVEL 5 OCCURS	738 TIMES	LEVEL -5 OCCURS	858 TIMES.
LEVEL 6 OCCURS	381 TIMES	LEVEL -6 OCCURS	459 TIMES.
LEVEL 7 OCCURS	233 TIMES	LEVEL -7 OCCURS	244 TIMES.
LEVEL 8 OCCURS	167 TIMES	LEVEL -8 OCCURS	184 TIMES.
LEVEL 9 OCCURS	92 TIMES	LEVEL -9 OCCURS	143 TIMES.
LEVEL 10 OCCURS	84 TIMES	LEVEL -10 OCCURS	107 TIMES.
LEVEL 11 OCCURS	72 TIMES	LEVEL -11 OCCURS	73 TIMES.
LEVEL 12 OCCURS	55 TIMES	LEVEL -12 OCCURS	70 TIMES.
LEVEL 13 OCCURS	39 TIMES	LEVEL -13 OCCURS	50 TIMES.
LEVEL 14 OCCURS	25 TIMES	LEVEL -14 OCCURS	44 TIMES.
LEVEL 15 OCCURS	25 TIMES	LEVEL -15 OCCURS	40 TIMES.
LEVEL 16 OCCURS	25 TIMES	LEVEL -16 OCCURS	34 TIMES.
LEVEL 17 OCCURS	20 TIMES	LEVEL -17 OCCURS	44 TIMES.
LEVEL 18 OCCURS	18 TIMES	LEVEL -18 OCCURS	37 TIMES.
LEVEL 19 OCCURS	13 TIMES	LEVEL -19 OCCURS	25 TIMES.

LEVEL 20 OCCURS	14 TIMES	LEVEL -20 OCCURS	33 TIMES.
LEVEL 21 OCCURS	2 TIMES	LEVEL -21 OCCURS	24 TIMES.
LEVEL 22 OCCURS	5 TIMES	LEVEL -22 OCCURS	23 TIMES.
LEVEL 23 OCCURS	6 TIMES	LEVEL -23 OCCURS	24 TIMES.
LEVEL 24 OCCURS	5 TIMES	LEVEL -24 OCCURS	13 TIMES.
LEVEL 25 OCCURS	2 TIMES	LEVEL -25 OCCURS	6 TIMES.
LEVEL 26 OCCURS	1 TIMES	LEVEL -26 OCCURS	7 TIMES.
LEVEL 27 OCCURS	1 TIMES	LEVEL -27 OCCURS	5 TIMES.
LEVEL 28 OCCURS	1 TIMES	LEVEL -28 OCCURS	5 TIMES.
LEVEL 29 OCCURS	0 TIMES	LEVEL -29 OCCURS	1 TIMES.
LEVEL 30 OCCURS	1 TIMES	LEVEL -30 OCCURS	3 TIMES.
LEVEL 31 OCCURS	16 TIMES	LEVEL -31 OCCURS	34 TIMES.

EOB_STATISTICS :

6021	2803	698	496	37	32	1	0
1748	865	375	48	22	1	0	0
1182	283	80	17	1	1	0	0
235	114	11	3	0	0	0	0
170	5	4	0	0	0	0	0
7	1	0	0	0	0	0	0
5	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0

EOB IS 15267 TIMES USED.
NUMBER OF BITS FOR EOB : 49085
--> 49085 [illegible]