CCITT SGXV
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Specialists Group on
Coding for Visual Telephony

Document #231

Title: Single and Multiple VLCs in Reference Model 4

Source: UK, F, NL, FRG

INTRODUCTION

This contribution supplements previous work [1] carried out by UK, Sweden, Netherlands and Germany into the use of single or multiple VLCs in the nx384 kbit/s codec.

The objective was to quantify the loss of coding efficiency resulting from the use of a reduced number of VLC sets and to study the robustness of code sets when applied to data from which they had not been derived.

The coding of block addressing, block attributes, scanning classes and motion vectors was investigated. Coefficient data was not included because previous reports [1][2] suggest that it is advantageous to allocate a 2-dimensional VLC to them.

METHOD

Data from the Split-Screen/Trevor and Miss America sequences coded by Reference Model 4 was used for "open loop" calculations of bit consumption using the following collections of VLCs:

1. The VLC sets which will be used initially in the hardware and are detailed in Dbcument #217.

2. A single code set derived from weighted averages of all the Block Address, Block Type, Class and Motion Vector data from the SS/T sequence. These weightings are from the relative occurences in RM4 SS/T:

BA	0.27
TYPE(Y)	0.20
TYPE(C)	0.07
CLASS	0.20
MV	0.26

3. A collection of 5 VLC sets each being the optimum for one parameter in the SS/T data.

4. A collection of 5 VLC sets each being the optimum for one parameter in the MISSA data.

All the code sets were made variable length up to 8 bits and 16 bits fixed length thereafter.

RESULTS and DISCUSSION

Tables 1 to 4 are for the Split-Screen/Trevor sequence and tables 5 to 8 for Miss America. Table 9 shows the total number of bits/picture for the sum of block address, block attributes, scanning class and motion vectors.

From table 9, it can be seen that changes to the overhead bit consumption caused by different VLCs are relatively small and do not affect the overall bit rate to any great extent. Therefore it is reasonably valid to have done the comparisons "open loop".

As expected, use of VLCs derived from one sequence give an increase over the optimum when used on a different sequence. The items Block Address and Block Attributes are most sensitive.

For Block Address, the single VLC with its shortest code of 2 bits yields about 500 bits per picture more than the others which start with 1 bit. Of these other three VLCs there is no outright winner.

Examination of Tables 2 and 6 reveal that the statistics of the block attributes are very different between the SS/T and MissA sequences. VLCs optimised on one of them for luminance and chrominance blocks and then applied to the other sequence are about 750 bits per picture worse than the optimal ones for that other sequence.

With only four classes, there is little variation and in fact trivial difference from a fixed length code of 2 bits.

Motion vectors also show that the differences between optimal sets for the two sequences are such that the single VLC is just as good over both.

The single VLC is about 1500 bits per picture worse than the five optimal VLCs for each sequence. This reduces to 500 when compared to the five optimum ones derived from the wrong sequence.

CONCLUSION

With just two sequences it has been shown that variations in source picture statistics can be large enough to make a search for many VLCs, each optimised for one parameter, a futile exercise.

Most of the gain of a VLC comes from the first few short codes. Therefore, it is conceivable that two VLC code sets with first words of 1 and 2 bits respectively will in practice be sufficient. Considering the limitations of simulation, this may be better investigated with hardware.

REFERENCES

[1]...A Study of the Use of Multiple VLCs and Single VLCs in the Okubo Reference Model 2. Document #145

[2]...Block coding using a two dimensional run-length table. Document #170.

Table 1

Bit Allocation using VLCs for Relative Block Addresses

SOURCE: UK 24/4/87 using RM4

Split-Screen/Trevor Sequence

Relative Blk Addr	Sample Freq	%	Doc #217 C.W.L.	Doc #217 Bit Usage	Single C.W.L.	Single Bit Usage	Optimal(SS/T) C.W.L.	Optimal(SS/T) Bit Usage	Optimal(MissA) C.W.L.	Optimal(MissA) Bit Usage
1	38097	75.79	1	75.79	2	151.58	1	75.79	1	75.79
2	3794	7.55	3	22.64	2	15.10	3	22.64	2	15.10
3	2124	4.23	3	12.68	3	12.68	3	12.68	4	16.90
4	1247	2.48	3	7.44	3	7.44	4	9.92	4	9.92
5	978	1.95	5	9.73	4	7.78	5	9.73	4	7.78
6	937	1.86	5	9.32	5	9.32	5	9.32	6	11.18
7	688	1.37	6	8.21	5	6.84	5	6.84	6	8.21
8	485	0.96	6	5.79	5	4.82	6	5.79	7	6.75
9	384	0.76	7	5.35	6	4.58	6	4.58	7	5.35
10	283	0.56	7	3.94	6	3.38	6	3.38	8	4.50
11	245	0.49	8	3.90	6	2.92	7	3.41	8	3.90
12	148	0.29	8	2.36	6	1.77	7	2.06	16	4.71
13	133	0.26	16	4.23	7	1.85	7	1.85	16	4.23
14	101	0.20	16	3.21	7	1.41	8	1.61	16	3.21
15	88	0.18	16	2.80	8	1.40	8	1.40	16	2.80
16	85	0.17	16	2.71	16	2.71	16	2.71	16	2.71
17	92	0.18	16	2.93	7	1.28	16	2.93	16	2.93
18	77	0.15	16	2.45	16	2.45	16	2.45	16	2.45
19	90	0.18	16	2.86	8	1.43	16	2.86	16	2.86
20	47	0.09	16	1.50	16	1.50	16	1.50	16	1.50
R. Sample	142	0.28	16	4.52	16	4.52	16	4.52	16	4.52
Total Samples =	50265			194.37		246.77		187.98		197.33
Average No. of Bits/Block =				1.9437		2.4677		1.8798		1.9733
Average No. of Blocks/picture =				1095		1095		1095		1095
Average No. of Bits/picture =				2128.31		2702.13		2058.38		2160.72

Table 2

Bit Allocation using VLCs for Block Attribrutes [TYPE3]

SOURCE: UK 24/4/87 using RM4

Split-Screen/Trevor Sequence

			Doc #217		Single		Optimal(SS/T)		Optimal(MissA)	
TYPE	Y-Modes	%	C.W.L.	Bit Usage	C.W.L.	Bit Usage	C.W.L.	Bit Usage	C.W.L.	Bit Usage
1	INTRA	5.14	5	25.70	5	25.70	4	20.56	6	30.84
3	FILTERED fixed	9.16	4	36.64	3	27.48	3	27.48	1	9.16
(5a)	NON-FILT fixed MC									
5b	NON-FILT fixed MC	6.52	5	32.60	4	26.08	4	26.08	3	19.56
(5c)	FILTERED fixed MC									
5d	FILTERED fixed MC	5.27	4	21.08	5	26.35	4	21.08	6	31.62
2	NON-FILT INTER	17.69	2	35.38	3	53.07	3	53.07	3	53.07
4	FILTERED INTER	4.89	5	24.45	5	24.45	4	19.56	5	24.45
(6a)	NON-FILT INTER MC									
6b	NON-FILT INTER MC	25.85	3	77.55	2	51.70	2	51.70	3	77.55
(6c)	FILTERED INTER MC									
6d	FILTERED INTER MC	25.47	3	76.41	2	50.94	2	50.94	4	101.88
				329.81		285.77		270.47		348.13
	Average No. of Bits/block =			3.2981		2.8577		2.7047		3.4813
	Average No. of Blocks/picture =			801		801		801		801
	Average No. of Bits/picture =			2641.78		2289.02		2166.46		2788.52

			Doc #217		Single		Optimal(SS/T)		Optimal(MissA)	
TYPE	UV-Modes	%	C.W.L.	Bit Usage	C.W.L.	Bit Usage	C.W.L.	Bit Usage	C.W.L.	Bit Usage
1	INTRA	3.08	4	12.32	3	9.24	3	9.24	3	9.24
3	FILTERED fixed	46.58	3	139.74	2	93.16	1	46.58	2	93.16
2	NON-FILT INTER	32.53	1	32.53	2	65.06	2	65.06	1	32.53
4	FILTERED INTER	17.81	2	35.62	3	53.43	2	35.62	3	53.43
				220.21		220.89		156.50		188.36
	Average No. of Bits/block =			2.2021		2.2089		1.565		1.8836
	Average No. of Blocks/picture =			294		294		294		294
	Average No. of Bits/picture =			647.42		649.42		460.11		553.78

NOTES: () indicates that no data was available in this implementation of RM4.

The average values exclude FIXED BLOCKS.

Table 3

Bit Allocation using VLCs for CLASS

SOURCE: UK 24/4/87 using RM4

Split-Screen Sequence

SCAN CLASS	%	Doc #217 C.W.L.	Doc #217 Bit Usage	Single C.W.L.	Single Bit Usage	Optimal(SS/T) C.W.L.	Optimal(SS/T) Bit Usage	Optimal(MissA) C.W.L.	Optimal(MissA) Bit Usage
Zig-zag	32.45	1	32.45	2	64.90	2	64.90	1	32.45
Horizontal	26.67	2	53.34	2	53.34	2	53.34	2	53.34
Vertical	17.37	3	52.11	3	52.11	2	34.74	3	52.11
Fourth	23.52	4	94.08	3	70.56	2	47.04	3	70.56
			231.98		240.91		200.02		208.46
Average No. of Bits/block =			2.3198		2.4091		2.0002		2.0846
Average No. of Blocks/picture =			630		630		630		630
Average No. of Bits/picture =			1461.47		1517.73		1260.13		1313.30

Table 4

Bit Allocation using VLCs for Motion Vectors

SOURCE: UK 24/4/87 using RM4

Split-Screen/Trevor Sequence

Mot. Vect.	Sample Frequency	%	Doc #217 C.W.L.	Doc #217 Bit Usage	Single C.W.L.	Single Bit Usage	Optimal(SS/T) C.W.L.	Optimal(SS/T) Bit Usage	Optimal(MissA) C.W.L.	Optimal(MissA) Bit Usage
-7	1056	4.26	6	25.56	6	25.56	4	17.04	7	29.83
-6	610	2.46	6	14.77	7	17.23	5	12.31	7	17.23
-5	805	3.25	5	16.24	7	22.74	5	16.24	6	19.49
-4	1356	5.47	5	27.36	5	27.36	4	21.89	5	27.36
-3	1554	6.27	5	31.35	5	31.35	4	25.08	4	25.08
-2	1984	8.01	4	32.02	3	24.02	4	32.02	4	32.02
-1	3315	13.38	3	40.13	2	26.75	3	40.13	3	40.13
0	3584	14.46	2	28.92	2	28.92	3	43.38	2	28.92
1	3234	13.05	3	39.15	3	39.15	3	39.15	2	26.10
2	1780	7.18	4	28.73	4	28.73	4	28.73	4	28.73
3	1502	6.06	5	30.30	5	30.30	4	24.24	4	24.24
4	1221	4.93	5	24.63	6	29.56	4	19.71	5	24.63
5	910	3.67	5	18.36	6	22.03	5	18.36	6	22.03
6	681	2.75	6	16.49	7	19.23	5	13.74	7	19.23
7	1192	4.81	6	28.86	6	28.86	4	19.24	7	33.67
Total=	24784			402.86		401.78		371.24		398.68
Average No. of Bits/block =				8.0572		8.0357		7.4249		7.9736
Average No. of Blocks/picture =				503		503		503		503
Average No. of Bits/picture =				4052.78		4041.94		3734.71		4010.73

NOTES: A subset of the VLC in Doc. #217 was used.
The Motion Vectors are absolute.
No DMV=0 blocks.

Table 5

Bit Allocation using VLCs for Relative Block Addresses

SOURCE: UK 24/4/87 using RM4

Miss America sequence

Relative Blk Addr	Sample Freq	%	Doc #217 C.W.L.	Doc #217 Bit Usage	Single C.W.L.	Single Bit Usage	Optimal(MissA) C.W.L.	Optimal(MissA) Bit Usage	Optimal(SS/T) C.W.L.	Optimal(SS/T) Bit Usage
1	42279	69.11	1	69.11	2	138.22	1	69.11	1	69.11
2	8046	13.15	3	39.46	2	26.30	2	26.30	3	39.46
3	3895	6.37	3	19.10	3	19.10	4	25.47	3	19.10
4	2185	3.57	3	10.71	3	10.71	4	14.29	4	14.29
5	1869	3.06	5	15.28	4	12.22	4	12.22	5	15.28
6	907	1.48	5	7.41	5	7.41	6	8.90	5	7.41
7	555	0.91	6	5.44	5	4.54	6	5.44	5	4.54
8	442	0.72	6	4.33	5	3.61	7	5.06	6	4.33
9	318	0.52	7	3.64	6	3.12	7	3.64	6	3.12
10	169	0.28	7	1.93	6	1.66	8	2.21	6	1.66
11	131	0.21	8	1.71	6	1.28	8	1.71	7	1.50
12	115	0.19	8	1.50	6	1.13	16	3.01	7	1.32
13	64	0.10	16	1.67	6	0.63	16	1.67	7	0.73
14	23	0.04	16	0.60	7	0.26	16	0.60	8	0.30
15	33	0.05	16	0.86	8	0.43	16	0.86	8	0.43
16	20	0.03	16	0.52	16	0.52	16	0.52	16	0.52
17	19	0.03	16	0.50	8	0.25	16	0.50	16	0.50
18	25	0.04	16	0.65	16	0.65	16	0.65	16	0.65
19	12	0.02	16	0.31	16	0.31	16	0.31	16	0.31
20	10	0.02	16	0.26	16	0.26	16	0.26	16	0.26
R. Sample	60	0.10	16	1.57	16	1.57	16	1.57	16	1.57
Total Samples =	61177			186.59		234.20		184.31		186.39
Average No. of Bits/Block =				1.8659		2.3420		1.8431		1.8639
Average No. of Blocks/picture =				1252		1252		1252		1252
Average No. of Bits/picture =				2336.14		2932.19		2307.55		2333.55

Table 6

Bit Allocation using VLCs for Block Attributes [TYPE3]

SOURCE: UK 24/4/87 using RM4

Miss America sequence

TYPE	Y-Modes	%	Doc #217 C.W.L.	Doc #217 Bit Usage	Single C.W.L.	Single Bit Usage	Optimal(MissA) C.W.L.	Optimal(MissA) Bit Usage	Optimal(SS/T) C.W.L.	Optimal(SS/T) Bit Usage
1	INTRA	0.00	5	0.00	5	0.00	6	0.00	4	0.00
3	FILTERED fixed	36.92	4	147.68	3	110.76	1	36.92	3	110.76
(5a)	NON-FILT fixed MC									
5b	NON-FILT fixed MC	13.99	5	69.95	4	55.96	3	41.97	4	55.96
(5c)	FILTERED fixed MC									
5d	FILTERED fixed MC	4.79	4	19.16	5	23.95	6	28.74	4	19.16
2	NON-FILT INTER	18.65	2	37.30	3	55.95	3	55.95	3	55.95
4	FILTERED INTER	5.05	5	25.25	5	25.25	5	25.25	4	20.20
(6a)	NON-FILT INTER MC									
6b	NON-FILT INTER MC	13.08	3	39.24	2	26.16	3	39.24	2	26.16
(6c)	FILTERED INTER MC									
6d	FILTERED INTER MC	7.51	3	22.53	2	15.02	4	30.04	2	15.02
				361.11		313.05		258.11		303.21
	Average No. of Bits/block =			3.6111		3.1305		2.5811		3.0321
	Average No. of Blocks/picture =			777		777		777		777
	Average No. of Bits/picture =			2805.82		2432.40		2005.51		2355.94

TYPE	UV-Modes	%	Doc #217 C.W.L.	Doc #217 Bit Usage	Single C.W.L.	Single Bit Usage	Optimal(MissA) C.W.L.	Optimal(MissA) Bit Usage	Optimal(SS/T) C.W.L.	Optimal(SS/T) Bit Usage
1	INTRA	0.21	4	0.84	3	0.63	3	0.63	3	2.52
3	FILTERED fixed	28.95	3	86.85	2	57.90	2	57.90	1	86.85
2	NON-FILT INTER	48.84	1	48.84	2	97.68	1	48.84	2	97.68
4	FILTERED INTER	21.99	2	43.98	3	65.97	3	65.97	2	87.96
				180.51		222.18		173.34		275.01
	Average No. of Bits/block =			1.8051		2.2218		1.7334		2.7501
	Average No. of Blocks/picture =			475		475		475		475
	Average No. of Bits/picture =			857.42		1055.36		823.37		1306.30

NOTES: () indicates that no data was available in this implementation of RM4.

The average values exclude FIXED BLOCKS.

Table 7

Bit Allocation using VLCs for CLASS

SOURCE: UK 24/4/87 using RM4

Miss America sequence

SCAN CLASS	%	Doc #217 C.W.L.	Doc #217 Bit Usage	Single C.W.L.	Single Bit Usage	Optimal(MissA) C.W.L.	Optimal(MissA) Bit Usage	Optimal(SS/T) C.W.L.	Optimal(SS/T) Bit Usage
Zig-zag	40.97	1	40.97	2	81.94	1	40.97	2	81.94
Horizontal	26.34	2	52.68	2	52.68	2	52.68	2	52.68
Vertical	16.74	3	50.22	3	50.22	3	50.22	2	33.48
Fourth	15.95	4	63.80	3	47.85	3	47.85	2	31.90
			207.67		232.69		191.72		200
Average No. of Bits/block =			2.0767		2.3269		1.9172		2
Average No. of Blocks/picture =			342		342		342		342
Average No. of Bits/picture =			710.23		795.80		655.68		684.00

Table 8

Bit Allocation using VLCs for Motion Vectors

SOURCE: UK 24/4/87 using RM4

Miss America sequence

Mot. Vect.	Sample Frequency	%	Doc #217 C.W.L.	Doc #217 Bit Usage	Single C.W.L.	Single Bit Usage	Optimal(MissA) C.W.L.	Optimal(MissA) Bit Usage	Optimal(SS/T) C.W.L.	Optimal(SS/T) Bit Usage
-7	115	0.77	6	4.60	6	4.60	7	5.36	4	3.06
-6	115	0.77	6	4.60	8	6.13	7	5.36	5	3.83
-5	285	1.90	5	9.49	6	11.39	6	11.39	5	9.49
-4	436	2.90	5	14.52	5	14.52	5	14.52	4	11.62
-3	724	4.82	5	24.12	5	24.12	4	19.29	4	19.29
-2	1139	7.59	4	30.35	3	22.76	4	30.35	4	30.35
-1	2810	18.72	3	56.16	2	37.44	3	56.16	3	56.16
0	3447	22.96	2	45.93	2	45.93	2	45.93	3	68.89
1	3229	21.51	3	64.54	3	64.54	2	43.02	3	64.54
2	1286	8.57	4	34.27	4	34.27	4	34.27	4	34.27
3	687	4.58	5	22.88	5	22.88	4	18.31	4	18.31
4	288	1.92	5	9.59	6	11.51	5	9.59	4	7.67
5	232	1.55	5	7.73	6	9.27	6	9.27	5	7.73
6	104	0.69	6	4.16	7	4.85	7	4.85	5	3.46
7	113	0.75	6	4.52	8	6.02	7	5.27	4	3.01
Total=	15010			337.46		320.25		312.97		341.71
Average No. of Bits/block =				6.7492		6.4049		6.2594		6.8341
Average No. of Blocks/picture =				304		304		304		304
Average No. of Bits/picture =				2051.77		1947.10		1902.87		2077.57

NOTES: A subset of the VLC in Doc. #217 was used.
The Motion Vectors are absolute.
No DMV=0 blocks.

Table 9

Totals of the Average bits per picture for Block Address, Block Type, Class and Motion Vectors

	VLC			
	Doc #217	Single	Optimal(SS/T)	Optimal(MissA)
Sequence				
Split-Screen/Trevor	10932	11200	9680	10827
Miss America	8761	9163	8757	7695