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

Document # 154
November 1986

SOURCE : NTT, KDD, NEC and FUJITSU

TITLE : FILTER INSIDE THE CODING LOOP

1. Introduction

Filter inside the coding loop is one of the future inclusion items. This document compares the three methods which were proposed at the last meeting in terms of coding efficiency and hardware size. Based on the result, we selected the most favorable method.

2. Filter in the loop

Three methods were proposed at the last Montreal meeting (#110,126,130). These filters can be translated as figure 1-3, and have following features.

Method I (Fig.1)
Noise produced in the moving area is reduced by the filter in front of the frame memory. There are two options of filtering. One uses pixels only within the block, while the other uses pixels from neighboring blocks for filtering. Output signal can be obtained at either point (b) or (c) according to the preference of reproduced picture quality.

Method II (Fig.2)
Filtering process is taken place in front of the motion vector detector for all reference blocks except one which occupies the same spatial position as the input block. Filtering process is carried out using pixels of several neighboring blocks.

Method III (Fig.3)
For the blocks which are detected as moving, a filtering process is applied both to the input signals and predicted ones. Filtering process uses pixels within the block.

3. Computer simulation results

Five filtering methods listed in Table 1 were applied to RM2. Different types of low pass filters shown in Table 1 were adopted in this simulation depending on the pixel location in the block.
The results are shown in Table 3. As is shown in Table 3 , superiority of the coding performance can be ordered as follows in terms of SNR .

1. Method II
2. Method I (type 3)
3,4. Method I (type 2) ,Method III
5. Method I (type 1)
6. RM2

It should be noted that the difference between RM2 and others is rather considerable, but among all filter processing methods it is small. The effect of these methods will be demonstrated by VTR.

4. Consideration of the hardware size

We also classified the factors which bring the difference in the hardware volume among these five filtering methods. Because of the fact that the inverse DCT is carried out on a block-by-block basis and the video multiplex format is tailored to block line scanning, this study is done on the assumption that pixels are scanned within the block line boundary.

There are two major factors which will make difference in hardware size.

1. Signal path in the loop : existence of extra path delay, branch and merge in the signal path.

2. Filtering process mode : use of pixels either within one block or over several blocks.

- Signal path -

Newly added signal path and extra delay increase hardware size. Branch also needs delay elements to adjust signal phase of each parallel path. Merge needs some processing units to accept multi signal inputs.

Method I needs new path from (a) to (b) as shown in Fig.1 . The motion vector in this path must be delayed, since processig such as DCT and quantizer will be carried out in pipeline manner over several block processing periods. However, amount of this delay seems to be small.

Method II has a branch at (e) and merge at (d) as shown in Fig.2. Due to the branch at (e), the block line delay is needed. Merge needs some circuits such as selectors. Even the hardware volume is not clear enough at present, it seems to be considerable.

Method III needs a new path from (f) to (g) as shown in Fig.3. But the amount of delay seems to be small becuase the vector information is used within the block processing period.

- Filter -

Two-dimensional filter which uses several adjacent pixels can

be realized as shown in Fig.4 . Input pixel stream is memorized in the memory unit. Then several pixels are simultaneously read out into the processing unit. The capacity of memory in Fig.4 heavily depends on the filtering process mode, whether it uses pixels within one block or over several blocks. All factors with rough estimations are listed in Table 2.

As is clear in Table 2, the filtering process within one block is favorable to implement a compact and economic codec. Even the precise estimation is not yet completed at present, the difference between Method II and Method I,III seems to be considerable.

5. Selection of the favorable filter

In selecting the filter, it should be emphasized that it is preferred not to use any filter in the loop as long as the high S/N ratio can be obtained without it, and that even when the filter is found to be necessary, the hardware size should be small. At 300 kb/s transmission rate, simulation showed the apparent superiority of appling the filter.

The most favorable filter in the loop seems to be Method I (type 1) where filtering process is carried out within one block. Reasons are as follows.

1. The coding performance resulting from each filtering process mode is almost the same.

2. The reproduced picture quality also seems to be the same for different filtering methods.

3. The difference of the hardware size between Method II and Method I,III seems to be considerable.

4. The choice of the picture quality can easily be done by selecting the output point in Method I and no post processing is needed.

6. Conclusion

We investigated the effects of the filters in the loop proposed at the last meeting. We compared five methods in terms of coding efficiency and hardware size. According to these comparison results, we selected and proposed one method which is located in front of the frame memory and uses 36 pixels within one block.

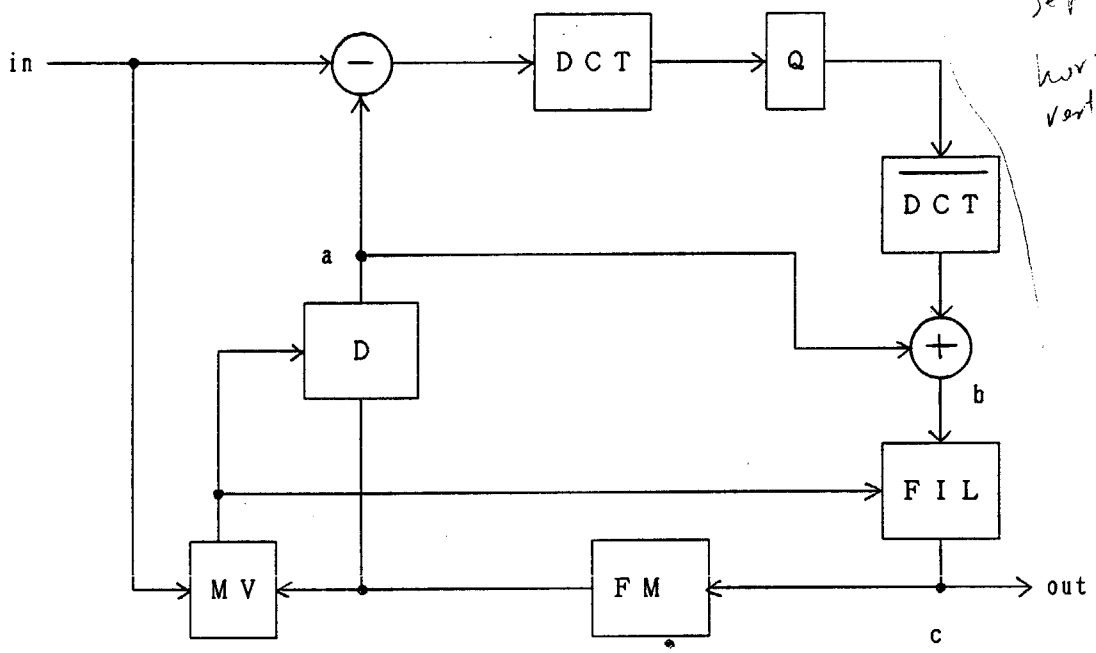


Fig. 1

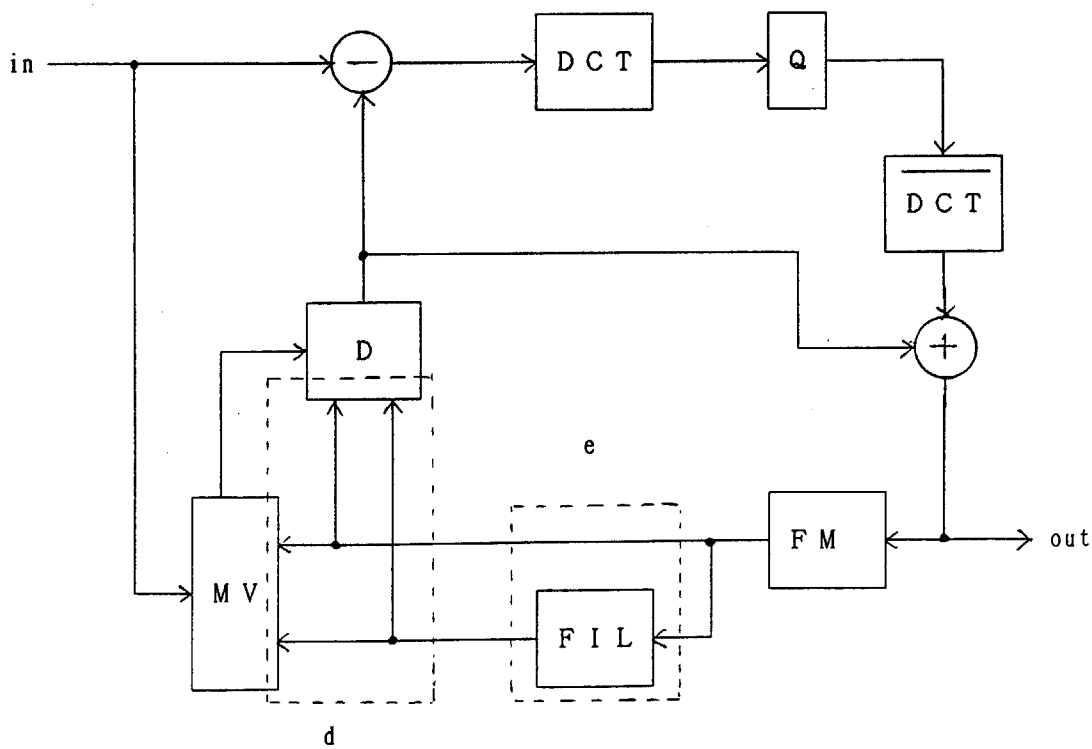
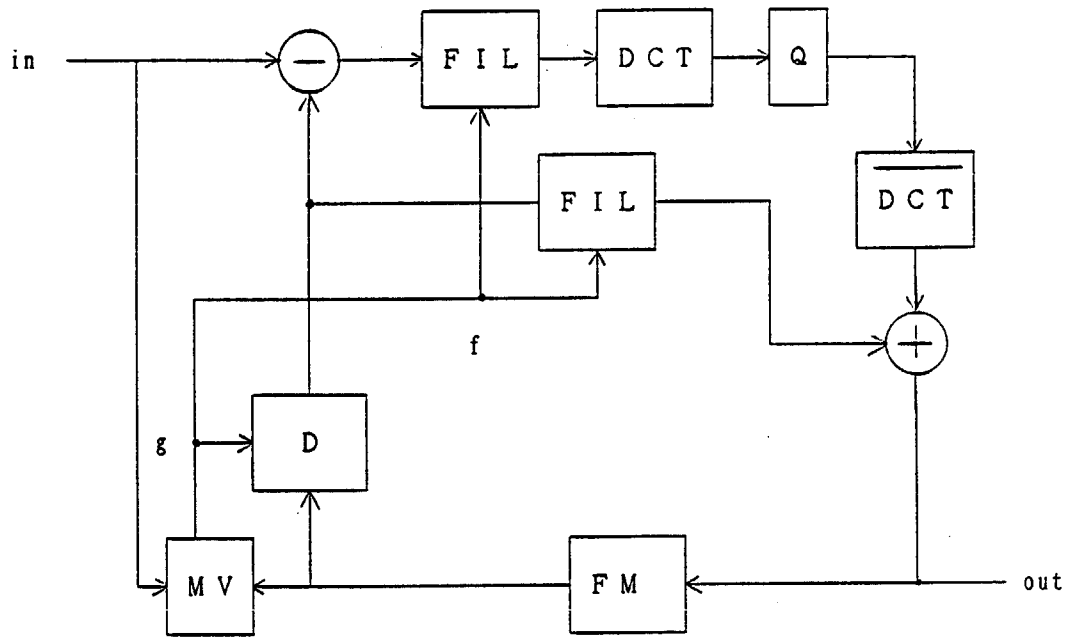
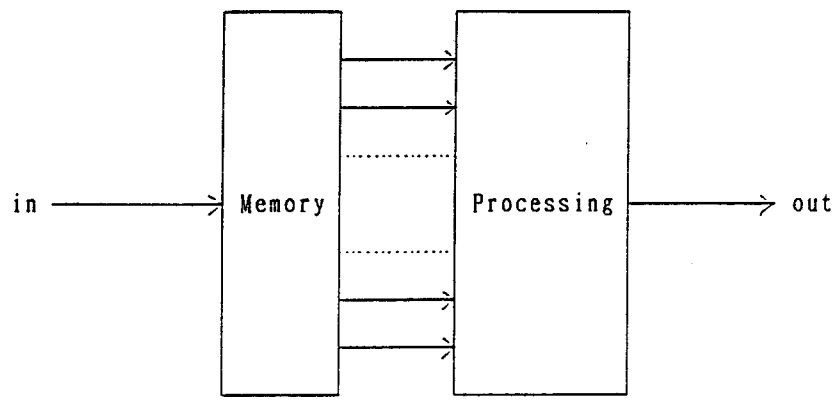


Fig. 2



F i g . 3



F i g . 4

Table 1

	Method I			Method II	Method III
	Type 1	Type 2	Type 3		
Filtering process	Within a block		Over neighboring blocks	Over neighboring blocks	Within a block
Filtering area	Only for 36 pixels around the center	All pixels	All pixels	All pixels	All pixels
Coefficient	1 1 4 1 1	① 1 1 4 1 1 ——— ② 1 5 1 1 ——— ③ 6 1 1	1 1 4 1 1	1 1 4 1 1	① 1 1 4 1 1 ——— ② 1 5 1 1 ——— ③ 6 1 1

① inside block ② edge of block ③ corner of block

Table 2

			Method I			Method II	Method III
			Type 1	Type 2	Type 3		
Filtering process			Within a block		Over neighboring blocks	Over neighboring blocks	Within a block
Filtering area			Only for 36 pixels around the center	All pixels	All pixels	All pixels	All pixels
Path	Delay		a little	a little	a little		a little
	Branch					3 kbyte	
	Merge					×	
Filter	Memory	RAM	a little	a little	* a little	* a little	a little
		Delay			6 kbyte	6 kbyte	
	Processing		×	×	×	×	×

* Complex addressing is required.

Table 3

Sequence : Miss America (1/2)			RM2		M-I (Type 1)	
Items			Average	15th	Average	15th
1) R.M.S for luminance			2.9	2.7	2.7	2.6
2) SNR for luminance			38.7	39.6	39.4	40.0
3) Mean value of the step size			9.0	7.8	8.5	7.7
4) Mean value of the number of non-zero coefficients			2.6	2.5	2.5	2.3
5) Mean value of the number of zeroes before the last non-zero coefficient			10.6	11.7	9.2	10.9
6) Block type of Y	Intra		2	0	1	0
	Fixed(Inter/No MC/No coded)		1127	1177	1115	1164
	Inter(Inter/No MC/coded)		137	255	154	270
	Fixed MC(Inter/MC/No coded)		155	74	151	74
	Inter MC(Inter/MC/Coded)		163	78	163	76
7) Block type of C	Intra	Cr	1	0	1	0
		Cb	0	0	0	0
		Cr+Cb	2	0	1	0
	Fixed (Inter/No coded)	Cr	285	291	277	287
		Cb	207	178	187	164
		Cr+Cb	492	469	464	451
	Inter(Inter/Coded)	Cr	110	105	118	109
		Cb	188	218	209	232
		Cr+Cb	299	323	326	341
8) Number of bits	Attributes	Y	2491	2394	2511	2422
		Cr	507	501	515	505
		Cb	585	614	605	628
		Total	3583	3509	3631	3555
	EOB words		1805	1968	1938	2061
	Motion Vectors		2543	1216	2512	1200
	Coefficients	Y	8108	8869	7384	8313
		Cr	1353	1368	1499	1374
		Cb	2517	3273	2944	3378
		Total	11978	13510	11827	13065
	Total		19910	20203	19907	19881

Table 3

Sequence : Miss America (2/2)

M-I (Type 2)		M-I (Type 3)		Method-II		Method-III	
Average	15th	Average	15th	Average	15th	Average	15th
2.7	2.5	2.6	2.5	2.6	2.5	2.7	2.5
39.6	40.2	39.7	40.3	39.9	40.3	39.5	40.1
8.6	7.4	8.5	7.4	8.4	7.4	8.0	7.3
2.5	2.4	2.5	2.4	2.5	2.4	2.4	2.4
9.3	10.0	9.2	10.3	9.2	10.7	8.0	9.6
1	0	1	0	1	0	1	0
1108	1161	1112	1162	1116	1154	1084	1135
164	275	170	271	162	267	191	293
152	75	145	77	143	63	160	87
159	73	156	74	162	100	148	69
1	0	1	0	1	0	1	0
0	0	0	0	0	0	0	0
2	0	2	0	2	0	1	0
278	283	277	277	276	280	271	276
189	151	185	148	182	154	165	141
467	434	462	425	458	434	436	417
117	113	118	119	119	116	124	120
207	245	211	248	213	242	230	255
324	358	329	367	332	358	355	375
2530	2432	2518	2431	2502	2407	2597	2500
514	509	515	515	516	512	521	516
603	641	607	644	610	638	627	651
3647	3582	3640	3590	3628	3557	3745	3667
1948	2118	1971	2136	1975	2175	2090	2211
2489	1184	2407	1208	2436	1304	2463	1248
7398	7966	7354	8266	7260	8672	6426	7645
1494	1446	1512	1513	1536	1479	1689	1622
2934	3547	3021	3668	3072	3674	3490	4068
11826	12959	11887	13447	11868	13825	11605	13335
19909	19843	19905	20381	19906	20861	19903	20461

Table 3

Sequence : Checked Jacket (1/2)			RM2		M-I (Type 1)	
Items			Average	15th	Average	15th
1) R.M.S for luminance			3.7	3.8	3.6	3.6
2) SNR for luminance			36.8	36.6	37.1	37.0
3) Mean value of the step size			9.7	9.9	9.4	9.7
4) Mean value of the number of non-zero coefficients			3.1	3.3	3.0	3.5
5) Mean value of the number of zeroes before the last non-zero coefficient			13.6	14.1	12.7	13.6
6) Block type of Y	Intra		4	2	3	3
	Fixed(Inter/No MC/No coded)		1112	1095	1098	1097
	Inter(Inter/No MC/coded)		312	299	330	319
	Fixed MC(Inter/MC/No coded)		49	70	49	59
	Inter MC(Inter/MC/Coded)		106	118	105	106
7) Block type of C	Intra	Cr	0	0	0	0
		Cb	0	0	0	0
		Cr+Cb	0	0	0	0
	Fixed (Inter/No coded)	Cr	323	335	317	332
		Cb	339	349	334	343
		Cr+Cb	662	684	652	675
	Inter(Inter/Coded)	Cr	73	61	79	64
		Cb	57	47	62	53
		Cr+Cb	130	108	140	117
8) Number of bits	Attributes	Y	2475	2516	2504	2514
		Cr	469	457	475	460
		Cb	453	443	458	449
		Total	3397	3416	3437	3423
	EOB words		1658	1581	1733	1635
	Motion Vectors		1244	1504	1229	1320
	Coefficients	Y	12457	12845	12268	13147
		Cr	471	382	520	449
		Cb	321	254	361	386
		Total	13249	13481	13149	14032
	Total		19548	19982	19547	20410

Table 3

Sequence : Checked Jacket (2/2)

M-I (Type 2)		M-I (Type 3)		Method-II		Method-III	
Average	15th	Average	15th	Average	15th	Average	15th
3.5	3.5	3.4	3.5	3.4	3.4	3.4	3.4
37.3	37.3	37.4	37.3	37.5	37.5	37.5	37.4
9.3	9.4	9.2	9.2	9.2	9.3	8.6	8.7
3.0	3.4	3.0	3.6	2.9	3.4	2.7	3.1
12.2	12.3	12.0	13.1	12.0	13.3	10.3	10.5
3	0	3	2	2	0	3	1
1087	1096	1092	1122	1084	1098	1054	1063
343	323	338	296	332	290	379	364
47	50	48	52	52	69	52	49
104	115	104	112	113	127	96	107
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
316	332	313	339	312	329	302	313
334	341	330	339	331	345	320	322
649	673	643	678	644	674	622	635
80	64	83	57	84	67	94	83
62	55	66	57	65	51	76	74
143	119	150	114	148	118	170	157
2522	2495	2515	2450	2524	2498	2603	2569
476	460	479	453	480	463	490	479
458	451	462	453	461	447	472	470
3456	3406	3456	3356	3465	3408	3565	3518
1778	1671	1784	1572	1786	1605	1944	1887
1204	1320	1215	1312	1324	1568	1186	1248
12169	12633	12122	12746	11994	12627	11698	12367
543	513	559	450	572	542	668	652
376	366	396	403	391	373	456	461
13088	13512	13077	13599	12957	13542	12822	13480
19527	19909	19531	19839	19531	20123	19517	20133

Table 3

Sequence : Split-Trevor (1/2)			RM2		M-I (Type 1)	
Items			Average	15th	Average	15th
1) R.M.S for luminance			4.2	5.2	3.8	4.7
2) SNR for luminance			35.7	33.8	36.4	34.7
3) Mean value of the step size			11.3	13.8	10.8	13.3
4) Mean value of the number of non-zero coefficients			3.9	3.5	3.9	3.5
5) Mean value of the number of zeroes before the last non-zero coefficient			11.1	10.4	10.1	9.5
6) Block type of Y	Intra		55	27	50	35
	Fixed(Inter/No MC/No coded)		873	754	861	725
	Inter(Inter/No MC/coded)		144	195	159	172
	Fixed MC(Inter/MC/No coded)		125	236	124	232
	Inter MC(Inter/MC/Coded)		388	372	391	420
7) Block type of C	Intra	Cr	6	15	6	12
		Cb	5	7	5	11
		Cr+Cb	11	22	11	23
	Fixed (Inter/No coded)	Cr	329	290	325	304
		Cb	326	319	323	311
		Cr+Cb	655	609	648	615
	Inter(Inter/Coded)	Cr	61	91	65	80
		Cb	65	70	68	74
		Cr+Cb	126	161	133	154
8) Number of bits	Attributes	Y	2798	3135	2813	3102
		Cr	463	502	467	499
		Cb	466	473	470	471
		Total	3727	4110	3750	4072
	EOB words		2168	2331	2231	2325
	Motion Vectors		4105	4864	4116	4864
	Coefficients	Y	18335	16801	18041	16196
		Cr	701	1173	772	1229
		Cb	740	843	839	814
		Total	19776	18817	19652	18239
	Total		29776	30122	29749	29500

Table 3

Sequence : Split-Trevor (2/2)

M-I (Type 2)		M-I (Type 3)		Method-II		Method-III	
Average	15th	Average	15th	Average	15th	Average	15th
3.7	4.4	3.6	4.3	3.6	4.2	3.6	4.4
36.8	35.4	37.0	35.5	37.1	35.7	36.9	35.3
10.6	12.9	10.5	12.9	10.4	12.8	9.4	11.7
3.9	3.6	3.8	3.5	3.8	3.5	3.6	3.4
9.8	9.5	9.7	8.9	9.7	8.7	8.0	7.5
47	17	47	16	45	17	48	17
861	763	859	752	856	741	828	735
165	209	166	217	157	193	201	240
120	221	120	217	124	239	115	207
391	374	392	382	403	394	392	385
6	15	6	14	6	15	6	16
5	9	5	7	5	8	5	7
11	24	11	21	11	23	11	23
324	286	323	285	323	283	313	272
321	312	320	315	320	315	308	299
645	598	643	600	643	598	622	571
66	95	67	97	67	98	76	108
70	75	71	74	71	73	83	90
136	170	138	171	138	171	159	198
2807	3090	2809	3099	2807	3132	2866	3121
468	506	469	507	469	509	479	520
471	480	472	477	472	477	484	493
3746	4076	3750	4083	3748	4118	3829	4134
2251	2382	2263	2421	2262	2394	2433	2589
4090	4760	4099	4792	4213	5064	4053	4736
17977	16896	17901	16310	17772	16024	17225	15731
801	1357	825	1359	835	1347	1022	1578
869	991	906	956	908	956	1135	1152
19647	19244	19632	18625	19515	18327	19382	18461
29735	30462	29745	29921	29738	29903	29696	29920

Annex/ Document #154

Filter Inside the Coding Loop

--- VTR Demonstration of Simulation Results ---

Simulation results obtained by the coding process described in Section 3 will be demonstrated on VTR at the meeting.

Contents of the video tape are as follows :

- Split
  (1) Method 1, Type 1

- Split
  (2) Method 1, Type 2 (point c)

- Split
  (3) Method 1, Type 2 (point b)

- Split
  (4) Method 1, Type 3

- Split
  (5) Method 2

- Split
  (6) Method 3

- Miss America
  (7) Method 1, Type 1

- Miss America
  (8) Method 1, Type 2 (point c)

- Miss America
  (9) Method 1, Type 2 (point b)

- Miss America
  (10) Method 3

The decoded images are displayed under the condition of 2:1 frame droping rate.