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

Document #356
September 19, 1988

SOURCE: Japan
TITLE: Loop Filter Improvement

1. Introduction

A filter placed in the coding loop has been investigated. In the RM series simulations, the coding efficiency has been improved by the adaptive smoothing filter (1 2 1 weighted). The efficiency can be further improved by introducing more adaptivity and optimizing the filter characteristics. This document describes a new filter, which is placed before the frame memory in order to control the filter adaptively by utilizing such block attributes as MC on/off, coded/not-coded and a position of the last non-zero coefficient and the average stepsize used in the coefficient quantization.

2. The filter

A loop filter is effective in reducing quantization noises, but at the same time it may reduce the higher spatial frequency component of the decoded images. The basic idea of introducing adaptivities in the loop filter is to make it work only for the quantization noises and to avoid the additional noises produced by the loop filter as far as possible.
The filter system consists of two filtering processes. One is used for reducing block-shape noises, hence, only performs on block boundaries. The other reduces random noises and is designed to preserve edges and lines in images. Input pixels to the processes are selected using MCV, coded/not-coded (block type) and a position of the last non-zero coefficients. Since the quantization noise level is related to the stepsize, the filter characteristics are controlled by the stepsize.

2.1 Step1: Filtering for reducing block-shape noises

a) Selection of pixels input to the process

A = pixels on a boundary (8 pixels) on a block
blockA = the block including A
lc = the position of the last non-zero coefficients in zig-zag scan (lc=0 corresponds to DC component only)
mcvA = mcv of the blockA
mcvB = mcv of the other side block facing the boundary

```
IF { (mcvA =\ mcvB) or (blockA is coded and lc < 10) } THEN
      A is filtered
   ELSE
      A is not filtered
END IF
```

b) Block boundary filtering process

x(0,0) = Input pixel
{ x(i,j),i=-1,1,j=-1,1 } = Neibouring pixels
th1 = (average step size in a image) * 1.25
th15 = th1 * 1.5
th25 = th1 * 2.5
{ fil(i,j),i=-1,1,j=-1,1 } = { 1, 2, 1, 2, 4, 2, 1, 2, 1} ---- see Figure 1.
yo = sum (x (i,j)* fil(i,j)) / 16
i,j
y(1) = { x(-1,-1) + x(0,0)*2 + x(1, 1) }/4 ---- see Figure 1.
y(2) = { x(-1, 1) + x(0,0)*2 + x(1,-1) }/4
y(3) = { x(0,-1) + x(0,0)*2 + x(0, 1) }/4
y(4) = { x(-1, 0) + x(0,0)*2 + x(1, 0) }/4
z(k) = absolute(y(i) - x(0,0))

IF (input pixel is on a corner) THEN ---- see Figure 2.
ym = y(k), where z(k) = min z(l)
l=1,2,3,4
ELSE IF (input pixel is on a horizontal boundary) THEN
ym = y(k), where z(k) = min z(l)
l=1,2,3
ELSE
ym = y(k), where z(k) = min z(l)
l=1,2,4
END IF
IF { absolute(yo - x(0,0)) less than th15 } THEN ---- see Figure 3.
output = yo
ELSE IF { absolute(ym - x(0,0)) less than th25 } THEN
output = ym
ELSE
output = x(0,0)
END IF

2.2 Step 2: Filtering for reducing random noise

a) Selection of pixels input to the process

IF { (the block is coded or MCV is not zero) and
(the pixel is not modified by the block boundary filter) } THEN
the pixel is input to the filter
END IF

b) Random noise reducing filtering process

x(0,0) = Input pixel
{ x(i,j),i=-1,1,j=-1,1 } = Neibouring pixels ---- see Figure 1.
th1 = (average step size in a image) * 1.25
th25 = th1 * 2.5
{ fil(i,j),i=-1,1,j=-1,1 } = { 1, 2, 1, 2, 4, 2, 1, 2, 1}
yo = sum (x (i,j)* fil(i,j)) / 16
i,j
y(1) = { x(-1,-1) + x(0,0)*2 + x(1, 1) }/4 ---- see Figure 1.
y(2) = { x(-1, 1) + x(0,0)*2 + x(1,-1) }/4

```
y(3) = { x( 0,-1) + x(0,0)*2 + x( 0, 1) }/4
y(4) = { x(-1, 0) + x(0,0)*2 + x( 1, 0) }/4
z(k) = absolute( y(k) - x(0,0) )
ym = y(k), where z(k) = min z(l)
                        l=1,2,3,4
IF { absolute( yo - x(0,0) ) less than th1 } THEN          ---- see Figure 4.
    output = yo
  ELSE IF { absolute( ym - x(0,0) ) less than th25 } THEN
    output = ym
  ELSE
    output = x(0,0)
END IF
```

3. Simulation

Table 1 and 2 show the simulation results. The average SNRs of RM5 with the improved loop filter are 0.3 to 0.6 dB higher than those of original RM5. The decoded images are also improved.

4.Conclusion

A new loop filter has been presented. The filter is placed before the frame memory in order to utilize the stepsize, MC vectors, coded/non-coded and position of the last non-zero coeffient for controlling the filter adaptively. Using this filter instead of the RM5 type filter, the average SNRs are improved by 0.3 to 0.6 dB.
Considering the potentiality of the adaptive loop filter presented here, we conclude that its characteristics should be further investigated and optimized.

END.

1 2 1 2 4 2 1 2 1 yo	1 0 0 0 0 1 0 1 0 0 0 0 0 2 0 0 2 0 0 2 0 1 2 1 0 0 1 1 0 0 0 1 0 0 0 0 y(1) y(2) y(3) y(4)
Filter coefficients for calculating yo, low pass filter.	Filter coefficients for calculating y(i), edge preserving filter.

Figure 1. Filter coefficients.

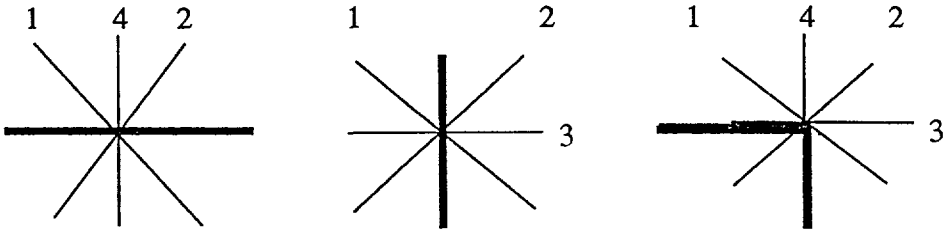


Figure 2. Filtering directions used in the block boundary filter

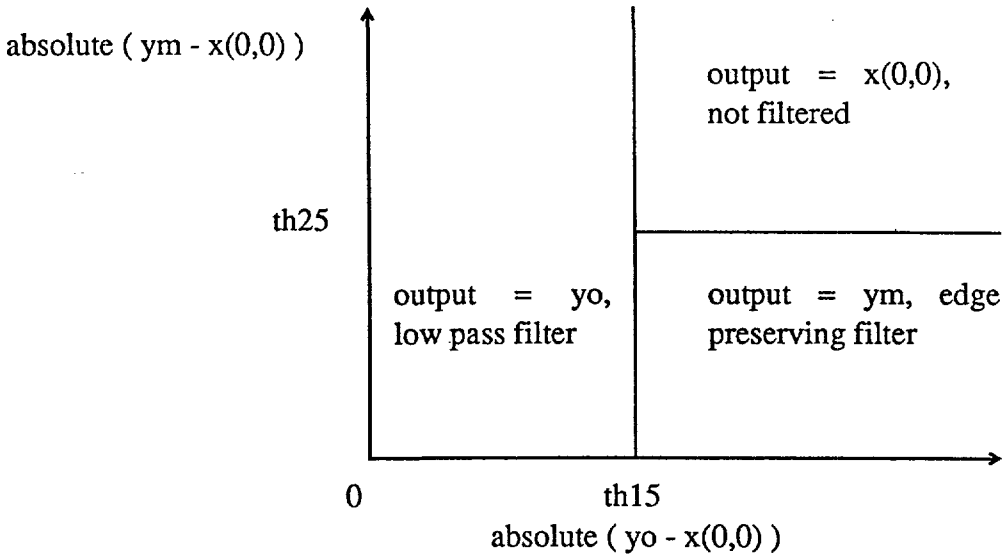


Figure 3. Filter adaptation by quantization stepsize
(block boundary filtering process)

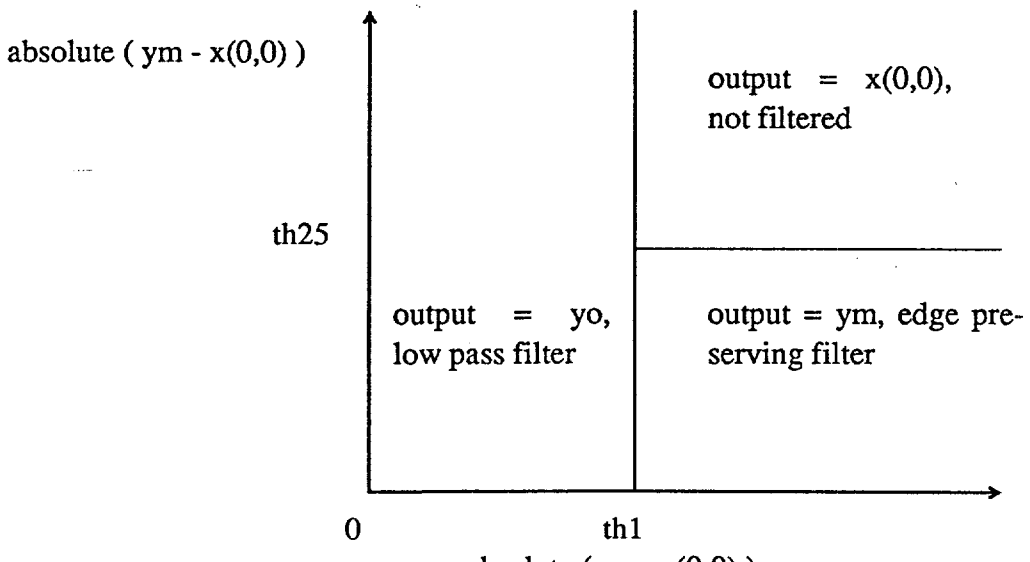


Figure 4. Filter adaptation by quantizaion stepsize
(random noise filtering process)

Table 1.

Evaluation table for RM5
Statistics RM5
Sequence : CLAIRE, MISS AMERICA AND SALESMAN
Modification : None and Loop filter

INSTITUTE : NTT
Date : Sep. 1
bit rate : 59400 (bits)
frame rate : 10.0 (Hz)

Sequence			Claire		Miss America		Salesman	
Item			RM5	FIL	RM5	FIL	RM5	FIL
Frame number			ave	ave	ave	ave	ave	ave
1) R.M.S. for Luminance			3.4	3.2	3.4	3.3	8.3	7.7
2) SNR for Luminance			37.60	38.13	37.59	37.86	29.72	30.37
3) Mean value of the step size			23.43	21.77	24.10	22.82	35.48	33.50
4) Mean value of the number of non-zero coefficients			2.76	2.83	1.94	1.95	2.16	2.24
5) Mean value of the number of zeroes before the last non-zero coefficient			8.16	7.91	5.11	5.16	10.84	10.47
6) Block type of MACRO	Fixed		287	285	229	231	259	257
	Fixed MC		8	8	27	26	8	9
	Coded		55	57	68	68	94	96
	Coded MC		47	46	72	71	35	34
7) Block type of Luminance	Fixed		1273	1275	1129	1133	1258	1256
	Fixed MC		94	95	271	265	86	89
	Coded		93	93	60	62	154	157
	Coded MC		124	121	124	123	86	82
8) Block type of Chrominance	Fixed		758	759	701	703	784	784
	Coded		34	33	91	89	8	8
9) Number of bits	MACRO block Attributes		511	517	646	641	601	608
	EOB		1220	1229	1676	1666	1544	1562
	Motion Vectors		436	432	790	777	344	341
	Coefficients	Y	3513	3491	2130	2184	3385	3369
		U (Cb)	165	172	281	288	25	21
		V (Cr)	69	72	326	288	16	14
		Total	3747	3735	2738	2760	3427	3405
	Total		5913	5912	5849	5845	5916	5916

RM5: Original RM5
FIL: Improved Loop Filter

Table 2.

Evaluation table for RM5
Statistics RM5
Sequence : SWING and BLUE JACKET
Modification : None and loop filter

INSTITUTE : NTT
Date : Sep. 1,
bit rate : 59400 (bits)
frame rate : 10.0 (Hz)

Sequence			Swing		Blue Jacket			
Item			RM5	FIL	RM5	FIL		
Frame number			ave	ave	ave	ave		
1) R.M.S. for Luminance			9.1	8.7	5.7	5.4		
2) SNR for Luminance			28.99	29.30	32.97	33.54		
3) Mean value of the step size			29.70	30.88	29.03	27.54		
4) Mean value of the number of non-zero coefficients			1.96	2.08	3.05	2.98		
5) Mean value of the number of zeroes before the last non-zero coefficient			19.68	19.10	11.80	11.35		
6) Block type of MACRO	Fixed		275	271	292	287		
	Fixed MC		2	3	4	4		
	Coded		111	115	78	82		
	Coded MC		8	7	23	23		
7) Block type of Luminance	Fixed		1378	1378	1343	1344		
	Fixed MC		20	24	48	50		
	Coded		167	166	133	132		
	Coded MC		19	16	60	58		
8) Block type of Chrominance	Fixed		753	755	760	756		
	Coded		39	37	32	36		
9) Number of bits	MACRO block Attributes		581	611	488	503		
	EOB		1422	1463	1207	1263		
	Motion Vectors		79	81	215	215		
	Coefficients	Y	3290	3247	3782	3675		
		U (Cb)	356	342	98	115		
		V (Cr)	177	160	127	145		
		Total	3823	3750	4007	3935		
	Total		5906	5905	5917	5916		

RM5: Original RM5
FIL: Improved Loop Filter

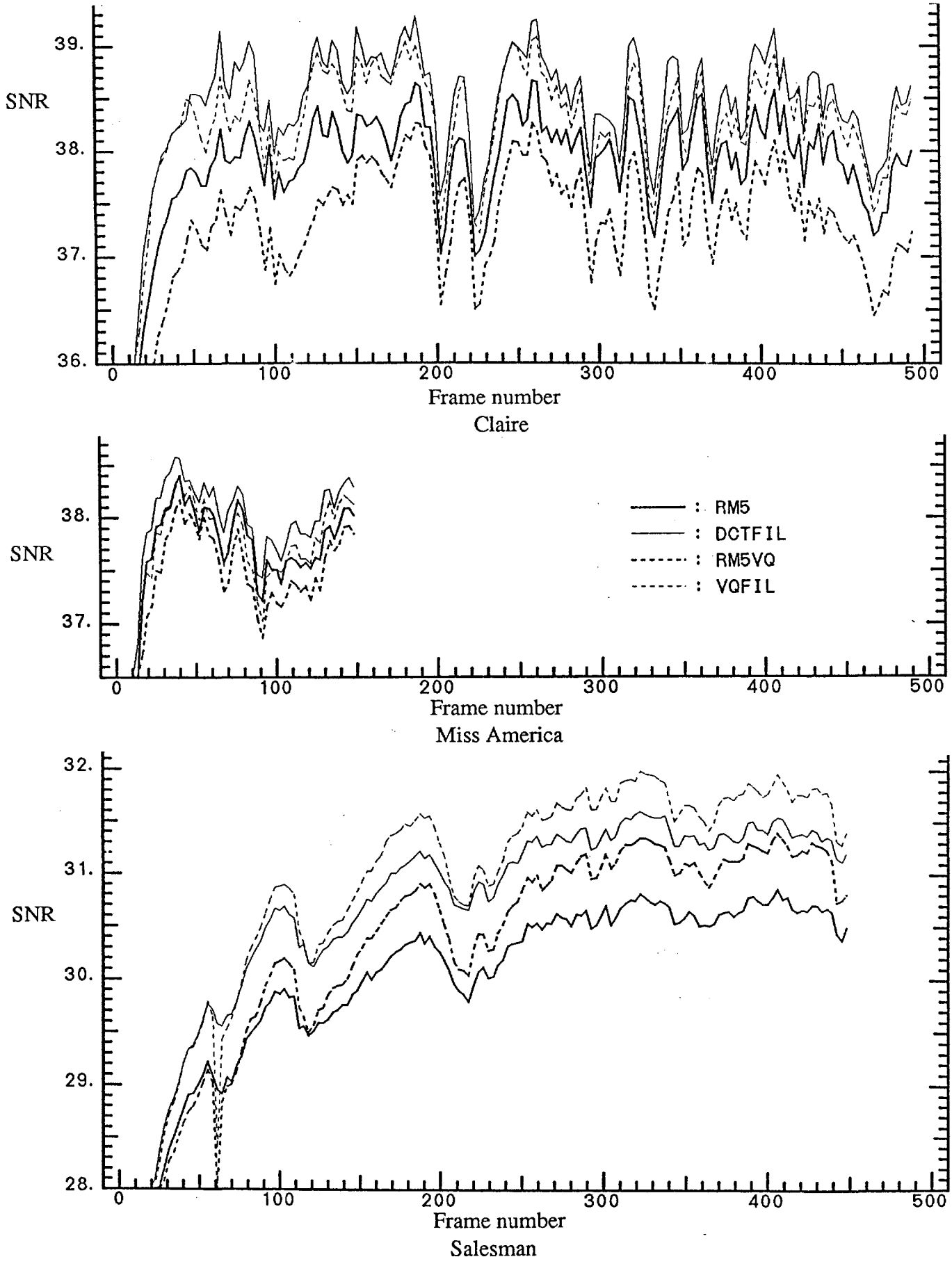


Figure 1. SNR vs Frame number (1)

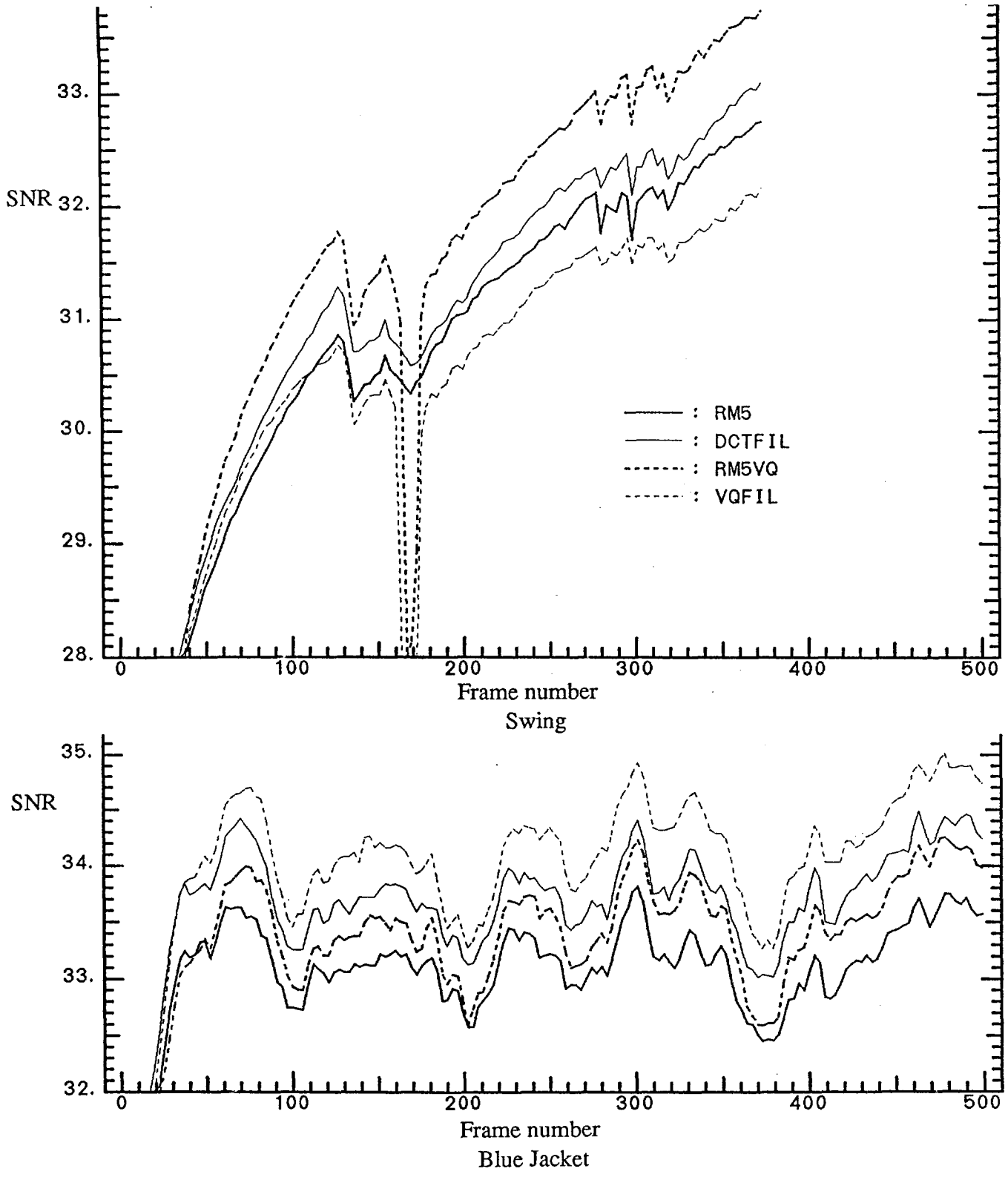
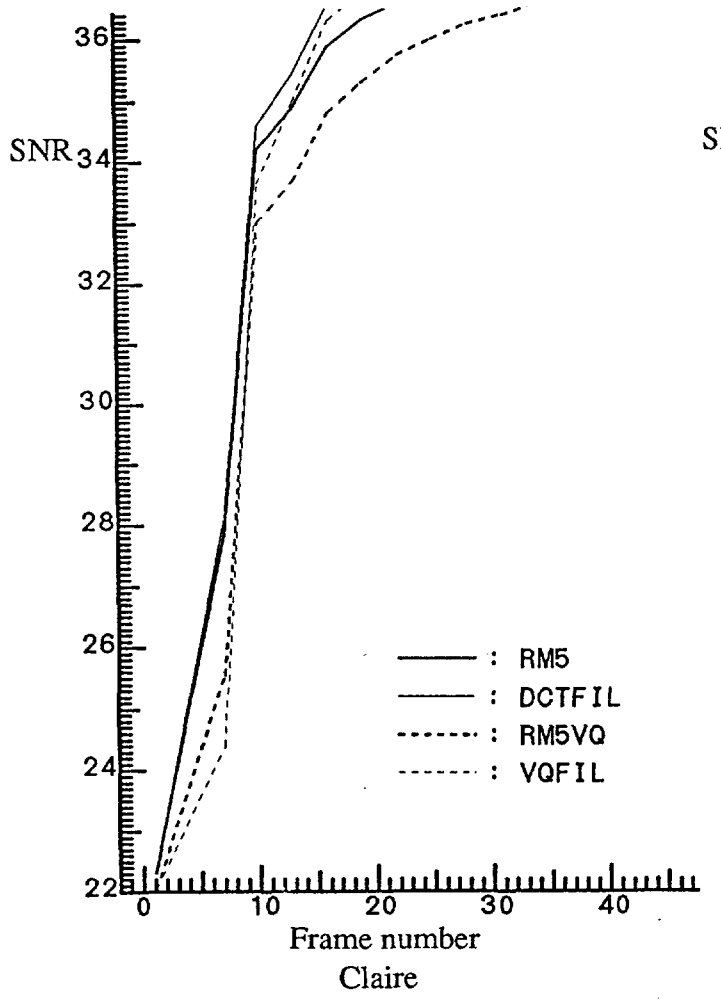
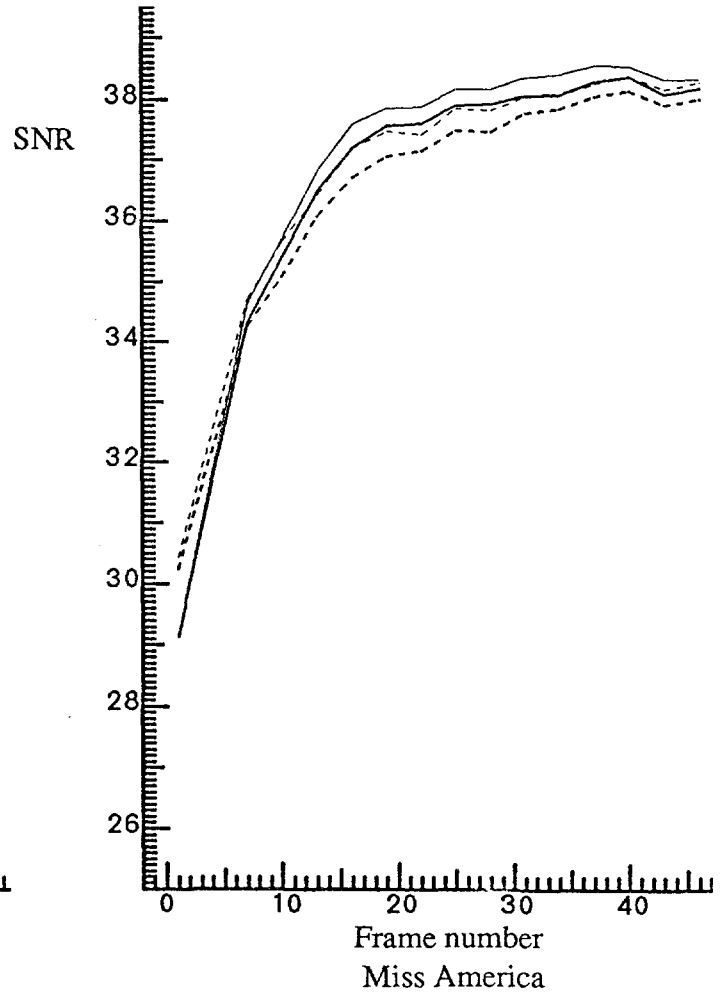


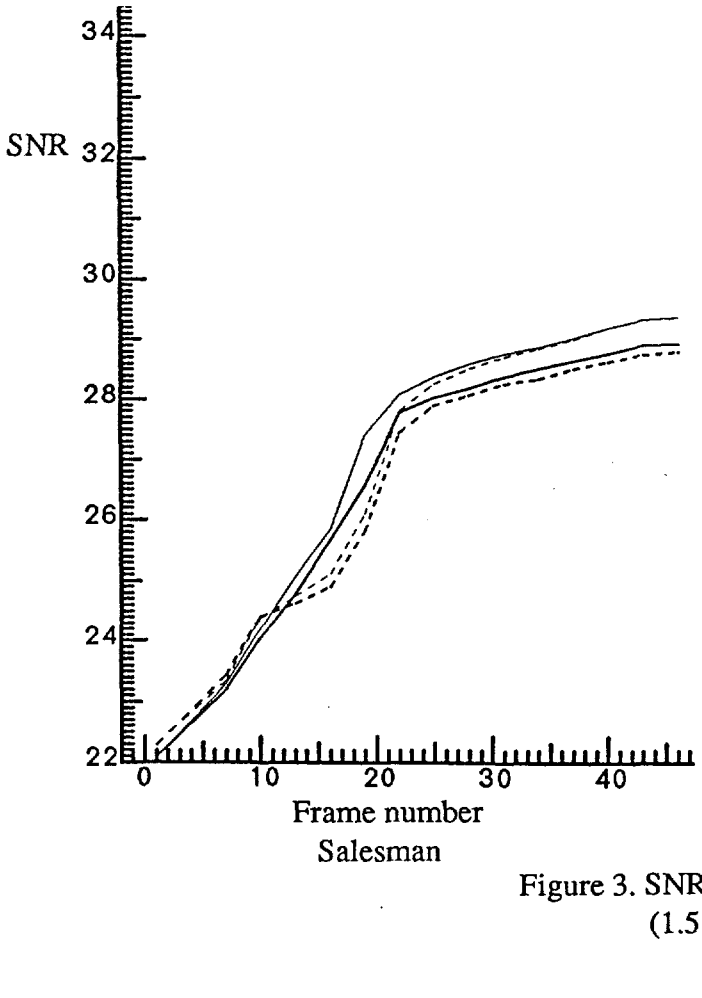
Figure 2. SNR vs Frame number (2)



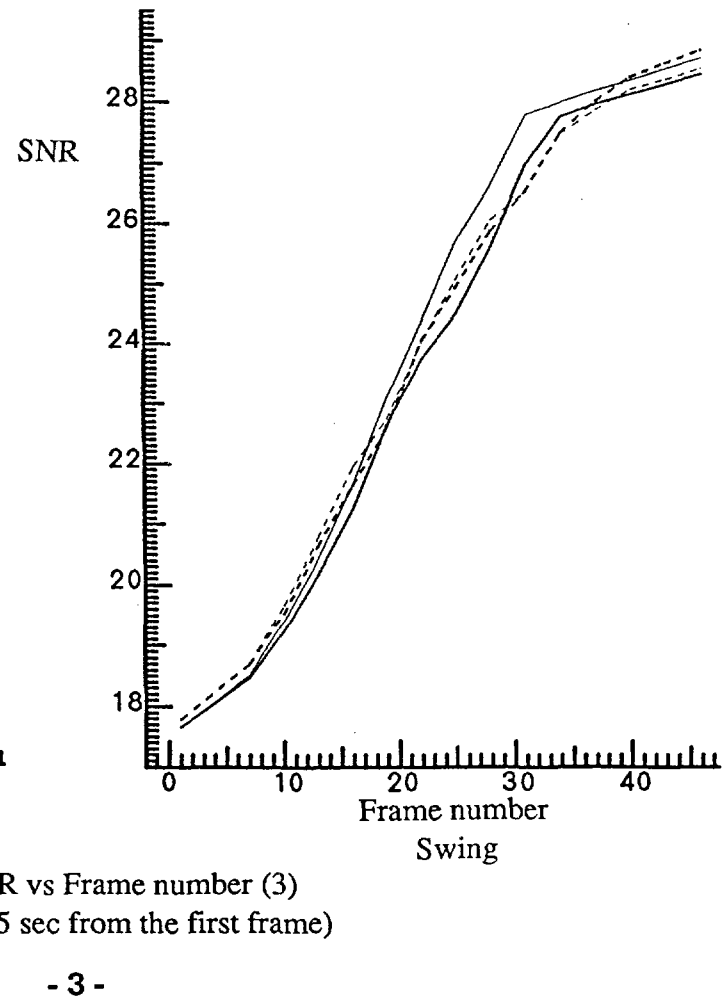
Claire



Miss America



Salesman



Swing

Figure 3. SNR vs Frame number (3)
(1.5 sec from the first frame)

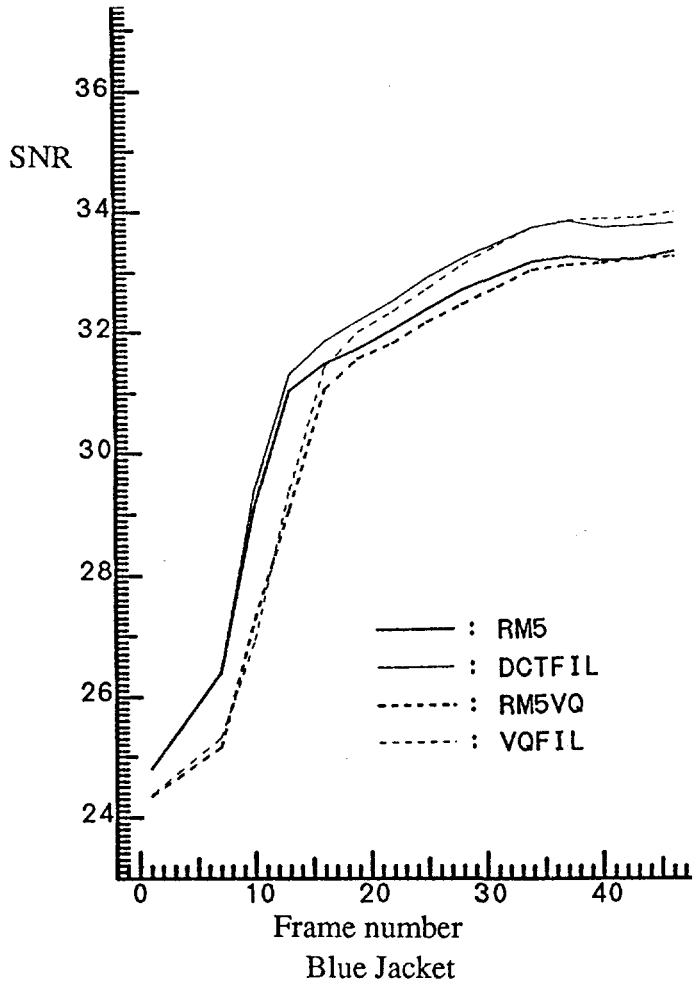


Figure 4. SNR vs Frame number (4)
(1.5 sec from the first frame)