



# **JCTVC-M0224**

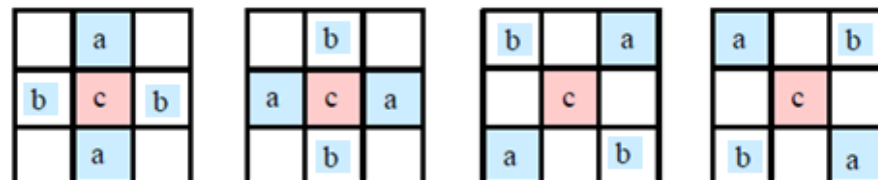
## **Non-SCE4.2: Inter-layer Fixed Directional Filtering**

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# Overall Summary

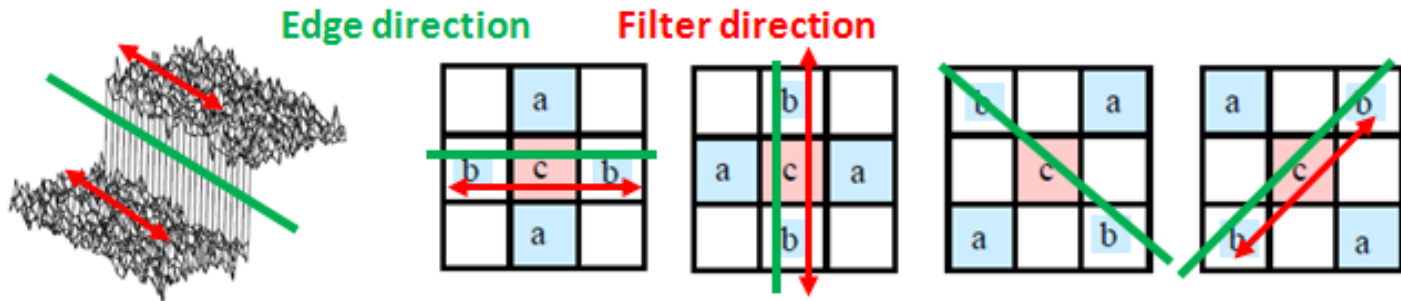
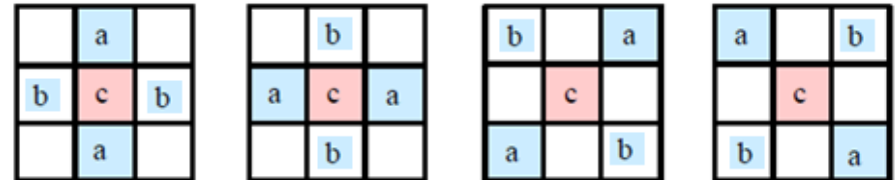
- Fixed directional filters
  - 3x3 footprint, using 5 pixels
  - Coefficients are fixed
  - Compute local orientation to select filter
- Complexity, only on IntraBL blocks
  - Orientation computation
  - Filtering operation: 5 pixels, 3 different coefficients
- BD-rate:



	2x			1.5X			SNR		
	Y	U	V	Y	U	V	Y	U	V
AI	-0.5%	-0.6%	-0.6%	-0.1%	-0.3%	-0.3%			
RA	-0.5%	-0.4%	-0.3%	0.0%	-0.2%	-0.1%	-0.8%	0.0%	0.1%
LD-P	-0.7%	-0.8%	-0.8%	-0.4%	-1.1%	-0.9%	-1.9%	-0.8%	-0.7%
LD-B	-0.5%	-0.7%	-0.7%	-0.1%	-0.6%	-0.4%	-0.9%	-0.4%	-0.3%
Ave	-0.6%	-0.6%	-0.6%	-0.2%	-0.6%	-0.4%	-1.2%	-0.4%	-0.3%

# The Fixed Directional Interlayer Filter

- 3x3 footprint
- 3 coefficients on 5 pixels
- 4 orientations for directional filtering
- Select filter according to orientation
  - Larger weights along local orientation



- Determine local orientation, to select filter

# Determine Local Orientation

- For a to-be-filtered pixel  $P(x,y)$ 
  - Compute gradients  $G_H$  and  $G_V$  using neighboring pixels

$$G_H(x,y) = \text{GraH} * P(x,y)$$

$$G_V(x,y) = \text{GraV} * P(x,y)$$

$$\begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix}$$

GraH

$$\begin{bmatrix} +1 & +1 & +1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

GraV

- Compare  $G_H$  and  $G_V$

if (  $|G_V| > 2 \times |G_H|$  )

Class 1

else if (  $|G_H| > 2 \times |G_V|$  )

Class 2

else if (  $\text{sign}(G_V) == \text{sign}(G_H)$  )

Class 3

else

Class 4

- Class 1: hor-dir smooth
- Class 2: ver-dir smooth
- Class 3: 135-dir smooth
- Class 4: 45-dir smooth

Class 1

	a	
b	c	b
	a	

Class 2

	b	
a	c	a
	b	

Class 3

b		a
	c	
a		b

Class 4

a		b
	c	
b		a

# Filter Strength according to Local Gradients

- Adjust filter strength
  - Smooth (small gradient-sum): Strong filter
  - Larger gradient-sum: Weak filter
  - Too large gradient-sum: No filter

	Class 1	Class 2	Class 3	Class 4
if ( $ G_v  +  G_h  < Th_1$ ) $\{a,b,c\} = \{2,1,2\}$ , aggressive				
else if ( $ G_v  +  G_h  < Th_2$ ) $\{a,b,c\} = \{2,1,10\}$ , conservative				

- Spatial:  $Th_1 = 32$ ,  $Th_2 = 96$
- SNR:  $Th_1 = 32$ ,  $Th_2 = \max$  (i.e. no  $Th_2$ )

# Computational Complexity

- Determine orientation:
  - 8 adds to compute  $G_H$  and  $G_V$ , 1 add to compute gradient-sum.
  - 3 Comparisons between  $G_H$  and  $G_V$
  - Comparison against Th is implemented using quantization.
- Filtering each pixel:
  - 3 multiplications for 3 distinct coefficients.
  - 5 adds, including adding the offset for rounding purposes.
  - Bandwidth: For a CU, 3×3 filter requires one additional line on each side of the CU boundary.

# Performance and Complexity Comparison

		M0213, SCE4.2.6			M0215, Non-SCE4.2			M0055, SEC4.2.5-DIV			M0055, SEC4.2.5-LUT			M0224, Non-SCE4.2		
Filter Kernel		Bilinear			Bilinear			S DeRing F - DIV			S DeRing F - LUT			Fixed Directional F		
	type	2D non-sep			1D separable			2D non-sep			2D non-sep			2D non-sep		
	size	5x5 square, 25 tap			3-tap			3x3 square, 9 tap			3x3 square, 9 tap			3x3 square, 5 tap		
Worst case	Mult	209%			100%			100%			100%			100%		
	Add	278%			100%			114%			114%			100%		
Per-fil-pixel	Mult	50			6			18			18			3 (or 5)		
	Add	72			10			27			27			14		
	Oth	1 division			LUT-256			1 division			LUT-size 768%			3 comparisons		
		AI,RA,LP			AI,RA,LP			AI,RA,LP			AI,RA,LP			AI,RA,LP		
		Y	U	V	Y	U	V	Y	U	V	Y	U	V	Y	U	V
BD-rates	2x	-1.4%	-0.8%	-1.5%	-0.9%	-0.2%	-0.3%	-1.0%	-1.2%	-1.2%	-0.7%	-0.6%	-0.7%	-0.6%	-0.6%	-0.6%
	1.5x	-0.4%	-0.3%	-0.8%	-0.2%	0.2%	0.2%	-0.4%	-0.6%	-0.6%	-0.2%	-0.6%	-0.8%	-0.2%	-0.5%	-0.4%
	SNR	-0.7%	-0.8%	-1.2%				-0.7%	-0.8%	-0.5%	-0.5%	-0.8%	-1.1%	-1.4%	-0.4%	-0.3%
Runtime	Enc	109.4%			108.9%			105.8%			105.8%			105.0%		
	Dec	131.1%			107.8%			109.5%			107.6%			106.8%		

# Detailed Results

	AI HEVC 2x			AI HEVC 1.5x					
	Y	U	V	Y	U	V			
Class A	-0.8%	-1.0%	-1.0%						
Class B	-0.4%	-0.5%	-0.4%	-0.1%	-0.3%	-0.3%			
Overall (Test vs Ref)	-0.5%	-0.6%	-0.6%	-0.1%	-0.3%	-0.3%			
Overall (Test vs single layer)	11.9%	13.0%	12.7%	10.2%	10.0%	9.5%			
EL only (Test vs Ref)	-0.6%	-0.7%	-0.7%	1.2%	1.0%	1.0%			
Enc Time[%]	111.5%			109.1%					
Dec Time[%]	113.8%			108.0%					
Enc Mem[%]	#DIV/0!			#DIV/0!			Enc all		104.2%
BL Match	Matched			Matched			Dec all		106.1%

	RA HEVC 2x			RA HEVC 1.5x			RA HEVC SNR		
	Y	U	V	Y	U	V	Y	U	V
Class A	-0.8%	-0.5%	-0.7%				-1.5%	0.0%	-0.1%
Class B	-0.4%	-0.3%	-0.1%	0.0%	-0.2%	-0.1%	-0.6%	0.0%	0.2%
Overall (Test vs Ref)	-0.5%	-0.4%	-0.3%	0.0%	-0.2%	-0.1%	-0.8%	0.0%	0.1%
Overall (Test vs single layer)	18.7%	31.6%	32.7%	16.5%	28.3%	30.8%	13.9%	28.9%	32.9%
EL only (Test vs Ref)	-0.8%	-0.6%	-0.5%	1.2%	0.9%	1.0%	-0.8%	0.0%	0.2%
Enc Time[%]	103.9%			103.2%			102.8%		
Dec Time[%]	105.1%			104.2%			105.3%		
Enc Mem[%]	#DIV/0!			#DIV/0!			#DIV/0!		
BL Match	Matched			Matched			Matched		

	LD-P HEVC 2x			LD-P HEVC 1.5x			LD-P HEVC SNR		
	Y	U	V	Y	U	V	Y	U	V
Class A	-0.9%	-0.9%	-1.2%				-3.1%	-0.8%	-0.9%
Class B	-0.7%	-0.8%	-0.6%	-0.4%	-1.1%	-0.9%	-1.4%	-0.7%	-0.6%
Overall (Test vs Ref)	-0.7%	-0.8%	-0.8%	-0.4%	-1.1%	-0.9%	-1.9%	-0.8%	-0.7%
Overall (Test vs single layer)	25.2%	35.4%	37.2%	22.1%	31.9%	34.9%	20.0%	33.5%	38.2%
EL only (Test vs Ref)	-1.1%	-1.2%	-1.1%	0.4%	-0.2%	0.0%	-2.5%	-1.3%	-1.2%
Enc Time[%]	103.7%			102.9%			102.6%		
Dec Time[%]	105.9%			105.9%			106.1%		
Enc Mem[%]	#DIV/0!			#DIV/0!			#DIV/0!		
BL Match	Matched			Matched			Matched		

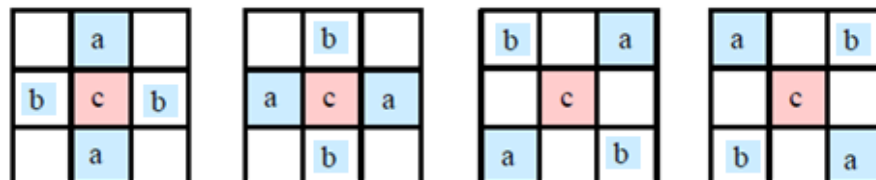
## Optional Tests

	LD-B HEVC 2x			LD-B HEVC 1.5x			LD-B HEVC SNR		
	Y	U	V	Y	U	V	Y	U	V
Class A	-0.8%	-0.7%	-1.0%				-1.7%	-0.2%	-0.6%
Class B	-0.4%	-0.7%	-0.5%	-0.1%	-0.6%	-0.4%	-0.6%	-0.5%	-0.2%
Overall (Test vs Ref)	-0.5%	-0.7%	-0.7%	-0.1%	-0.6%	-0.4%	-0.9%	-0.4%	-0.3%
Overall (Test vs single layer)	27.5%	36.5%	37.7%	24.6%	32.2%	34.6%	22.6%	33.0%	36.7%
EL only (Test vs Ref)	-0.8%	-0.9%	-0.9%	0.9%	0.3%	0.5%	-1.1%	-0.5%	-0.4%
Enc Time[%]	102.7%			101.9%			101.9%		
Dec Time[%]	104.1%			104.0%			104.7%		
Enc Mem[%]	#DIV/0!			#DIV/0!			#DIV/0!		
BL Match	Matched			Matched			Matched		



# Conclusions

- Fixed directional filters
  - 3x3 footprint, using 5 pixels
  - Coefficients are fixed
  - Compute local orientation to select filter
- Complexity, only on IntraBL blocks
  - Orientation computation: 14 adds, 3 comparisons.
  - Filtering operation: 5 pixels, 3 distinct coefficients
- BD-rate:



	2x			1.5X			SNR		
	Y	U	V	Y	U	V	Y	U	V
AI	-0.5%	-0.6%	-0.6%	-0.1%	-0.3%	-0.3%			
RA	-0.5%	-0.4%	-0.3%	0.0%	-0.2%	-0.1%	-0.8%	0.0%	0.1%
LD-P	-0.7%	-0.8%	-0.8%	-0.4%	-1.1%	-0.9%	-1.9%	-0.8%	-0.7%
LD-B	-0.5%	-0.7%	-0.7%	-0.1%	-0.6%	-0.4%	-0.9%	-0.4%	-0.3%
Ave	-0.6%	-0.6%	-0.6%	-0.2%	-0.6%	-0.4%	-1.2%	-0.4%	-0.3%