

Non-CE9: Simplification of BDOF (JVET-O0304)

Y. Kato, K. Abe, T. Toma
Panasonic Corporation

BDOF (VTM5.0)

■ Calculation of correlation and bdofoffset

Correlation (per 4x4 sub block unit)

$$s_1 = \sum_{[i,j] \in \Omega} (I_x^1 + I_x^0) \times (I_x^1 + I_x^0)$$

$$s_2 = \sum_{[i,j] \in \Omega} (I_y^1 + I_y^0) \times (I_y^1 + I_y^0)$$

$$s_3 = \sum_{[i,j] \in \Omega} -(I_x^1 + I_x^0) \times (I^0 - I^1)$$

$$s_4 = \sum_{[i,j] \in \Omega} -(I_y^1 + I_y^0) \times (I^0 - I^1)$$

$$s_5 = \sum_{[i,j] \in \Omega} (I_x^1 + I_x^0) \times (I_y^1 + I_y^0)$$

$$v_x = \frac{s_3}{s_1}$$

$$v_y = \frac{s_4 - v_x \times s_5}{s_2}$$

BDOFoffset (sample unit)

$$bdofOffset = (v_x \times (I_x^1 - I_x^0)) / 2 + (v_y \times (I_y^1 - I_y^0)) / 2$$

I^0, I^1 : pred image from MC

$I_x^0, I_x^1, I_y^0, I_y^1$: gradient image

Ω : 6x6 area for each 4x4 sub block

Total number of multiplication

= $(5 \times 6 \times 6 + 1) \times (\# \text{ 4x4 sub block in CU})$

+ $2 \times (\# \text{ samples in CU})$

Note:

The minimum number of multiplications is $5 \times (\text{width}+2) \times (\text{height}+2)$, which requires additional memory. So, we use the above calculation. (maybe not needed)

BDOF (VTM5.0)

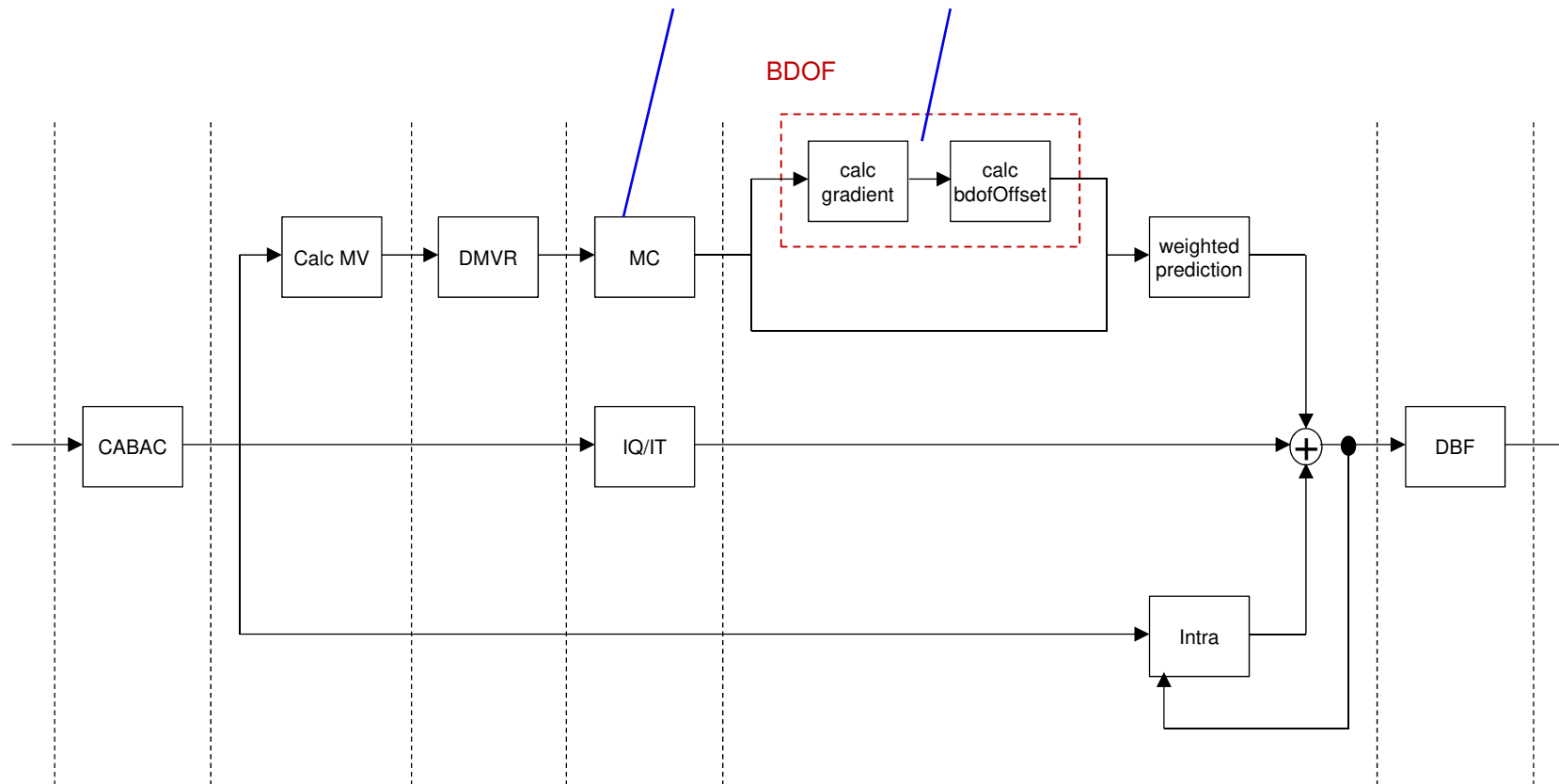
Decoder block diagram

Number of multiplication per 16x16 luma block

9984 (6bit*10bit multi)

3408 (13bit*11bit multi)

Complexity of BDOF is large enough compared to MC



BDOF (Our proposal)

■ Calculation of correlation and bdofoffset

Correlation (per 4x4 sub block unit)

$$s_1 = \sum_{[i,j] \in \Omega} \text{abs}(I_x^1 + I_x^0)$$

$$s_2 = \sum_{[i,j] \in \Omega} \text{abs}(I_y^1 + I_y^0)$$

$$s_3 = \sum_{[i,j] \in \Omega} (-\text{sign}(I_x^1 + I_x^0) \times (I^0 - I^1))$$

$$s_4 = \sum_{[i,j] \in \Omega} (-\text{sign}(I_y^1 + I_y^0) \times (I^0 - I^1))$$

$$s_5 = \sum_{[i,j] \in \Omega} \text{sign}(I_y^1 + I_y^0) \times (I_x^1 + I_x^0)$$

Replace multiplication with Sign function
(Modification1)

$$v_x = \frac{s_3}{s_1}$$

$$v_y = \frac{s_4 - v_x \times s_5}{s_2}$$

LUT based division
(Modification2)

Total number of multiplication
= $3 \times (\# \text{ 4x4 sub block in CU})$
+ $2 \times (\# \text{ samples in CU})$

BDOFoffset (sample unit)

$$\text{bdofOffset} = (v_x \times (I_x^1 - I_x^0)) / 2 + (v_y \times (I_y^1 - I_y^0)) / 2$$

BDOF (Our proposal)

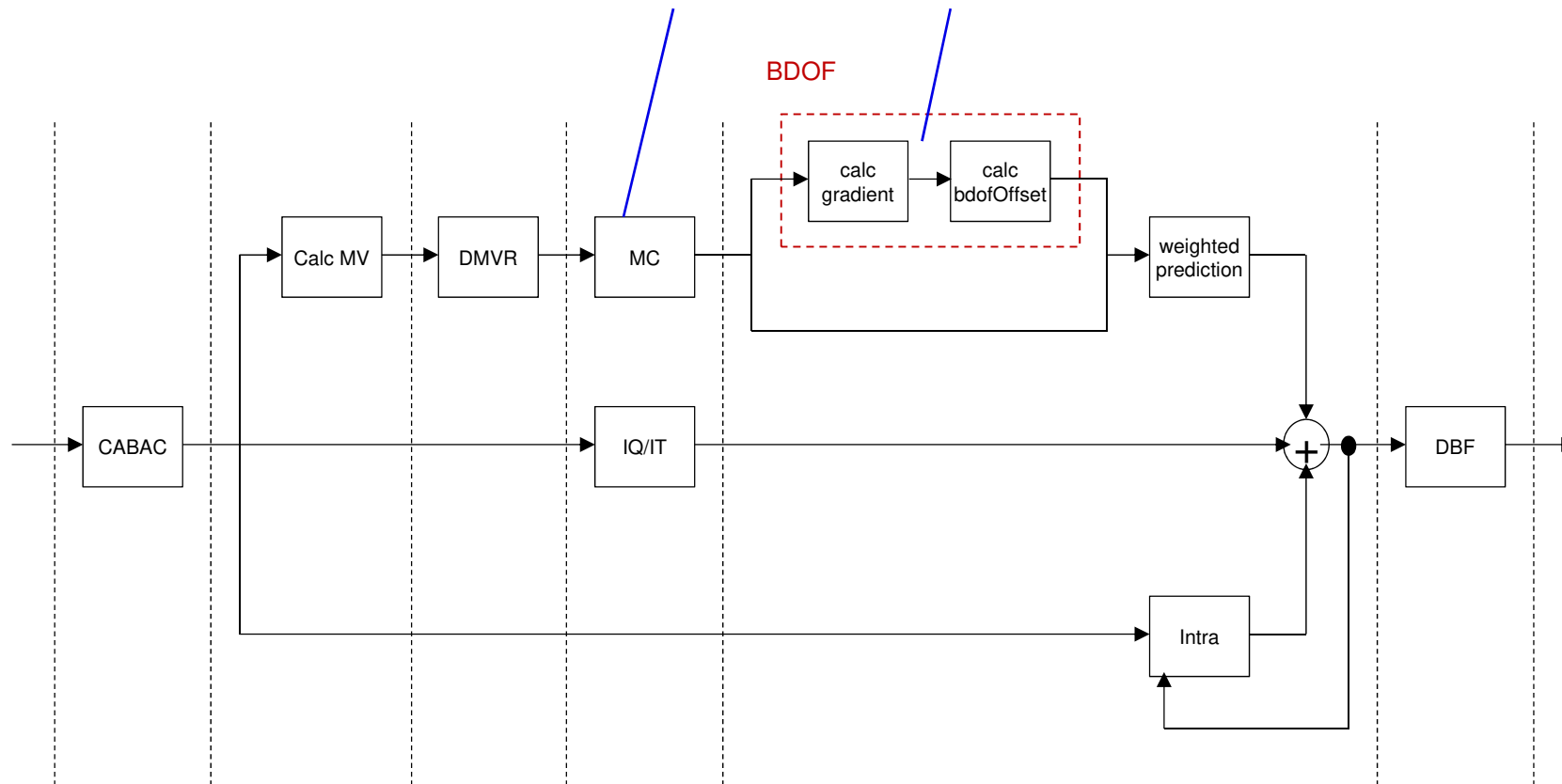
■ Decoder block diagram

Number of multiplication per 16x16 luma block

reduce from **3408** to **560** (about 1/7)

9984 (6bit*10bit multi)

560 (6bit*11bit multi)



Derivation of proposed BDOF equations

Horizontal component of optical flow in VTM5.0 is calculated as follows:

$$v_x = \frac{s_3}{s_1} = \frac{\sum_{[i,j] \in \Omega} (-(I_x^1 + I_x^0) \times (I^0 - I^1))}{\sum_{[i,j] \in \Omega} (I_x^1 + I_x^0) \times (I_x^1 + I_x^0)}$$

It is assumed that values $abs(I_x^1 + I_x^0)$ for all pixel positions in Ω are uniform. Then, the above formula can be transformed as follows:

$$= \frac{\sum_{[i,j] \in \Omega} -sign(I_x^1 + I_x^0) \times abs(I_x^1 + I_x^0) \times (I^0 - I^1)}{\sum_{[i,j] \in \Omega} abs(I_x^1 + I_x^0) \times abs(I_x^1 + I_x^0)}$$

$$= \frac{abs(I_x^1 + I_x^0) \times \sum_{[i,j] \in \Omega} -sign(I_x^1 + I_x^0) \times (I^0 - I^1)}{abs(I_x^1 + I_x^0) \times \sum_{[i,j] \in \Omega} abs(I_x^1 + I_x^0)}$$

$$= \frac{\cancel{abs(I_x^1 + I_x^0)} \times \sum_{[i,j] \in \Omega} -sign(I_x^1 + I_x^0) \times (I^0 - I^1)}{\cancel{abs(I_x^1 + I_x^0)} \times \sum_{[i,j] \in \Omega} abs(I_x^1 + I_x^0)}$$

$$= \frac{\sum_{[i,j] \in \Omega} -sign(I_x^1 + I_x^0) \times (I^0 - I^1)}{\sum_{[i,j] \in \Omega} abs(I_x^1 + I_x^0)}$$

(proposed equation)



v_y can be obtained in the same way.

Simulation result

Table: proposal (over VTM5.0)

	Random Access Main10				
	Over VTM-5.0				
	Y	U	V	EncT	DecT
Class A1	0.02%	-0.12%	0.01%	100%	100%
Class A2	0.03%	-0.04%	-0.05%	100%	99%
Class B	0.02%	0.00%	-0.03%	99%	99%
Class C	0.01%	-0.02%	-0.11%	99%	98%
Class E					
Overall	0.02%	-0.04%	-0.05%	99%	99%
Class D	0.09%	0.06%	0.03%	100%	97%
Class F	0.00%	-0.02%	-0.03%	100%	100%

- **BD-rate loss 0.02%**
- **EncT and DetT is reduced to 99%**

Conclusion

- Proposed method reduces the number of multiplications in BDOF process to about 1/7 (98% reduction w.r.t correlation)
- BD-rate loss 0.02%, which is negligible
- EncT and DetT are reduced to 99%

→ Propose to adopt this into the test model

Thank Ittiam for cross checking our proposal.

Comparison of mutiplications of proposed BDOF with BDOF in VTM5.0 (information)

Table1

BDOF in VTM5.0

W	H	Correlation	BDOFOffset	Total
128	128	185,344	32,768	218,112
128	64	92,672	16,384	109,056
64	128	92,672	16,384	109,056
128	32	46,336	8,192	54,528
32	128	46,336	8,192	54,528
128	16	23,168	4,096	27,264
16	128	23,168	4,096	27,264
128	8	11,584	2,048	13,632
8	128	11,584	2,048	13,632
64	64	46,336	8,192	54,528
64	32	23,168	4,096	27,264
32	64	23,168	4,096	27,264
64	16	11,584	2,048	13,632
16	64	11,584	2,048	13,632
64	8	5,792	1,024	6,816
8	64	5,792	1,024	6,816
32	32	11,584	2,048	13,632
32	16	5,792	1,024	6,816
16	32	5,792	1,024	6,816
32	8	2,896	512	3,408
8	32	2,896	512	3,408
16	16	2,896	512	3,408
16	8	1,448	256	1,704
8	8	724	128	852

Proposed BDOF

W	H	Correlation	BDOFOffset	Total
128	128	3,072	32,768	35,840
128	64	1,536	16,384	17,920
64	128	1,536	16,384	17,920
128	32	768	8,192	8,960
32	128	768	8,192	8,960
128	16	384	4,096	4,480
16	128	384	4,096	4,480
128	8	192	2,048	2,240
8	128	192	2,048	2,240
64	64	768	8,192	8,960
64	32	384	4,096	4,480
32	64	384	4,096	4,480
64	16	192	2,048	2,240
16	64	192	2,048	2,240
64	8	96	1,024	1,120
8	64	96	1,024	1,120
32	32	192	2,048	2,240
32	16	96	1,024	1,120
16	32	96	1,024	1,120
32	8	48	512	560
8	32	48	512	560
16	16	48	512	560
16	8	24	256	280
8	8	12	128	140

Comparison of mutiplications of BDOF and MC in VTM5.0 (information)

Table2

W	H	MC	BDOF (Total)	
			VTM5.0	Proposal
128	128	538,624	218,112	35,840
128	64	276,480	109,056	17,920
64	128	269,312	109,056	17,920
128	32	145,408	54,528	8,960
32	128	134,656	54,528	8,960
128	16	79,872	27,264	4,480
16	128	67,328	27,264	4,480
128	8	47,104	13,632	2,240
8	128	33,664	13,632	2,240
64	64	138,240	54,528	8,960
64	32	72,704	27,264	4,480
32	64	69,120	27,264	4,480
64	16	39,936	13,632	2,240
16	64	34,560	13,632	2,240
64	8	23,552	6,816	1,120
8	64	17,280	6,816	1,120
32	32	36,352	13,632	2,240
32	16	19,968	6,816	1,120
16	32	18,176	6,816	1,120
32	8	11,776	3,408	560
8	32	9,088	3,408	560
16	16	9,984	3,408	560
16	8	5,888	1,704	280
8	8	2,944	852	140