

JCT3V-H0127 Complexity Assessment on Depth Intra Modes

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Abstract

- Complexity assessment on depth intra modes (DIM), including depth modeling modes 1 (DMM 1), DMM 4, angular mode
 - Number of operations
 - Data storage requirement
 - Data transfer rate
- Complexity at 64×64 block with various prediction unit (PU) sizes
- Discussion on issues of storage and data transfer rate of DIM
- Coding performance: DMM 1 and DMM 4 are both OFF
 - Anchor: HTM-10.0r1

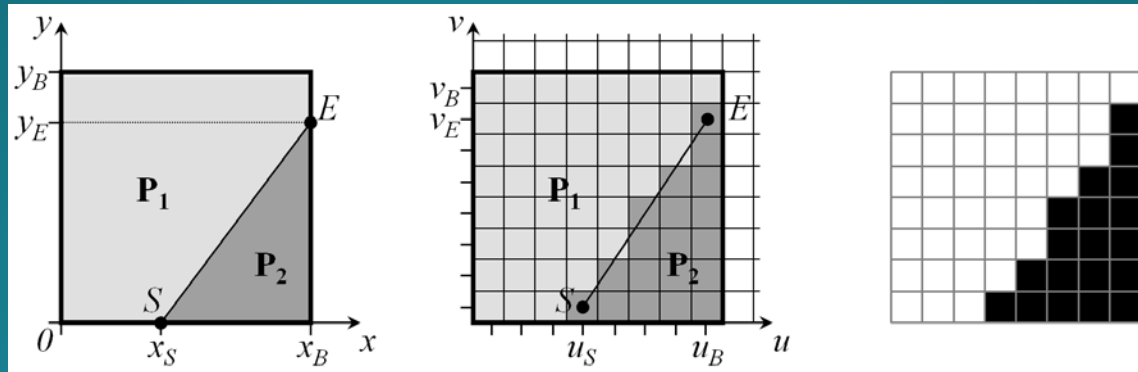
	Video PSNR vs. video bitrate	Video PSNR vs. total bitrate	Synth PSNR vs. total bitrate
All intra	0.00%	-0.23%	5.73%
Common test condition	0.11%	-0.15%	2.39%

Outline

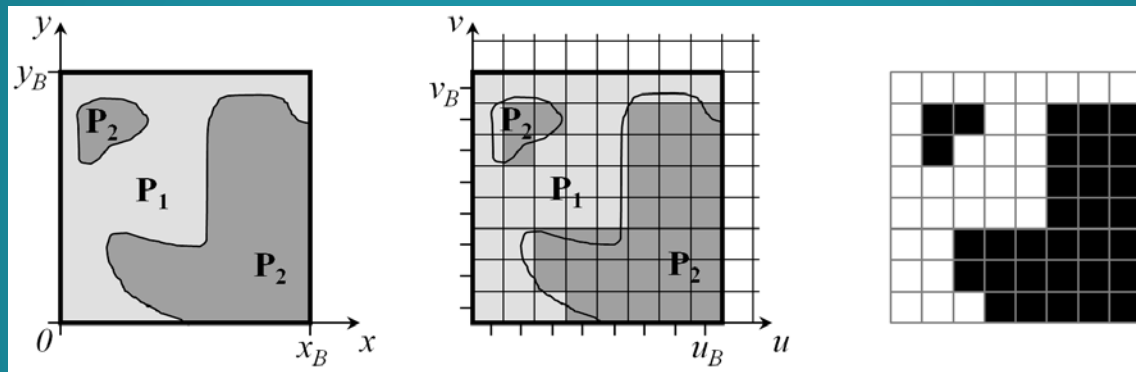
- Abstract
- Flowcharts of DMM 1, DMM 4, and angular mode
- Complexity assessment at PU level
 - Number of operations
 - Data storage requirement
 - Data transfer rate
- Complexity of depth intra modes at 64×64 block level
- Discussion on issues of storage and data transfer rate of DIM
- Report on tradeoff between coding performance and different coding tools under common test condition (CTC) and all intra (AI)
 - DMM 1 and DMM 4 are both OFF (Anchor: HTM-10.0r1)
 - DMM 1 is OFF (Anchor: HTM-10.0r1)
 - DMM 4 is OFF (Anchor: HTM-10.0r1)
- Conclusion

Introduction to DMM 1 and DMM 4

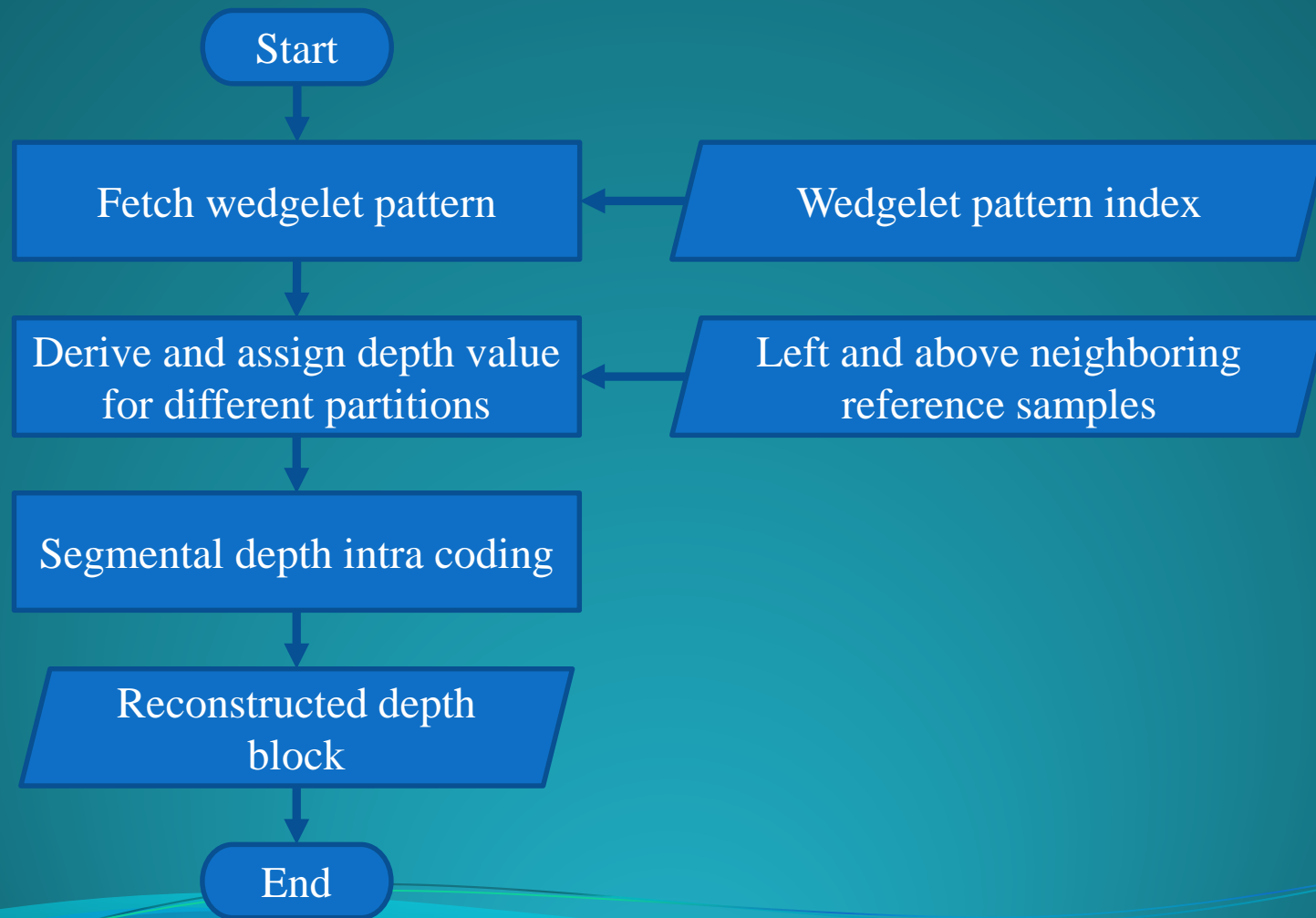
- DMM 1: Wedgelet partitioning



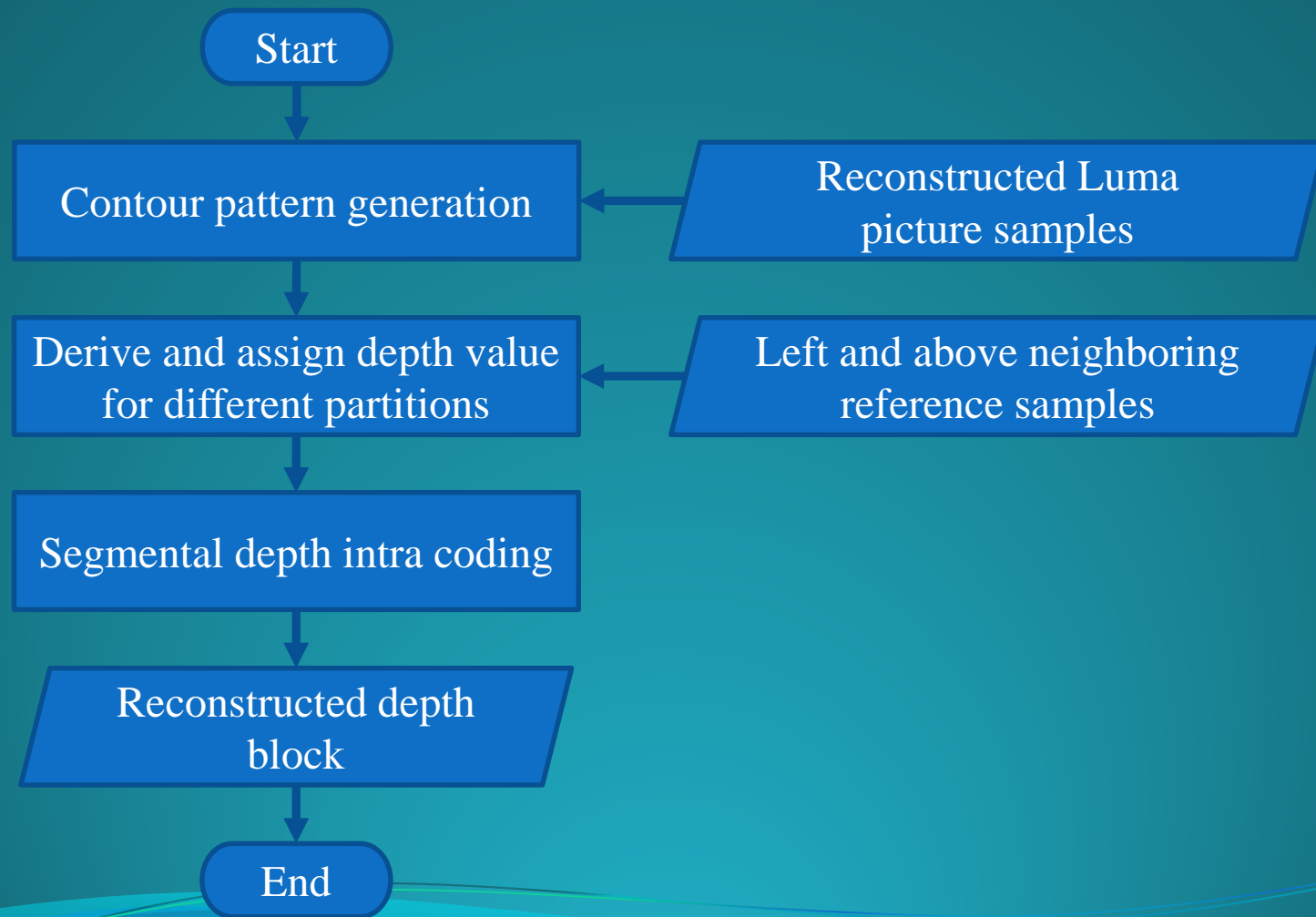
- DMM 4: Inter-component-predicted contour partitioning



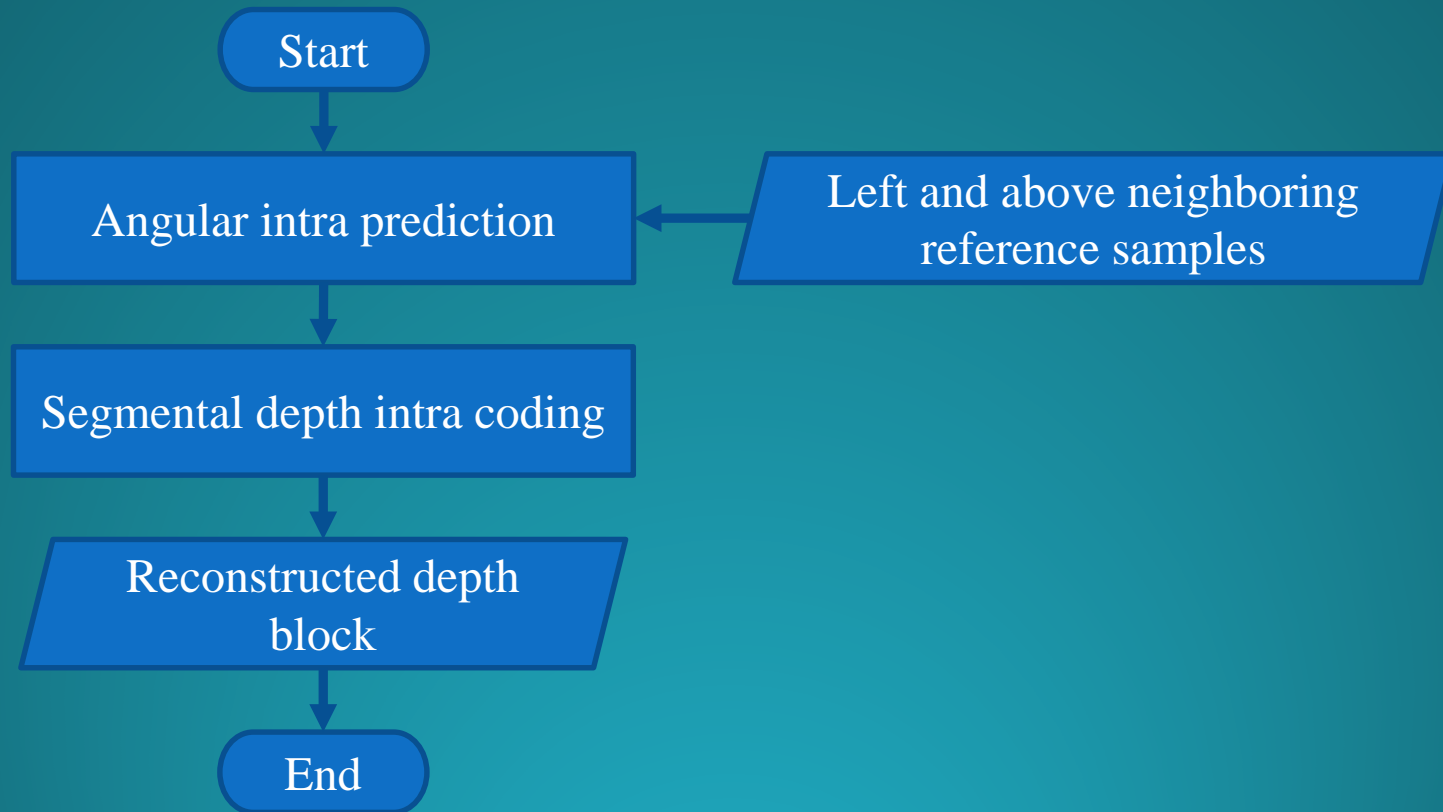
Flowchart of DMM 1



Flowchart of DMM 4

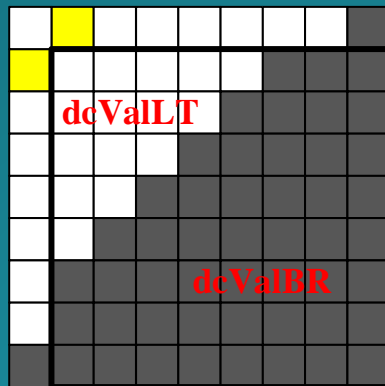


Flowchart of angular mode

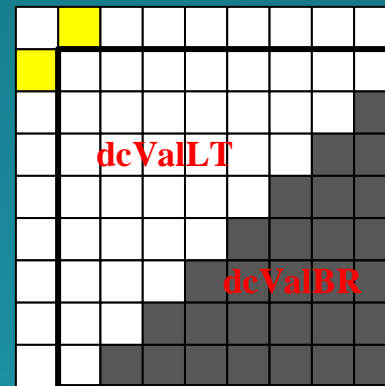


Number of operations (1/9)

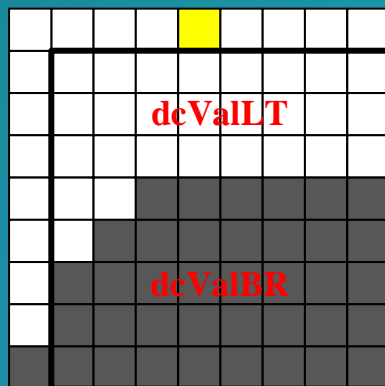
- DMM 1 and DMM 4: derive and assign depth value for different partitions



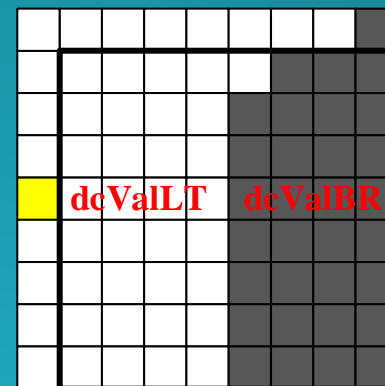
Case 1



Case 2



Case 3



Case 4

Number of operations (2/9)

- **DMM 1 and DMM 4:** derive and assign depth value for different partitions

vertEdgeFlag = (**partitionPattern**[0][0] != **partitionPattern**[N-1][0])? 1 : 0;

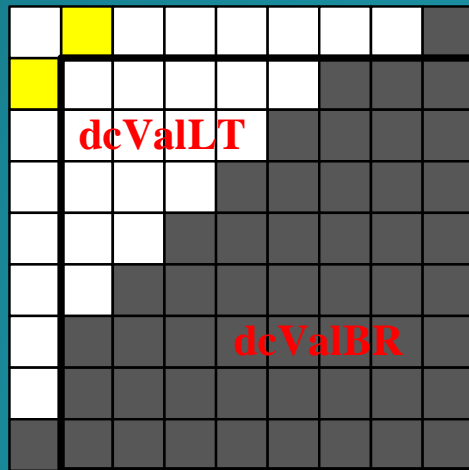
horEdgeFlag = (partitionPattern[0][0] != **partitionPattern**[0][N-1])? 1 : 0;

If (vertEdgeFlag == horEdgeFlag) (**case 1 and case 2**)

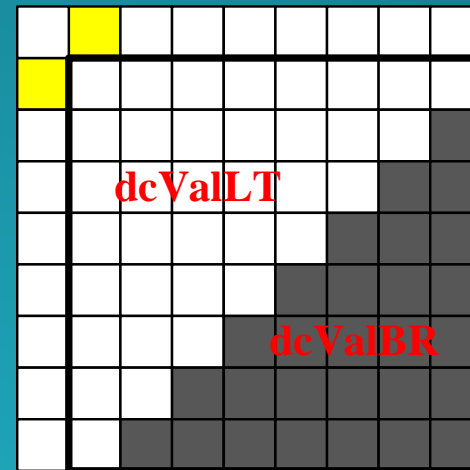
dcValLT = (neiSamples[-1][0] + neiSamples[0][-1]) >> 1;

If (horEdgeFlag == 1) (**case 1**)

dcValBR = (neiSamples[-1][N-1] + neiSamples[N-1][-1]) >> 1; (**case 1**)



Case 1



Case 2

N: PU size

neiSamples: left and above reference samples

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Number of operations (3/9)

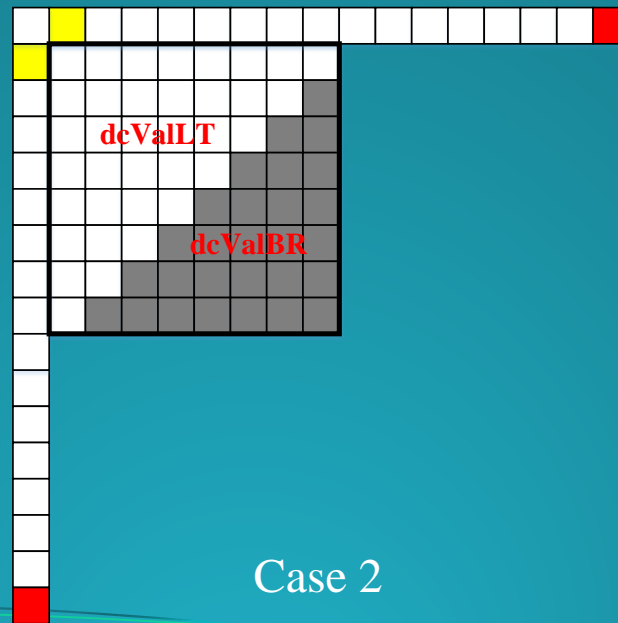
- DMM 1 and DMM 4:** derive and assign depth value for different partitions

If (horEdgeFlag == 0), and neiSamples[-1][2N-1] and neiSamples[2N-1][-1] are both available, (**case 2**)

dcValBR = abs(neiSamples[-1][2N-1] - neiSamples[-1][0]) >
abs(neiSamples[2N-1][-1] - neiSamples[0][-1]) ?
neiSamples[-1][2N-1]: neiSamples[2N-1][-1]

Otherwise

dcValBR = $2^{\text{BitDepth}-1}$



Case 2

neiSamples: left and above reference samples

N: PU size

Number of operations (4/9)

- **DMM 1 and DMM 4:** derive and assign depth value for different partitions

Otherwise ($\text{vertEdgeFlag} \neq \text{horEdgeFlag}$) (case 3 and case 4)

$\text{dcValLT} = \text{horEdgeFlag} ? \text{neiSamples}[(N-1) \gg 1][-1] : \text{neiSamples}[-1][(N-1) \gg 1]$

$\text{dcValBR} = \text{horEdgeFlag} ? \text{neiSamples}[-1][N-1] : \text{neiSamples}[N-1][-1]$

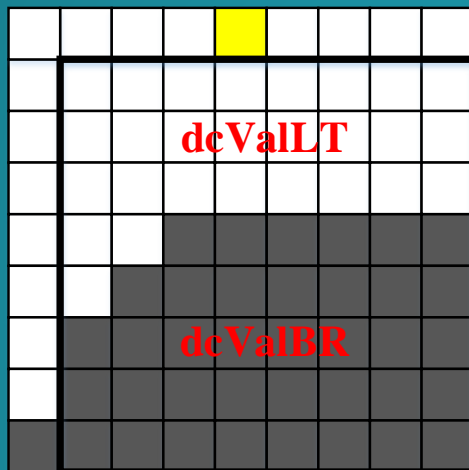
For $0 \leq x, y < N-1$:

$\text{predDCVal} = (\text{partitionPattern}[x][y] == \text{partitionPattern}[0][0]) ? \text{dcValLT} : \text{dcValBR}$

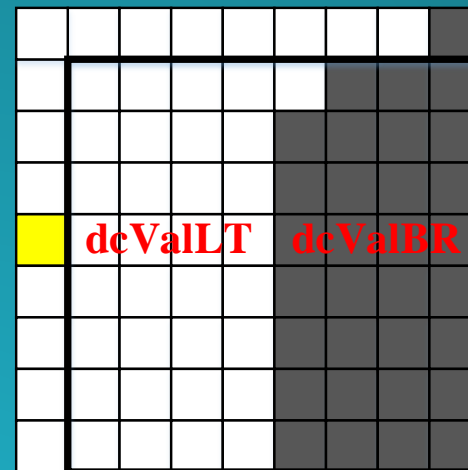
$\text{dcOffset} = \text{dcOffsetAvailFlag} ? \text{DcOffset}[xTb][yTb][\text{partitionPattern}[x][y]] : 0$

$\text{predSamples}[x][y] = \text{Idx2DepthValue}[\text{DepthValueIdx}[\text{predDCVal}] + \text{dcOffset}]$

- **$3+N^2$ additions/subtractions, $3+3N^2$ LUT access**



Case 3



Case 4

xTb, yTb : top-left
sample position of
current block
 N : PU size

Number of operations (5/9)

- **DMM 1: segmental depth intra coding**
 - $\text{dcPred}[\text{wedgePattern}[0][0]] = \text{predSamples}[0][0]$
 $\text{dcPred}[\text{wedgePattern}[N-1][0]] = \text{predSamples}[N-1][0]$
 $\text{dcPred}[\text{wedgePattern}[0][N-1]] = \text{predSamples}[0][N-1]$
 $\text{dcPred}[\text{wedgePattern}[N-1][N-1]] = \text{predSamples}[N-1][N-1]$
 - For $0 \leq x, y < N$:
 $\text{dltIdxPred} = \text{DepthValue2Idx}[\text{dcPred}[\text{wedgePattern}[x][y]]]$
 $\text{dltIdxResi} = \text{DcOffset}[xTb][yTb][\text{wedgePattern}[x][y]]$
 $\text{Recblock}[x][y] = \text{Idx2DepthValue}[\text{dltIdxPred} + \text{dltIdxResi}]$
- **N^2 additions, $4+3N^2$ LUT access**

xTb, yTb : top-left sample position of current block

Recblock: reconstructed block

N: PU size

Complexity – DMM 1 (1/2)

- Number of operations for one PU (N is PU size)

Process		Add/Sub		LUT access*	
		Depth lookup table (DLT)			
		ON	OFF	ON	OFF
Derive and assign depth value for different partitions		3+N ²	3+N ²	3+3N ²	3+N ²
Segmental depth intra coding	ON	N ²	N ²	4+3N ²	N ²
	OFF	N ²	N/A	2N ²	N/A

*LUT access: denote the behavior that access the content from a storage component

When SDC and DLT are off, inversion transform and inversion quantization will be performed.

Complexity – DMM 1 (2/2)

Case: Segment-wise DC coding ON and DLT ON

- Data storage requirement (N is PU size)

Data	Number of bits
Wedgelet pattern	$N \times N \times 1$
Wedgelet pattern index	11
Above and left reference samples	8×8
Predicted DC	2×8
dcOffset	$2 \times 2 \times 8$
Reconstructed block*	$N \times N \times 8$

- Data transfer rate

Data	Bits/PU
Wedgelet pattern (Input)	$N \times N \times 1$
Wedgelet pattern index (Input)	11
Above and left reference samples (Input)	8×8
dcOffset (Input)	$2 \times 2 \times 8$
Reconstructed block (Output)	$N \times N \times 8$

*: the storage of reconstructed block could be also used to save the prediction block due to the fact that the predicted block is no longer required after generating reconstructed block

Number of operations (6/9)

- **DMM 4: contour pattern generation**

$$\text{ThreshVal} = \left(\sum_{0 \leq x, y < N} \text{refSamples}[x][y] \right) \gg (2 \times \log_2 N)$$

- $\text{wedgePattern}[x][y] = (\text{refSamples}[x][y] > \text{ThreshVal})$, for $0 \leq x, y < N$
- **N^2 comparisons, N^2 additions/subtractions**

refSamples: co-located reconstructed Luma picture
N: PU size.

Number of operations (7/9)

- **DMM 4:** segmental depth intra coding
 - $\text{dcPred}[\text{wedgePattern}[0][0]] = \text{predSamples}[0][0]$
 $\text{foundFlag} = 0$
 - for ($x = 0; x < N; x++$)
 for ($y = 0; y < N; y++$)
 if ($\text{foundFlag} == 0 \ \&\& \text{wedgePattern}[x][y] \neq \text{wedgePattern}[0][0]$) {
 $\text{dcPred}[\text{wedgePattern}[x][y]] = \text{predSamples}[x][y]$
 $\text{foundFlag} = 1$
 }
 - For $0 \leq x, y < N$:
 $\text{dltIdxPred} = \text{DepthValue2Idx}[\text{dcPred}[\text{wedgePattern}[x][y]]]$
 $\text{dltIdxResi} = \text{DcOffset}[xTb][yTb][\text{wedgePattern}[x][y]]$
 $\text{Recblock}[x][y] = \text{Idx2DepthValue}[\text{dltIdxPred} + \text{dltIdxResi}]$
- **N^2 additions, $4N^2$ LUT access**

xTb, yTb : top-left sample position of current block

Recblock : reconstructed block

N : PU size

Complexity – DMM 4 (1/2)

- Number of operations for one PU (N is PU size)

Process		Add/Sub/Comp		LUT access*	
		Depth lookup table			
		ON	OFF	ON	OFF
Contour pattern generation		N ² +N ²		0	
derive and assign depth value for different partitions		3+N ²	3+N ²	3+3N ²	3+N ²
Segmental depth intra coding	ON	N ²	N ²	4N ²	N ²
	OFF	N ²	N/A	2N ²	N/A

*LUT access: denote the behavior that access the content from a storage component

When SDC and DLT are off, inversion transform and inversion quantization will be performed.

Complexity – DMM 4 (2/2)

- The data storage and data transfer rate is identical to DMM 1 except for the reconstructed Luma samples and wedgelet pattern index.
- Data storage requirement (N is PU size)

Case: Segment-wise DC coding ON and DLT ON

Data	Number of bits
Reconstructed Luma samples	$N \times N \times 8$
Contour pattern	$N \times N \times 1$
Above and left reference samples	8×8
Predicted DC	2×8
dcOffset	$2 \times 2 \times 8$
Reconstructed block*	$N \times N \times 8$

- Data transfer rate

Data	Bits/PU
Reconstructed Luma samples (Input)	$N \times N \times 8$
Above and left reference samples (Input)	8×8
dcOffset (Input)	$2 \times 2 \times 8$
Reconstructed block (Output)	$N \times N \times 8$

*: the storage of reconstructed block could be also used to save the prediction block due to the fact that the predicted block is no longer required after generating reconstructed block

Number of operations (8/9)

- **Angular mode:** angular intra prediction
 - For $0 \leq x, y < N-1$:
 - $iIdx = ((y + 1) \times intraPredAngle) \gg 5$
 $iFact = ((y + 1) \times intraPredAngle) \& 31$
 - If $(iFact \neq 0)$
 $predSamples[x][y] =$
 $((32 - iFact) \times neiSamples[x + iIdx + 1] + iFact \times neiSamples[x + iIdx + 2] + 16) \gg 5$
Otherwise $(iFact == 0)$
 $predSamples[x][y] = neiSamples[x + iIdx + 1]$
 - If $(predModeIntra == 26 \text{ (Vertical mode)} \&\& cIdx == 0 \&\& N < 32)$
For $0 \leq x < N-1$ and $y = 0$:
 $predSamples[x][y] =$
 $Clip1_Y(predSamples[x][-1] + ((predSamples[-1][y] - predSamples[-1][-1]) \gg 1))$
- **$4N^2 (4N^2 + 2N)$ addition/subtractions, $4N^2$ multiplications**

Number of operations (9/9)

- **Angular mode:** segmental depth intra coding:
 - Angular mode:
 - $\text{dcPred}[0] = (\text{predSamples}[0][0] + \text{predSamples}[0][N - 1] + \text{predSamples}[N - 1][0] + \text{predSamples}[N - 1][N - 1] + 2) \gg 2$
 - For $0 \leq x, y < N$:
 $\text{dltIdxPred} = \text{DepthValue2Idx}[\text{dcPred}[0]]$
 $\text{dltIdxResi} = \text{DcOffset}[xTb][yTb][0]$
 $\text{Recblock}[x][y] = \text{predSamples}[x][y] + \text{Idx2DepthValue}[\text{dltIdxPred} + \text{dltIdxResi}] - \text{dcPred}[0]$
- **3+3N² additions, 2N² LUT access**

Complexity – angular mode (1/2)

- Number of operations for one PU (N is PU size)

Process		Mul.		Add/Sub		LUT access*	
		Depth lookup table					
		ON	OFF	ON	OFF	ON	OFF
Angular intra prediction		4N ²		4N ² (4N ² +2N)		0	
Segmental depth intra coding	ON	0		3+N ²	N ²	2N ²	0
	OFF	N/A		N/A		N/A	

*LUT access: denote the behavior that access the content from a storage component
When SDC is off, inversion transform and inversion quantization will be performed.

Complexity – angular mode (2/2)

Case: Segment-wise DC coding ON and DLT ON

- Data storage requirement (N is PU size)

Data	Number of bits
Above and left reference samples	$(2N+2N) \times 8$ ($(2N+N) \times 8$ for 64x64 block)
Predicted DC	1×8
dcOffset	1×8
Reconstructed block*	$N \times N \times 8$

- Data transfer rate

Data	Bits/PU
Above and left reference samples (Input)	$(2N+2N) \times 8$ ($(2N+N) \times 8$ for 64x64 block)
dcOffset (Input)	1×8
Reconstructed block (Output)	$N \times N \times 8$

*: the storage of reconstructed block could be also used to save the prediction block due to the fact that the predicted block is no longer required after generating reconstructed block

Complexity of depth intra modes at 64×64 block level (1/2)

Number of operations

	DMM 1		DMM 4		Angular mode		
PU size	Add/Sub	LUT access	Add/Sub/Comp	LUT access	Mul	Add/Sub	LUT access
4×4	8,960	26,368	17,152	29,440	16,384	31,488	8,192
8×8	8,384	25,024	16,576	28,864	16,384	29,888	8,192
16×16	8,240	24,688	16,432	28,720	16,384	29,232	8,192
32×32	8,204	24,604	16,396	28,684	16,384	28,684	8,192
64×64	8,204	24,604	16,396	28,684	16,384	28,675	8,192

- Comparing DMM 1 and DMM 4:
 - DMM 4 requires more add/sub/comp to compute contour pattern.
 - Number of LUT access is comparable since the number of LUT access in DMM 4 is the worst case scenario.
- Comparing angular mode to DMM, including DMM 1 and DMM 4
 - Since angular mode needs compute each prediction samples with weighing sum process and hence it requires more add/sub and even mul. is necessary to complete its procedure.
 - From the perspective of LUT access, in DMM, there are two kinds of LUT access, one is 1-bit pattern reading and the other one is 8-bit depth value to index conversion and versa. However, LUT access in angular is always 8-bit depth value to index conversion and versa. Therefore, when considering all the operations as a whole, angular mode is still more complex than DMM 1 and DMM 4 due to involving lots of multiplications.

Complexity of depth intra modes at 64×64 block level (2/2)

Data storage requirement (bits)

PU size	DMM 1	DMM 4	Angular mode
4×4	256	384	272
8×8	688	1,200	784
16×16	2,416	4,464	2,576
32×32	9,328	17,520	9,232
64×64	32,072	59,840	34,344

Data transfer rate (bits/64×64 block)

PU size	DMM 1	DMM 4	Angular mode
4×4	64,256	90,112	67,584
8×8	43,712	71,680	49,664
16×16	38,576	67,072	41,088
32×32	37,292	65,920	36,896
64×64	37,069	65,728	34,848

- DMM 4 requires an entire co-located Luma samples to compute contour pattern and hence, it requires largest storage requirement. In addition, the data transfer rate of DMM 4 will also be increased to the largest one.
- Storage size of DMM 1 and angular mode are comparable since DMM 1 must store wedgelet pattern and angular needs more reference samples.

Current DMM only support 32×32 block; hence, the storage should be considered at 32×32 block only.

Data storage requirement for wedgelet patterns of DMM 1

- The wedgelet pattern size of 64×64 block is increased to 14 times as compared to size required by 32×32 block. In addition, the wedgelet pattern size goes to a comparable level to one 1920×1088 pictures.

PU size	Number of possible wedgelet pattern	Number of bits for one wedgelet pattern	Total bits	Accumulated bits	% w.r.t 32×32 block	% w.r.t. one 1920×1088 picture
4×4	86	16	1,376	1,376	17%	0.01%
8×8	766	64	46,024	50,400	615%	0.20%
16×16	1,350	256	345,600	396,000	4,834%	1.58%
32×32 (worst case)	1,503	1,024	1,539,072	1,935,072	236,21%	7.72%
64×64^b	6,079	4,096	24,899,584	26,834,656	327,571%	107.05%

The result of 64×64 block is derived the equation in spec text by setting the variable, block size, as 64

One 32×32 block = $32 \times 32 \times 8$ bits

One 1920×1088 picture = $1920 \times 1088 \times 1.5 \times 8$ bits

The column of accumulated bits denotes that the accumulated bits from the block size less than current row

Input data transfer rate: DIM vs. MC (1/3)

- Transferred bits for M N×N bi-prediction motion compensation (MC)
 - Input (reference pixels):
 $M \times 2 \times (N+7) \times (N+7) \times 8 + 2 \times M \times 2 \times (N/2+3) \times (N/2+3) \times 8$ bits
 - Two cases are considered: (I) M=4, N=32; (II) M=64, N=8

Data transfer rate comparison at 64×64 block level

	Amount of data transfer (Input)	Ratio to 4 32×32 MC (Input)	Ratio to 64 8×8 MC (Input)
DMM 1	31,488	21.93%	9.52%
DMM 4	57,344	39.95%	17.34%
Angular mode	34,816	24.25%	10.53%
4 32×32 bi-prediction MC	143,552	100%	43.40%
64 8×8 bi-prediction MC	330,752	N/A	100%

Output data transfer rate: DIM vs. MC (2/3)

- Transferred bits for M N×N bi-prediction motion compensation (MC)
 - Output (reconstructed block):
 $M \times N \times N \times 1.5 \times 8$ bits
 - Two cases are considered: (I) M=4, N=32; (II) M=64, N=8

Data transfer rate comparison at 64×64 block level

	Amount of data transfer (Output)	Ratio to 4 32×32 MC (Output)	Ratio to 64 8×8 MC (Output)
DMM 1	32,768	66.67%	66.67%
DMM 4	32,768	66.67%	66.67%
Angular mode	32,768	66.67%	66.67%
4 32×32 bi-prediction MC	49,152	100%	100%
64 8×8 bi-prediction MC	49,152	N/A	100%

Total data transfer rate: DIM vs. MC (3/3)

- Transferred bits for M N×N bi-prediction motion compensation (MC)
 - Input (reference pixels):
 $M \times 2 \times (N+7) \times (N+7) \times 8 + 2 \times M \times 2 \times (N/2+3) \times (N/2+3) \times 8$ bits
 - Output (reconstructed block):
 $M \times N \times N \times 1.5 \times 8$ bits
 - Two cases are considered: (I) M=4, N=32; (II) M=64, N=8

Data transfer rate comparison at 64×64 block level

	Amount of data transfer (Input+Output)	Ratio to 4 32×32 MC (Input+Output)	Ratio to 64 8×8 MC (Input+Output)
DMM 1	64,256	33.34%	16.91%
DMM 4	90,112	46.76%	23.72%
Angular mode	67,584	35.07%	17.79%
4 32×32 bi-prediction MC	192,704	100.00%	50.72%
64 8×8 bi-prediction MC	379,904	N/A	100.00%

Coding performance (1/6)

- All intra configuration: coding results when **DMM 1 and DMM 4 are disable**. (Anchor: HTM-10.0r1)
- Encoding time is dropped significantly since DMM 1 is disable. However, the coding results on synthesis view is also dropped significantly since DMM could present the edge in depth map well.

	video 0	video 1	video 2	video PSNR / video bitrate	video PSNR / total bitrate	synth PSNR / total bitrate	enc time	dec time	ren time
Balloons	0.0%	0.0%	0.0%	0.00%	-0.21%	4.27%	58.2%	101.6%	100.7%
Kendo	0.0%	0.0%	0.0%	0.00%	-0.23%	4.52%	58.9%	101.9%	100.8%
Newspaper_CC	0.0%	0.0%	0.0%	0.00%	-0.67%	7.77%	56.4%	101.6%	100.8%
GT_Fly	0.0%	0.0%	0.0%	0.00%	-0.30%	4.68%	56.7%	100.4%	81.7%
Poznan_Hall2	0.0%	0.0%	0.0%	0.00%	-0.27%	6.12%	55.4%	100.6%	100.2%
Poznan_Street	0.0%	0.0%	0.0%	0.00%	-0.37%	2.24%	56.2%	100.4%	72.8%
Undo_Dancer	0.0%	0.0%	0.0%	0.00%	0.05%	8.39%	56.3%	100.6%	94.4%
Shark	0.0%	0.0%	0.0%	0.00%	0.19%	7.85%	59.9%	100.4%	78.8%
1024x768	0.0%	0.0%	0.0%	0.00%	-0.37%	5.52%	57.8%	101.7%	100.7%
1920x1088	0.0%	0.0%	0.0%	0.00%	-0.14%	5.86%	56.9%	100.5%	85.6%
average	0.0%	0.0%	0.0%	0.00%	-0.23%	5.73%	57.3%	100.9%	91.3%

Coding performance (2/6)

- CTC configuration: coding results when **DMM 1 and DMM 4 are disable**. (Anchor: HTM-10.0r1)
- Encoding time is reduced since DMM 1 is disable. However, the coding results on synthesis view is also dropped since DMM could present the edge in depth map well.

	video 0	video 1	video 2	video PSNR / video bitrate	video PSNR / total bitrate	synth PSNR / total bitrate	enc time	dec time	ren time
Balloons	0.0%	0.2%	0.1%	0.07%	-0.18%	1.55%	95.4%	100.1%	109.1%
Kendo	0.0%	0.1%	-0.2%	-0.01%	-0.09%	1.35%	96.2%	100.0%	118.5%
Newspaper_CC	0.0%	0.1%	0.0%	0.00%	-0.72%	4.32%	93.7%	100.3%	112.8%
GT_Fly	0.0%	1.0%	0.6%	0.16%	-0.34%	0.81%	94.0%	100.1%	100.2%
Poznan_Hall2	0.0%	0.4%	0.0%	0.10%	-0.26%	2.07%	93.4%	100.0%	100.0%
Poznan_Street	0.0%	0.1%	0.3%	0.05%	-0.33%	1.26%	93.6%	100.1%	100.1%
Undo_Dancer	0.0%	1.0%	0.9%	0.26%	0.41%	3.95%	95.0%	100.2%	100.0%
Shark	0.0%	1.4%	1.3%	0.26%	0.29%	3.84%	94.7%	100.1%	99.8%
1024x768	0.0%	0.1%	0.0%	0.02%	-0.33%	2.40%	95.1%	100.1%	113.5%
1920x1088	0.0%	0.8%	0.6%	0.17%	-0.04%	2.39%	94.1%	100.1%	100.0%
average	0.0%	0.5%	0.4%	0.11%	-0.15%	2.39%	94.5%	100.1%	105.1%

Coding performance (3/6)

- All intra configuration: coding results when **DMM 1 is disable**. (Anchor: HTM-10.0r1)
- Encoding time is dropped significantly since DMM 1 is disable. However, the coding results on synthesis view is also dropped significantly since DMM 1 could present the edge in depth map well.

	video 0	video 1	video 2	video PSNR / video bitrate	video PSNR / total bitrate	synth PSNR / total bitrate	enc time	dec time	ren time
Balloons	0.0%	0.0%	0.0%	0.00%	-0.13%	3.52%	67.5%	101.3%	100.5%
Kendo	0.0%	0.0%	0.0%	0.00%	-0.18%	3.69%	68.2%	101.3%	100.7%
Newspaper_CC	0.0%	0.0%	0.0%	0.00%	-0.44%	5.91%	67.2%	101.5%	100.4%
GT_Fly	0.0%	0.0%	0.0%	0.00%	-0.29%	2.27%	65.9%	100.0%	81.4%
Poznan_Hall2	0.0%	0.0%	0.0%	0.00%	-0.17%	4.76%	64.1%	100.5%	100.2%
Poznan_Street	0.0%	0.0%	0.0%	0.00%	-0.24%	1.62%	65.3%	100.1%	73.3%
Undo_Dancer	0.0%	0.0%	0.0%	0.00%	0.02%	3.61%	65.9%	100.2%	94.4%
Shark	0.0%	0.0%	0.0%	0.00%	-0.21%	3.75%	69.0%	100.1%	78.6%
1024x768	0.0%	0.0%	0.0%	0.00%	-0.25%	4.37%	67.6%	101.4%	100.5%
1920x1088	0.0%	0.0%	0.0%	0.00%	-0.18%	3.20%	66.0%	100.2%	85.6%
average	0.0%	0.0%	0.0%	0.00%	-0.21%	3.64%	66.6%	100.6%	91.2%

Coding performance (4/6)

- CTC configuration: coding results when **DMM 1 is disable**. (Anchor: HTM-10.0r1)
- Encoding time is dropped but not significant since not all block perform DMM 1. However, the coding results on synthesis view is also dropped significantly since DMM 1 could present the edge in depth map well.

	video 0	video 1	video 2	video PSNR / video bitrate	video PSNR / total bitrate	synth PSNR / total bitrate	enc time	dec time	ren time
Balloons	0.0%	0.4%	0.1%	0.08%	-0.10%	1.39%	96.6%	99.7%	103.9%
Kendo	0.0%	0.1%	0.0%	0.00%	-0.11%	1.13%	97.2%	100.1%	114.4%
Newspaper_CC	0.0%	-0.1%	-0.1%	-0.02%	-0.55%	3.28%	95.3%	100.5%	110.8%
GT_Fly	0.0%	0.5%	0.3%	0.09%	-0.11%	0.81%	95.3%	99.8%	100.1%
Poznan_Hall2	0.0%	-0.1%	-0.3%	-0.05%	-0.30%	1.52%	94.7%	100.5%	99.9%
Poznan_Street	0.0%	0.2%	0.2%	0.06%	-0.24%	0.99%	95.2%	100.0%	100.0%
Undo_Dancer	0.0%	0.7%	0.6%	0.17%	0.25%	1.76%	96.0%	100.4%	99.9%
Shark	0.0%	0.8%	0.9%	0.17%	0.07%	1.84%	95.8%	100.2%	99.7%
1024x768	0.0%	0.1%	0.0%	0.02%	-0.25%	1.94%	96.4%	100.1%	109.7%
1920x1088	0.0%	0.4%	0.4%	0.09%	-0.07%	1.39%	95.4%	100.2%	99.9%
average	0.0%	0.3%	0.2%	0.06%	-0.14%	1.59%	95.8%	100.1%	103.6%

Coding performance (5/6)

- All intra configuration: coding results when **DMM 4 is disable**. (Anchor: HTM-10.0r1)
- Encoding time is dropped but not significant since the contour pattern of DMM 4 is fixed when its co-located Luma samples is determined. However, the coding results did not dropped a lot since some cases of DMM 4 can be covered by DMM 1.

	video 0	video 1	video 2	video PSNR / video bitrate	video PSNR / total bitrate	synth PSNR / total bitrate	enc time	dec time	ren time
Balloons	0.0%	0.0%	0.0%	0.00%	0.00%	0.08%	90.9%	100.2%	100.3%
Kendo	0.0%	0.0%	0.0%	0.00%	0.00%	0.07%	90.9%	100.2%	100.4%
Newspaper_CC	0.0%	0.0%	0.0%	0.00%	0.00%	0.12%	89.6%	100.1%	100.2%
GT_Fly	0.0%	0.0%	0.0%	0.00%	0.22%	0.49%	90.1%	100.2%	79.2%
Poznan_Hall2	0.0%	0.0%	0.0%	0.00%	-0.01%	0.06%	91.2%	100.6%	99.8%
Poznan_Street	0.0%	0.0%	0.0%	0.00%	0.00%	0.04%	88.4%	100.2%	70.6%
Undo_Dancer	0.0%	0.0%	0.0%	0.00%	0.08%	0.18%	90.9%	100.2%	98.8%
Shark	0.0%	0.0%	0.0%	0.00%	0.43%	0.54%	92.3%	100.0%	81.6%
1024x768	0.0%	0.0%	0.0%	0.00%	0.00%	0.09%	90.5%	100.2%	100.3%
1920x1088	0.0%	0.0%	0.0%	0.00%	0.14%	0.26%	90.6%	100.3%	86.0%
average	0.0%	0.0%	0.0%	0.00%	0.09%	0.20%	90.5%	100.2%	91.4%

Coding performance (6/6)

- CTC configuration: coding results when **DMM 4 is disable**. (Anchor: HTM-10.0r1)
- Encoding time and coding results are comparable to anchor since the contour pattern of DMM 4 is fixed when its co-located Luma samples is determined some cases of DMM 4 can be covered by DMM 1 or other modes..

	video 0	video 1	video 2	video PSNR / video bitrate	video PSNR / total bitrate	synth PSNR / total bitrate	enc time	dec time	ren time
Balloons	0.0%	0.2%	0.0%	0.05%	0.01%	-0.01%	98.5%	98.0%	100.1%
Kendo	0.0%	0.1%	0.0%	0.00%	0.00%	0.03%	99.4%	98.0%	113.0%
Newspaper_CC	0.0%	0.0%	-0.1%	0.00%	-0.02%	0.04%	98.1%	97.8%	110.8%
GT_Fly	0.0%	0.0%	0.0%	-0.02%	-0.06%	-0.28%	98.5%	98.1%	100.2%
Poznan_Hall2	0.0%	0.1%	-0.4%	-0.04%	-0.05%	-0.15%	98.4%	98.6%	100.1%
Poznan_Street	0.0%	0.0%	0.0%	0.00%	-0.01%	0.02%	98.1%	98.1%	100.1%
Undo_Dancer	0.0%	0.1%	0.1%	0.02%	0.06%	0.06%	98.4%	97.4%	99.8%
Shark	0.0%	-0.1%	-0.1%	-0.01%	0.13%	0.25%	98.6%	97.8%	99.7%
1024x768	0.0%	0.1%	0.0%	0.01%	-0.01%	0.02%	98.7%	97.9%	108.0%
1920x1088	0.0%	0.0%	-0.1%	-0.01%	0.01%	-0.02%	98.4%	98.0%	100.0%
average	0.0%	0.0%	-0.1%	0.00%	0.01%	0.00%	98.5%	98.0%	103.0%

Conclusion

- A comprehensive complexity assessment on depth intra modes is presented.
 - Number of operations
 - Data storage requirement
 - Data transfer rate
- With the analysis of complexity, we can reassure the maximum block size of DMM 1 should be 32×32 instead of 64×64 since storage requirement is 14 times larger.
- Complexity of DMM 1 and DMM 4 are comparable to angular intra modes from the viewpoint of 64×64 block level.
- Coding gain on synthesis view from DMM 1 and DMM 4 are significant and these tools are worth such complexity.