Point Cloud Attribute Compression Using Region Adaptive Hierarchical Transform

Internship Report

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Education

PhD, Electrical Engineering
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MS, Electrical Engineering
University of Alabama, Huntsville
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B.Tech, Electronics and Communication Engineering
Visvesvaraya Technological University, India
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Outline

- Introduction
- Variants of RAHT
- Dyadic RAHT early termination
    - Fixed per Node
    - Fixed per Level
    - Adaptive: Based on geometry
    - Adaptive: Based on geometry and attribute
        - (a) Naïve approach
        - (b) 3D edge detection
- Point cloud compression using DNN
- Conclusion

Introduction

- What is a Point cloud?

  -Geometry -> 3D coordinates

  - Attributes -> color information or normal vectors

Point Cloud	
Geometry	Attribute

- Applications: Cultural heritage, Autonomous driving, Robotics etc.
- Need of Point Cloud Compression.
- MPEG PCC standardization:

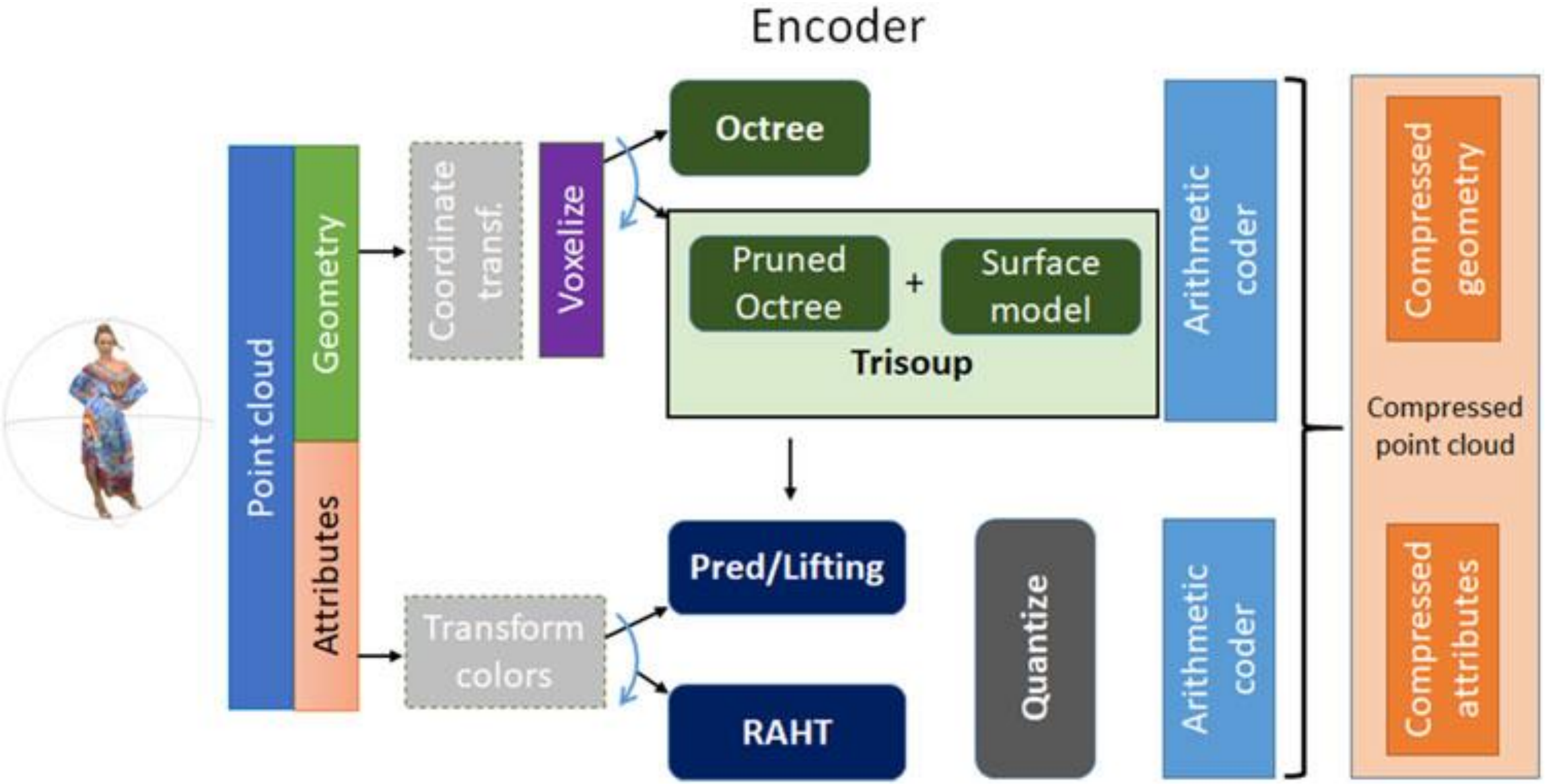
PCC

V-PCC G-PCC

Introduction

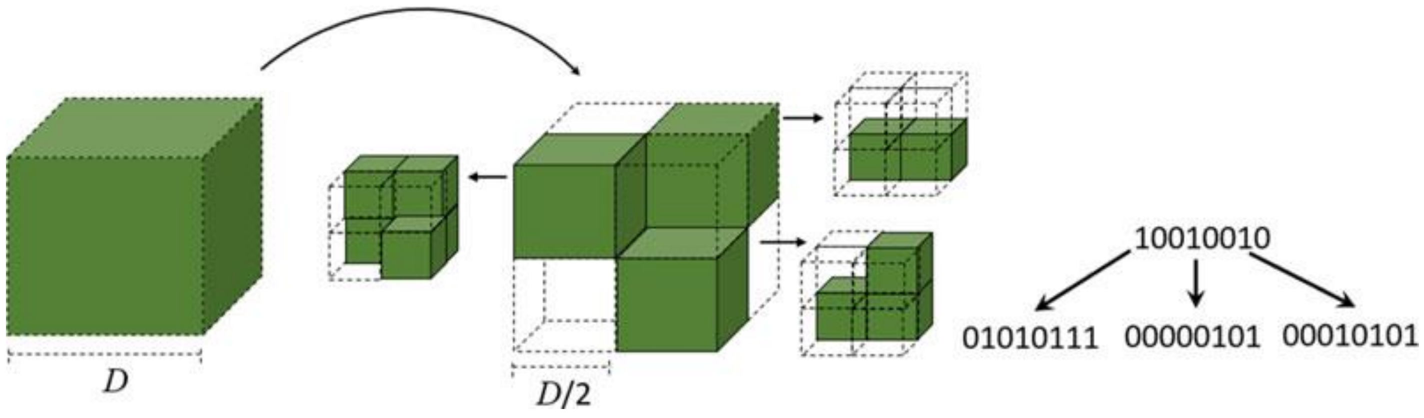
- Geometry-based PCC (GPCC)
- Common test conditions:
  - C1 (Lossless geometry, Lossy attribute)
  - C2 (Lossy geometry, Lossy attribute)
  - CW (Lossless geometry, Lossless attribute)
  - CY (Lossless geometry, Near-lossless attribute)
- Test sequences:
  - Category 1: Static objects and scenes
  - Category 2: Dynamic objects
  - Category 3: Dynamic acquisition

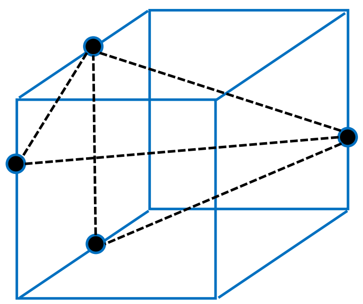
G-PCC Encoding Architecture

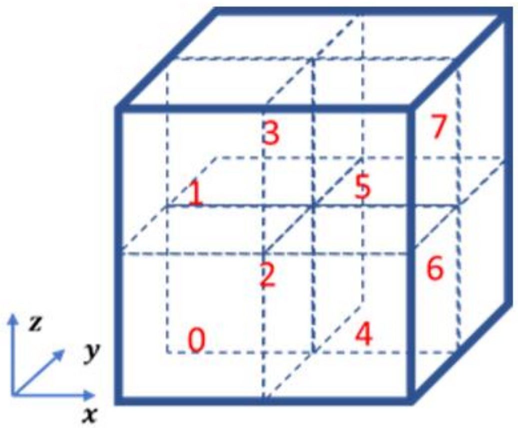


Geometry Encoding

- Coordinate transform
- Voxelization:
  - Quantization
  - Duplicate point removal
  - Assigning attribute values
- Octree
- Trisoup:
  - Pruning
  - Surface approximation

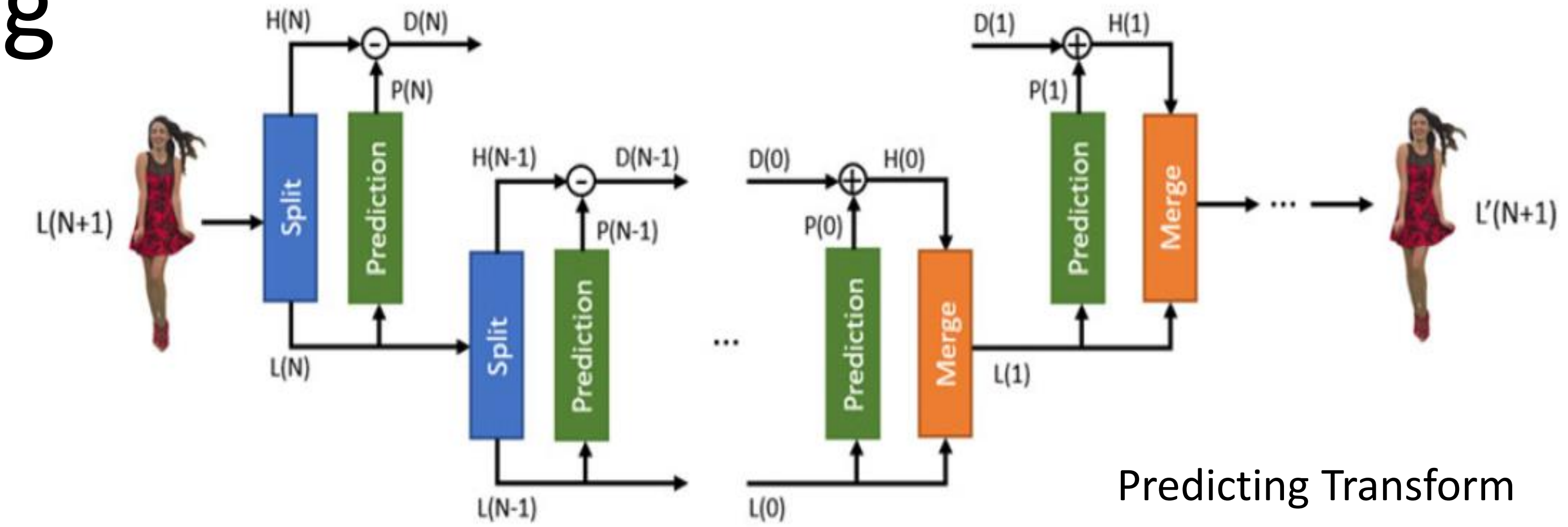




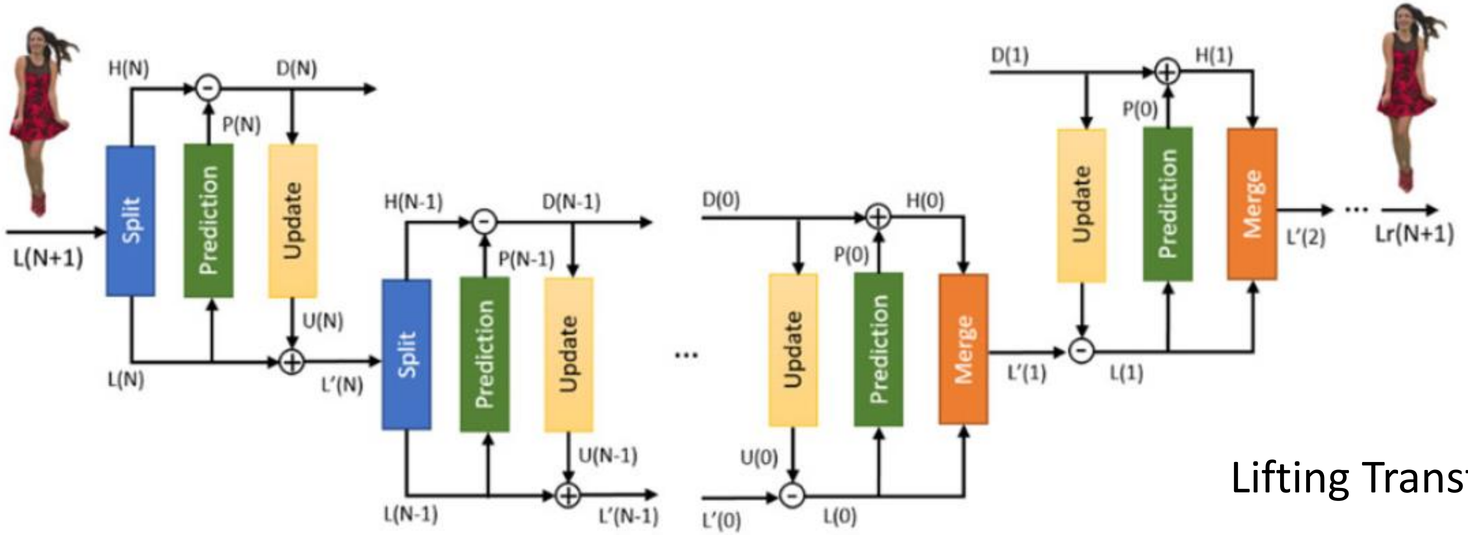


Attribute Encoding

- Color transform
- Attribute coding:
  - Predicting Transform
  - Lifting Transform
  - RAHT

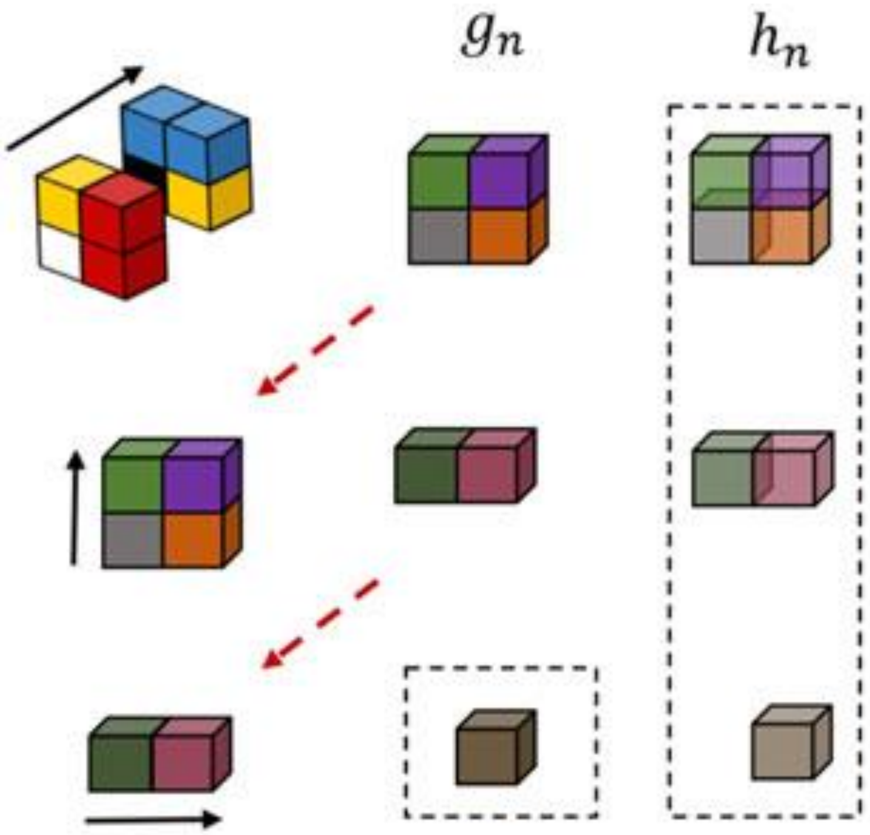


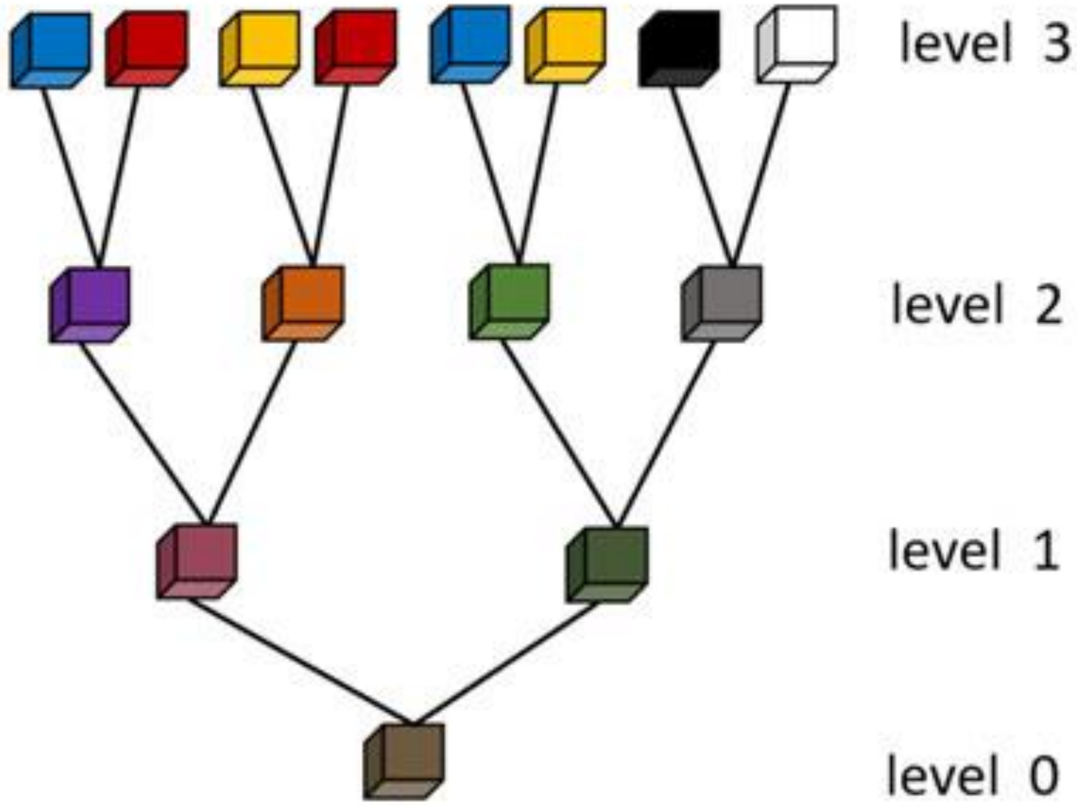
Predicting Transform



Lifting Transform

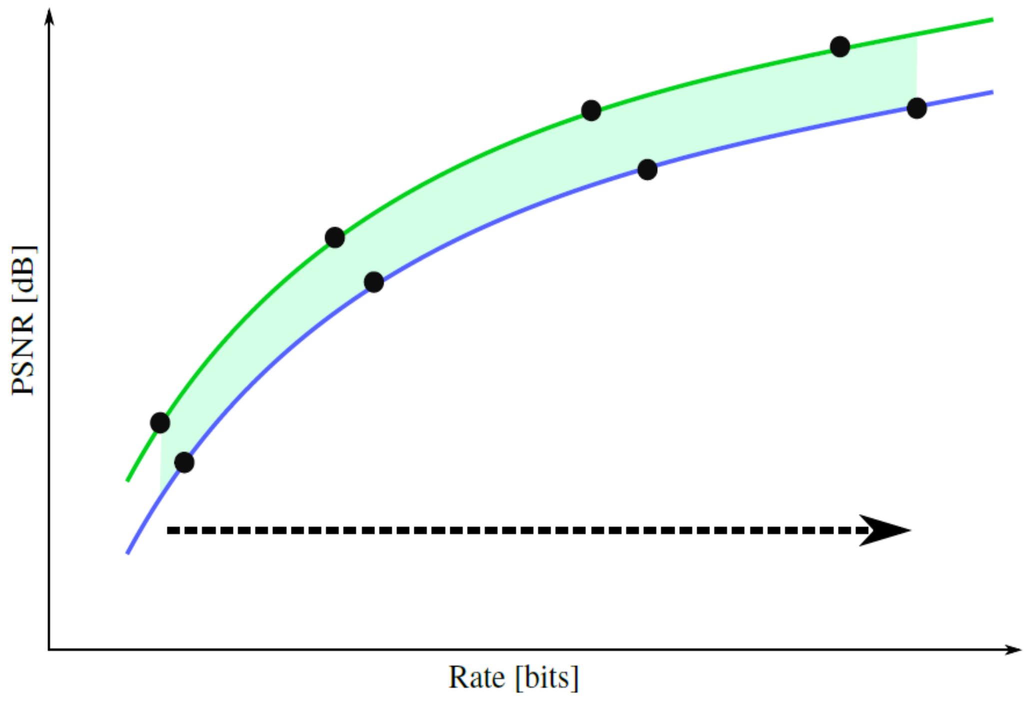
Attribute Encoding: RAHT



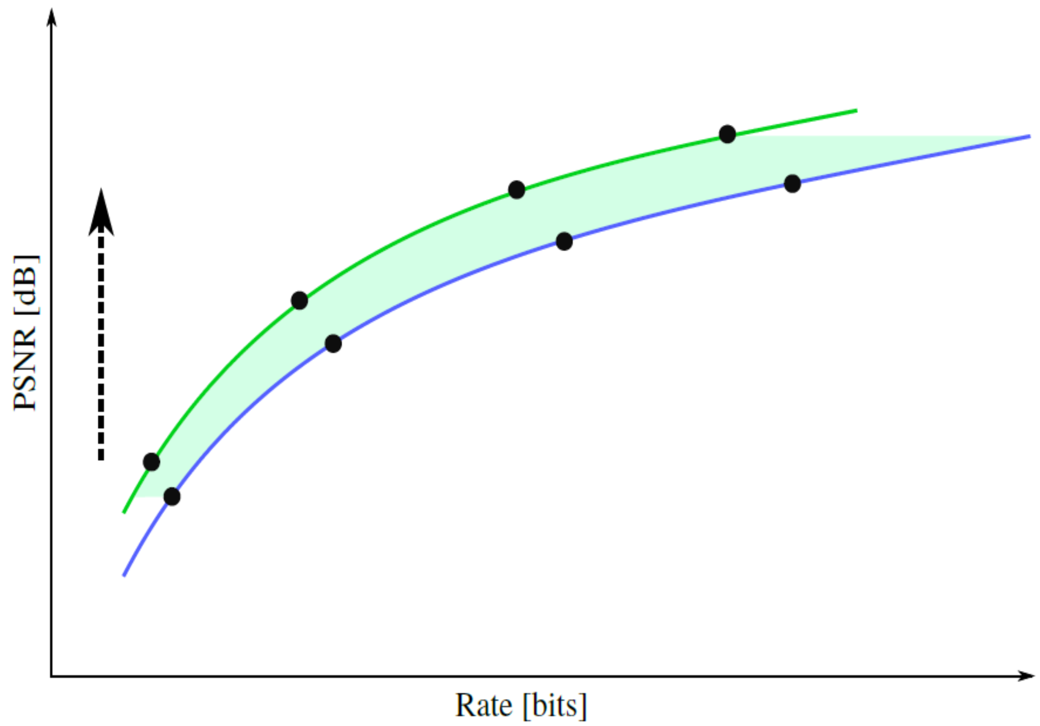


Performance Metrics

$$PSNR = A_0 + A_1\, log(rate) + A_2\, log(rate)^2 + A_3\, log(rate)^3 \text{ or}$$
$$log(rate) = B_0 + B_1\, PSNR + B_2\, PSNR^2 + B_3\, PSNR^3,$$



BD-PSNR



BD-Rate

$$PSNR = 10\, log_{10}\left(\frac{A_{max}^2}{MSE}\right)$$

Variants of RAHT

- Lifting Style
- Butterfly Style
- Predictive RAHT
- Dyadic RAHT

Variants of RAHT : 2D example

$$\mathbf{x} = (x_0, x_1, \ldots, x_{N-1}) \rightarrow \begin{cases} \mathbf{h} = (h_0, h_1, \ldots, h_{N/2-1}) \\ \mathbf{g} = (g_0, g_1, \ldots, g_{N/2-1}) \end{cases}$$

$w^4_{0,3} = 0$	$F^4_{1,3} = 10.00$ $w^4_{1,3} = 1$	$F^4_{2,3} = 9.00$ $w^4_{2,3} = 1$	$F^4_{3,3} = 7.00$ $w^4_{3,3} = 1$
$F^4_{0,2} = 12.00$ $w^4_{0,2} = 1$	$F^4_{1,2} = 14.00$ $w^4_{1,2} = 1$	$w^4_{2,2} = 0$	$w^4_{3,2} = 0$
$F^4_{0,1} = 10.00$ $w^4_{0,1} = 1$	$F^4_{1,1} = 11.00$ $w^4_{1,1} = 1$	$w^4_{2,1} = 0$	$F^4_{3,1} = 4.00$ $w^4_{3,1} = 1$
$F^4_{0,0} = 8.00$ $w^4_{0,0} = 1$	$w^4_{1,0} = 0$	$w^4_{2,0} = 0$	$w^4_{3,0} = 0$

→

low-pass

$F^3_{0,3} = 10.00$ $w^3_{0,3} = 1$	$F^3_{1,3} = 11.31$ $w^3_{1,3} = 2$
$F^3_{0,2} = 18.38$ $w^3_{0,2} = 2$	$w^3_{1,2} = 0$
$F^3_{0,1} = 14.85$ $w^3_{0,1} = 2$	$F^3_{1,1} = 4.00$ $w^3_{1,1} = 1$
$F^3_{0,0} = 8.00$ $w^3_{0,0} = 1$	$w^3_{1,0} = 0$

high-pass

	$G^3_{1,3} = -1.41$
$G^3_{0,2} = 1.41$	
$G^3_{0,1} = 0.71$	

↓

low-pass

$F^2_{0,1} = 20.78$ $w^2_{0,1} = 3$	$F^2_{1,1} = 11.31$ $w^2_{1,1} = 2$
$F^2_{0,0} = 16.74$ $w^2_{0,0} = 3$	$F^2_{1,0} = 4.00$ $w^2_{1,0} = 1$

high-pass

$G^2_{0,1} = 2.45$	
$G^2_{0,0} = -2.04$	

←

low-pass

$F^1_{0,1} = 23.25$ $w^1_{0,1} = 5$
$F^1_{0,0} = 16.49$ $w^1_{0,0} = 4$

high-pass

$G^1_{0,1} = -4.38$
$G^1_{0,0} = -4.91$

←

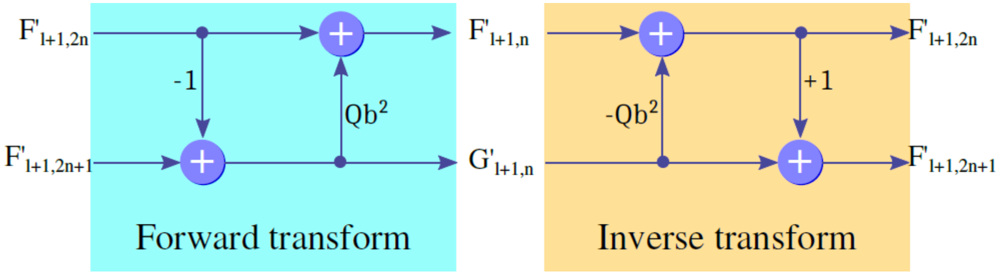
low-pass

$F^0_{0,0} = 28.32$ $w^0_{0,0} = 9$

high-pass

$G^0_{0,0} = -3.21$

Lifting Style



$$\begin{bmatrix} F^{\ell}_{i,j,k}{}' \\ G^{\ell}_{i,j,k}{}' \end{bmatrix} = \begin{bmatrix} a^2 & b^2 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} F^{\ell+1}_{2i,j,k}{}' \\ F^{\ell+1}_{2i+1,j,k}{}' \end{bmatrix} \qquad \begin{bmatrix} F^{\ell+1}_{2i,j,k}{}' \\ F^{\ell+1}_{2i+1,j,k}{}' \end{bmatrix} = \begin{bmatrix} 1 & -b^2 \\ 1 & a^2 \end{bmatrix} \begin{bmatrix} F^{\ell}_{i,j,k}{}' \\ G^{\ell}_{i,j,k}{}' \end{bmatrix}$$

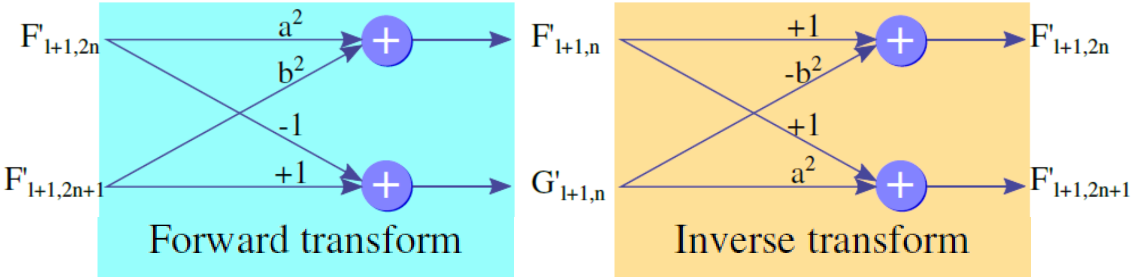
$$\downarrow \qquad\qquad\qquad \downarrow$$

$$\begin{bmatrix} 1-Qb^2 & Qb^2 \\ -1 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & -Qb^2 \\ 1 & 1-Qb^2 \end{bmatrix}$$

$we\ substitute\ Qb^2 = b^2\ and\ a^2 = 1 - b^2 = 1 - Qb^2$

- Used in Version 6
- Fixed point implementation
- Ascent approach: From leaves to root.

Butterfly Style

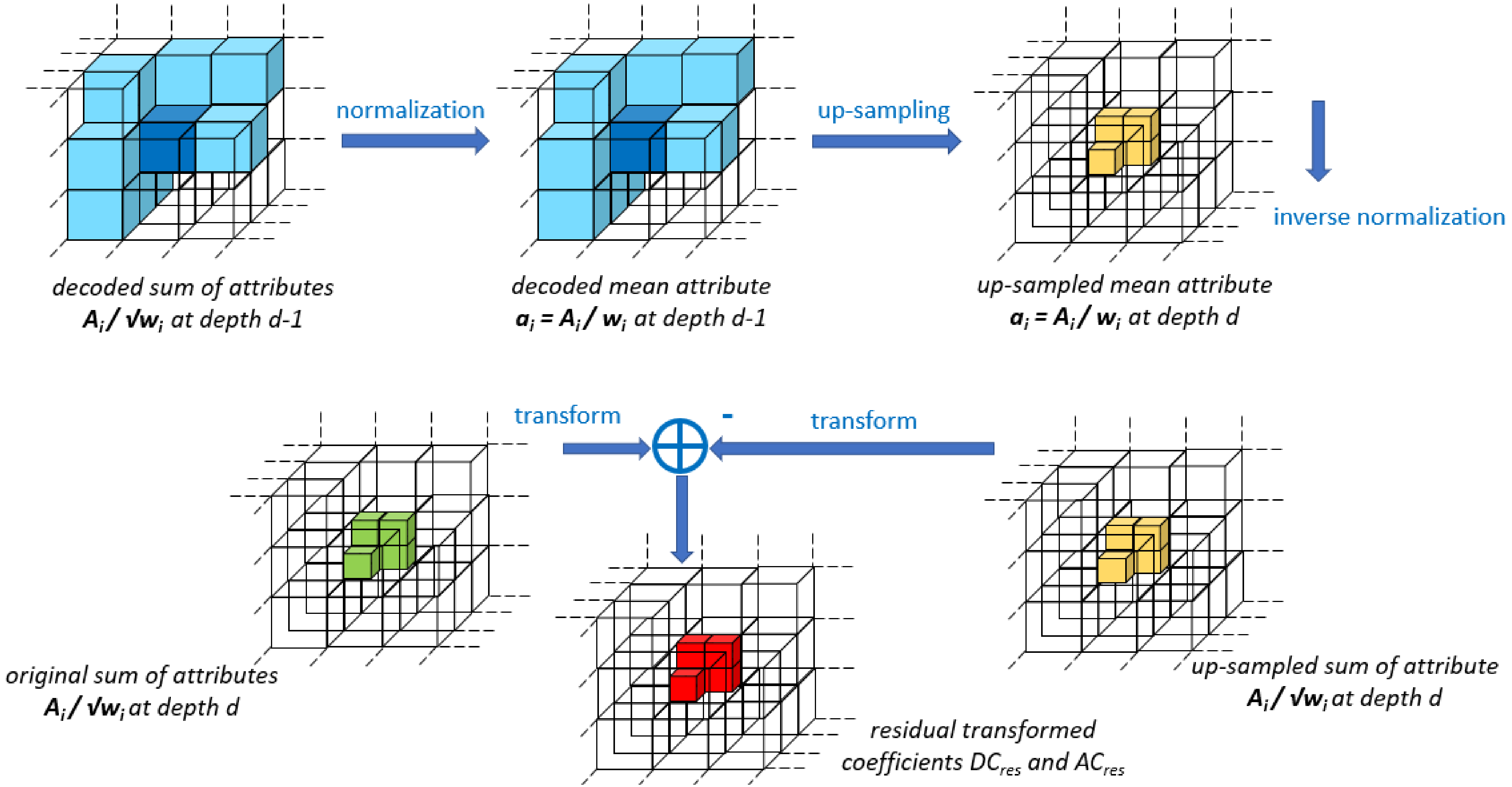


$$\begin{bmatrix} F^{\ell}_{i,j,k} \\ G^{\ell}_{i,j,k} \end{bmatrix} = \begin{bmatrix} a & b \\ -b & a \end{bmatrix} \begin{bmatrix} F^{\ell+1}_{2i,j,k} \\ F^{\ell+1}_{2i+1,j,k} \end{bmatrix} \qquad \begin{bmatrix} F^{\ell+1}_{2i,j,k} \\ F^{\ell+1}_{2i+1,j,k} \end{bmatrix} = \begin{bmatrix} a & -b \\ b & a \end{bmatrix} \begin{bmatrix} F^{\ell}_{i,j,k} \\ G^{\ell}_{i,j,k} \end{bmatrix}$$

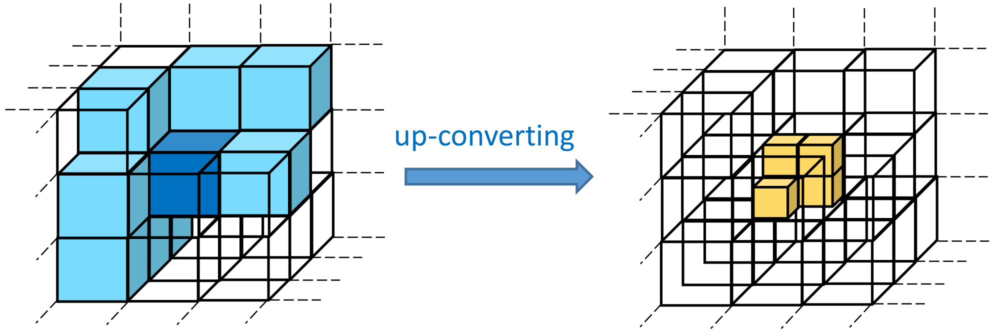
$$a^2 = \frac{w_{\ell+1,2n}}{w_{\ell+1,2n} + w_{\ell+1,2n+1}},\ b^2 = \frac{w_{\ell+1,2n}}{w_{\ell+1,2n+1} + w_{\ell+1,2n+1}}.$$ and $a^2 + b^2 = 1$

- Used in version 7 to current version
- Fixed point implementation
- Descent approach: From root to leaves.

Predictive RAHT

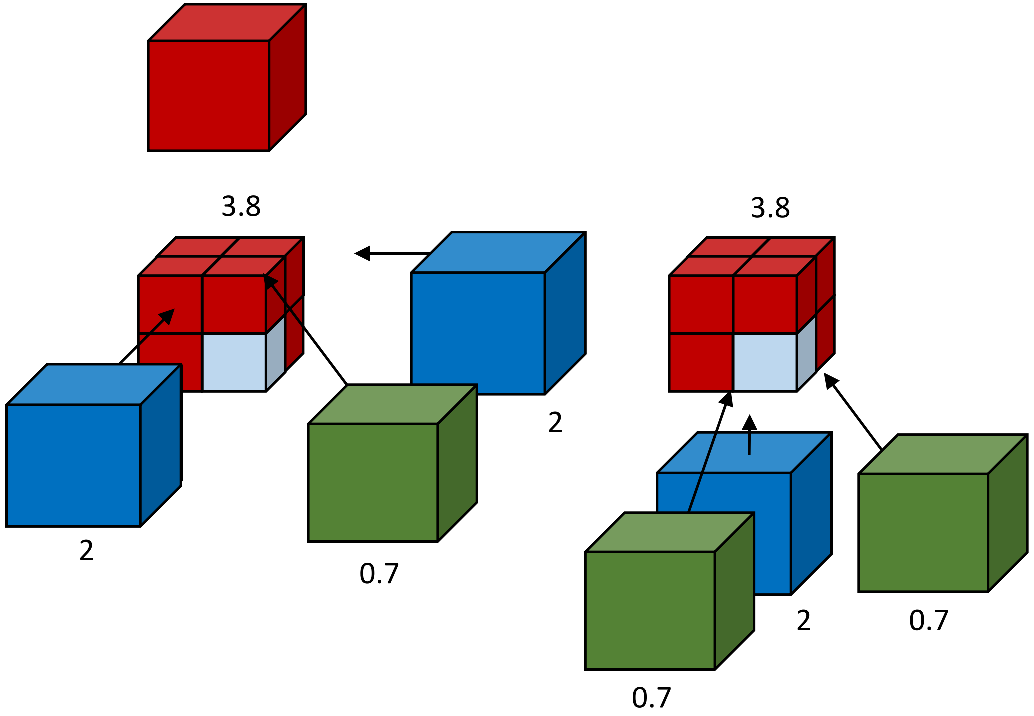


Predictive RAHT

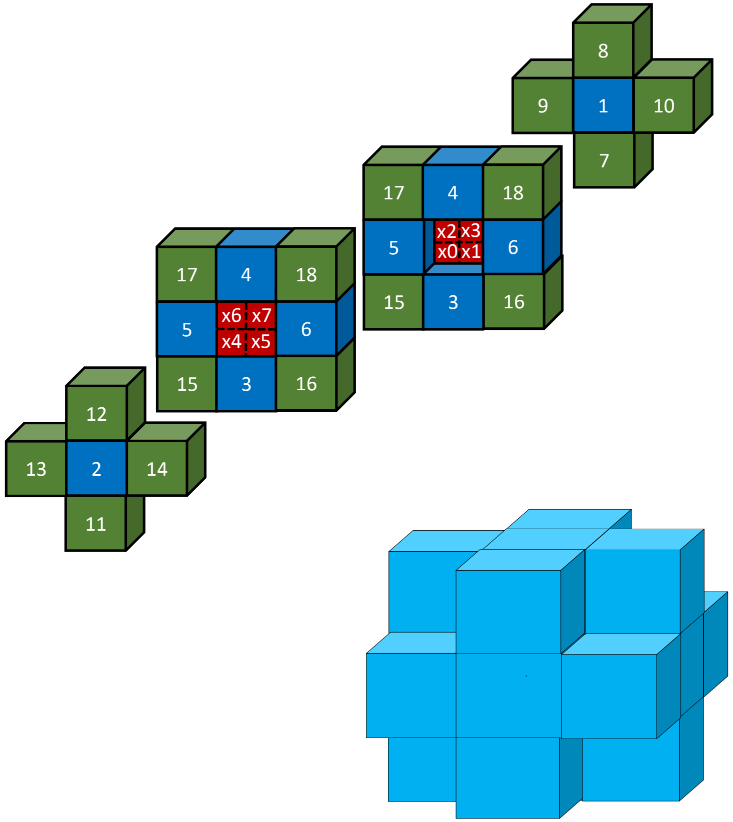


decoded mean attribute $\boldsymbol{a}_i = \boldsymbol{A}_i / \boldsymbol{w}_i$ *at depth d-1*

up-converted mean attribute $\boldsymbol{a}_i = \boldsymbol{A}_i / \boldsymbol{w}_i$ *at depth d*



Predictive RAHT

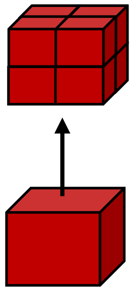


neighbourIdx		predMasks xi: 7 6 5 4 3 2 1 0
0	255	'1 1 1 1 1 1 1 1'
1	15	'0 0 0 0 1 1 1 1'
2	240	'1 1 1 1 0 0 0 0'
3	51	'0 0 1 1 0 0 1 1'
4	204	'1 1 0 0 1 1 0 0'
5	85	'0 1 0 1 0 1 0 1'
6	170	'1 0 1 0 1 0 1 0'
7	3	'0 0 0 0 0 0 1 1'
8	12	'0 0 0 0 1 1 0 0'
9	5	'0 0 0 0 0 1 0 1'
10	10	'0 0 0 0 1 0 1 0'
11	48	'0 0 1 1 0 0 0 0'
12	192	'1 1 0 0 0 0 0 0'
13	80	‘0 1 0 1 0 0 0 0'
14	160	'1 0 1 0 0 0 0 0'
15	17	'0 0 0 1 0 0 0 1'
16	34	'0 0 1 0 0 0 1 0'
17	68	'0 1 0 0 0 1 0 0'
18	136	'1 0 0 0 1 0 0 0'

predWeights

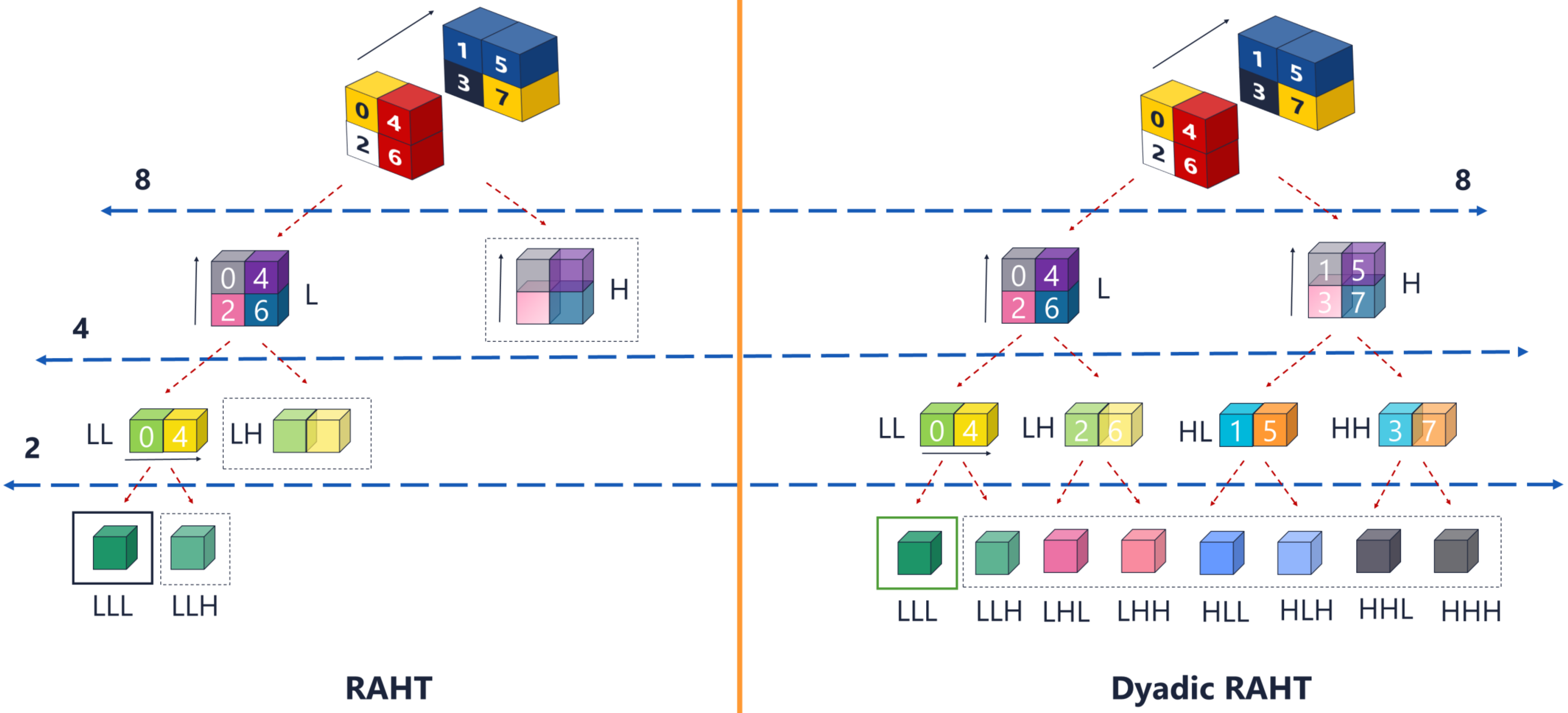
	3.8	2			0.7		
x0:	0	1	3	5	7	9	15
x1:	0	1	3	6	7	10	16
x2:	0	1	4	5	8	9	17
x3:	0	1	4	6	8	10	18
x4:	0	2	3	5	11	13	15
x5:	0	2	3	6	11	14	16
x6:	0	2	4	5	12	13	17
x7:	0	2	4	6	12	14	18

3.8
xi: 0



x0, x1, x4, x5

Dyadic RAHT


0
4
2
6
1
5
3
7
8
8
L
H
4
LL
LH
HL
HH
2
LLL
LLH
LHL
LHH
HLL
HLH
HHL
HHH
RAHT
Dyadic RAHT

Results: Dyadic RAHT

Reference:	tmc3v9.0=anchor_octree_raht_dl580
Tested:	tmc3v9.0-13-g6f56454=release-v9.0_octree_raht_raht_dyadic_dl580

All Intra

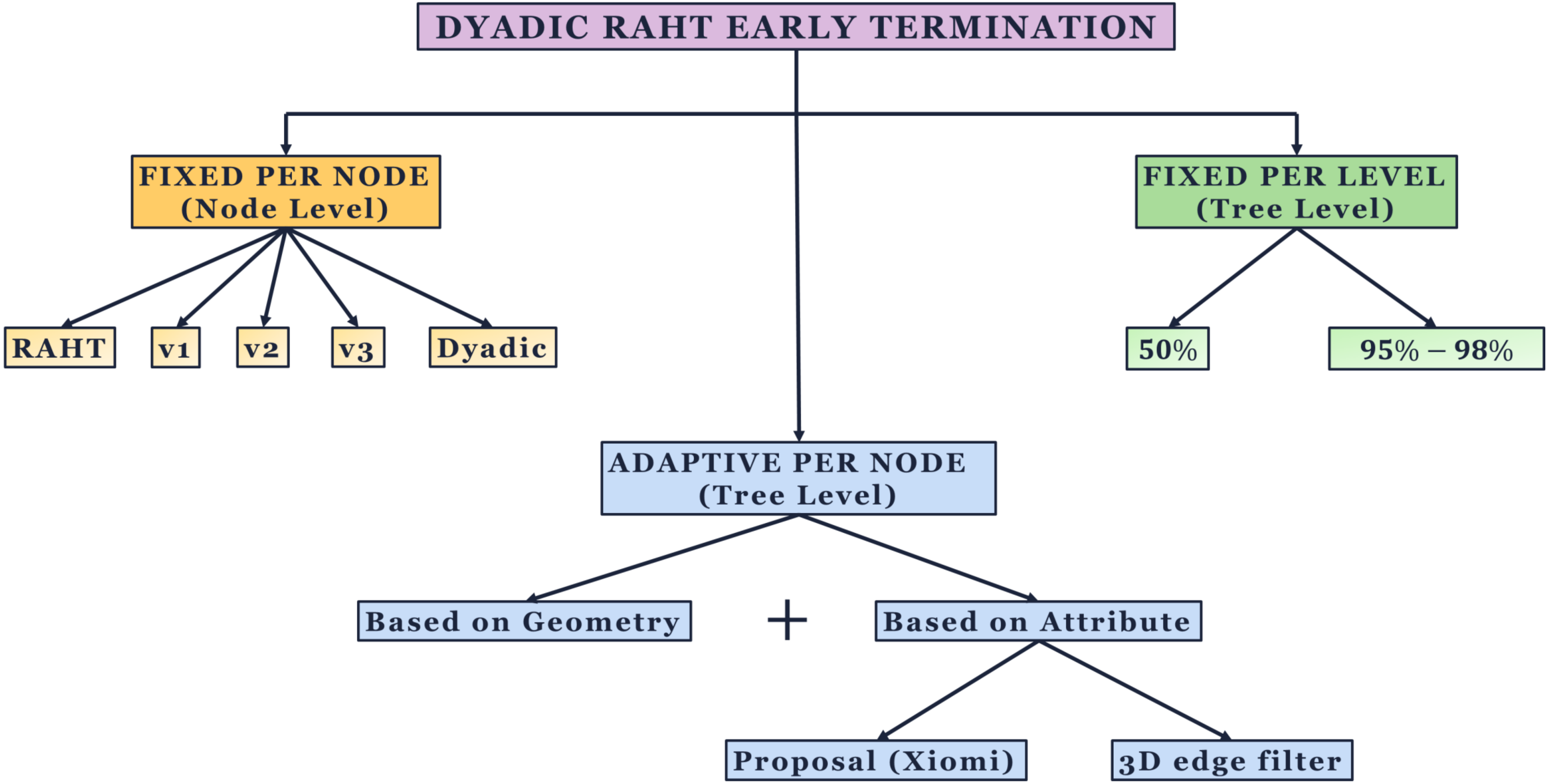
C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%]			
	Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-1.2%	-0.8%	-0.9%	
Cat1-B average	-1.1%	-1.6%	-1.8%	
Cat3-fused average	-0.2%	0.7%	0.7%	-1.0%
Cat3-frame average				-0.8%
Overall average	-1.1%	-1.1%	-1.2%	-0.9%
Avg. Enc Time [%]	104%			
Avg. Dec Time [%]	104%			

C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%]			
	Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-2.4%	-2.2%	-2.2%	
Cat1-B average	-1.6%	-2.3%	-2.7%	
Cat3-fused average	-1.2%	0.5%	0.4%	-1.9%
Cat3-frame average				-0.9%
Overall average	-2.0%	-2.1%	-2.3%	-1.2%
Avg. Enc Time [%]	96%			
Avg. Dec Time [%]	100%			

Dyadic RAHT Early Termination

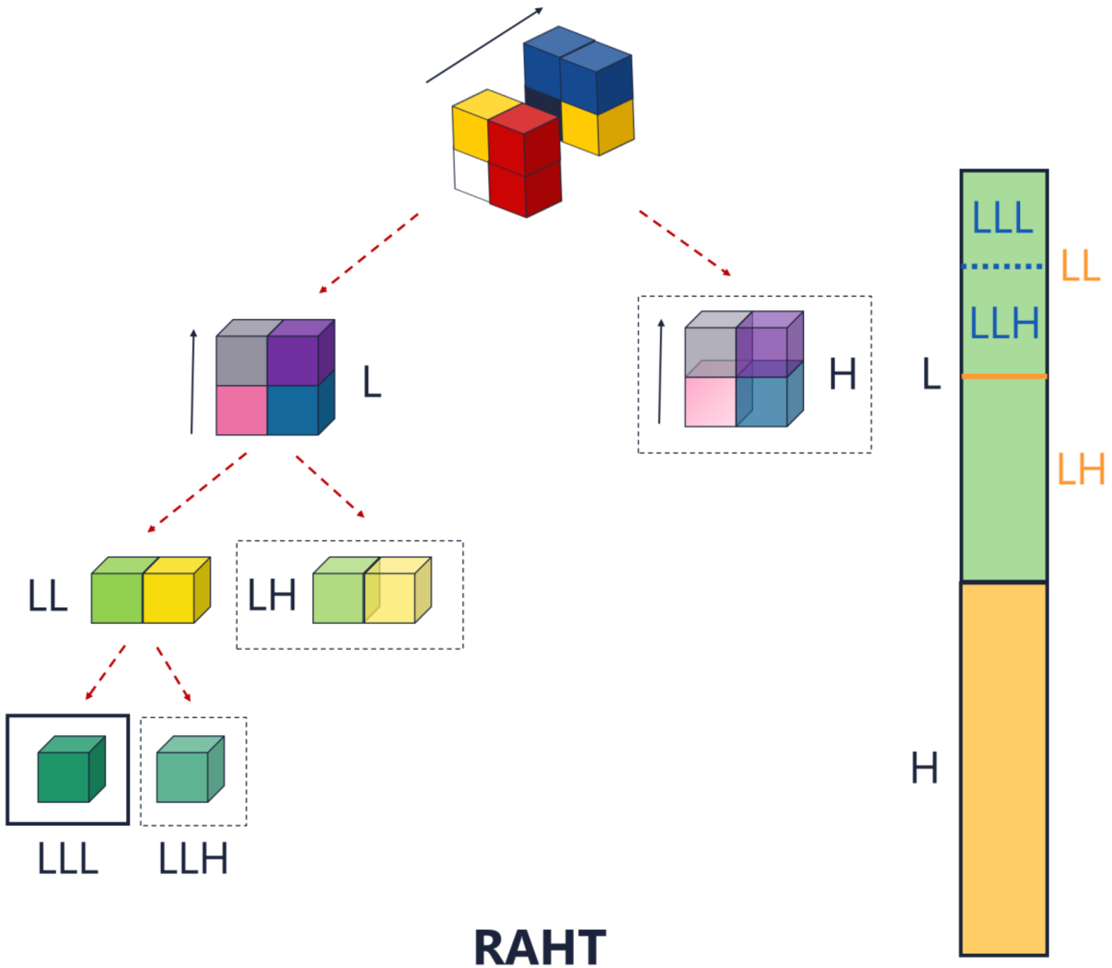
- Is dyadic really necessary?
- Fixed per Node
- Fixed per Level
- Adaptive: Based on Geometry
- Adaptive: Based on Geometry and attribute:
  - Naïve Approach
  - 3D edge Detection

Overview

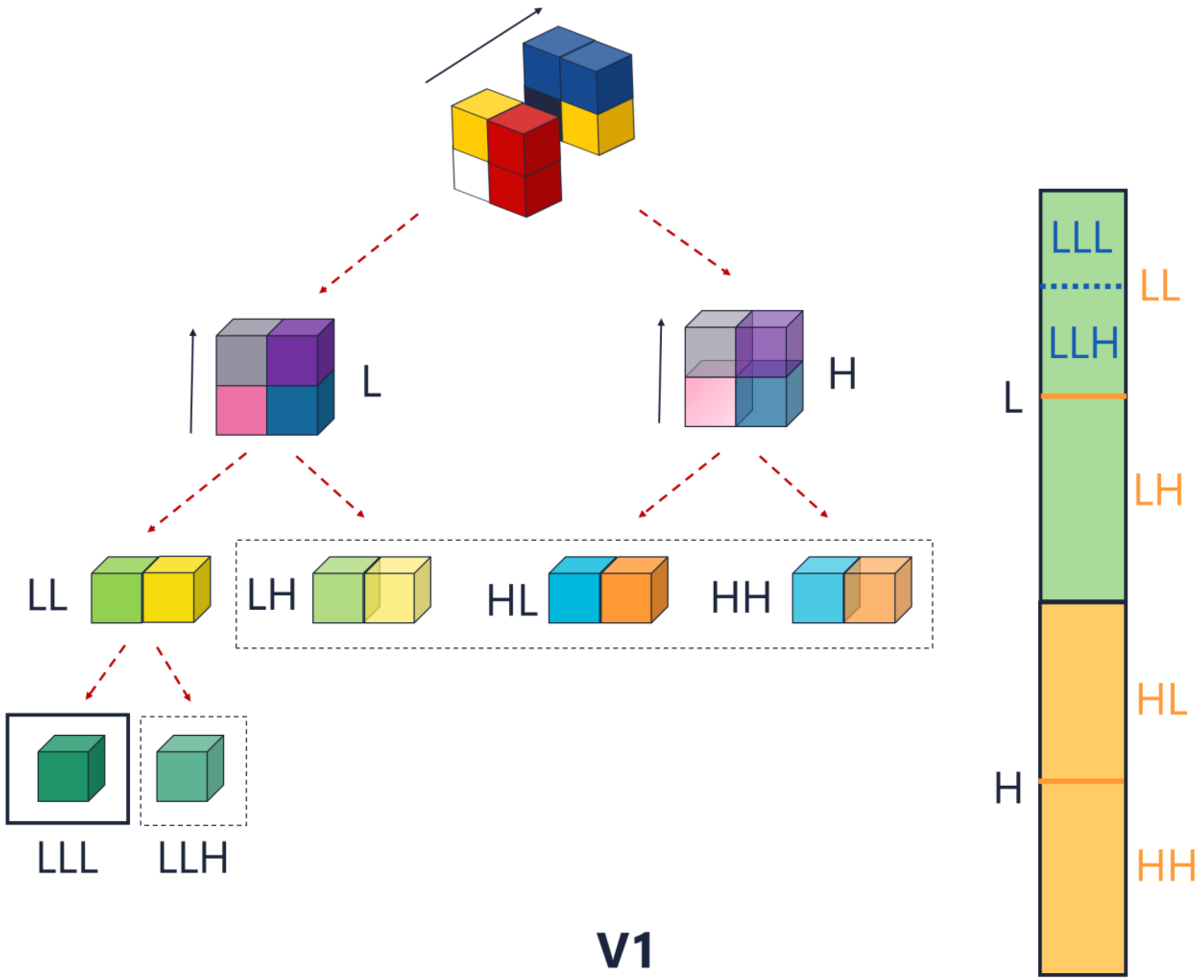


DYADIC RAHT EARLY TERMINATION
FIXED PER NODE
(Node Level)
RAHT
v1
v2
v3
Dyadic
FIXED PER LEVEL
(Tree Level)
50%
95% – 98%
ADAPTIVE PER NODE
(Tree Level)
Based on Geometry
+
Based on Attribute
Proposal (Xiomi)
3D edge filter

Fixed per Node: Partial Dyadic V1

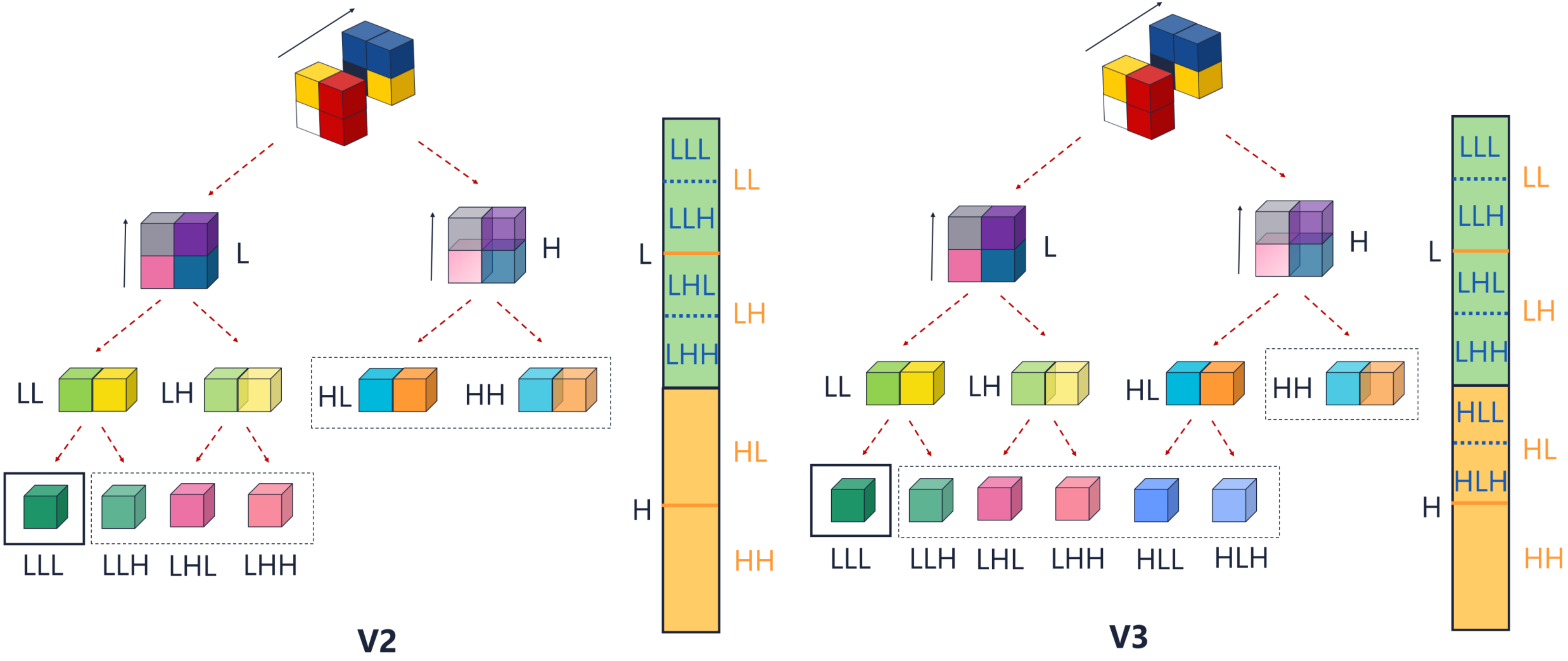


RAHT

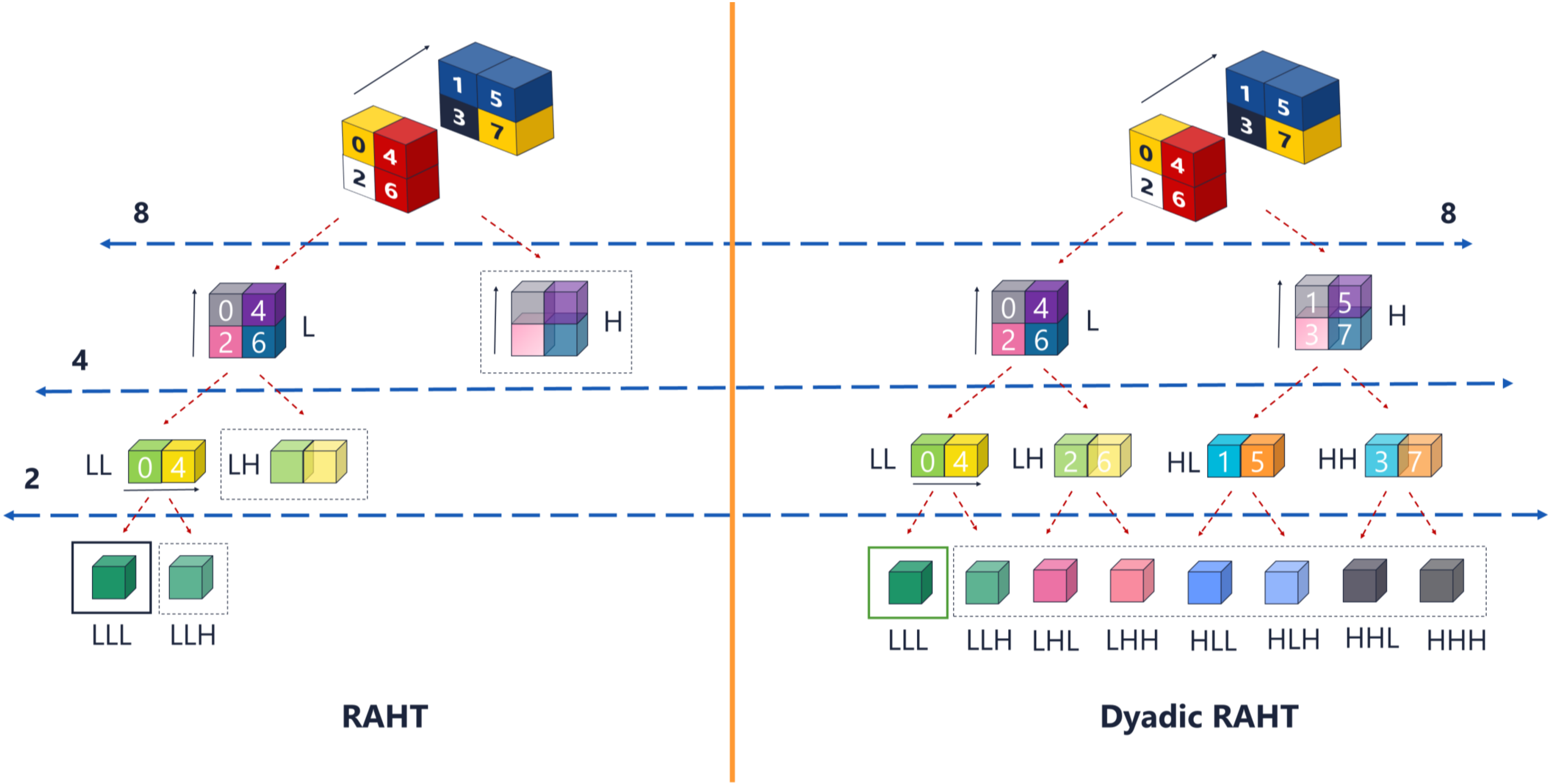


V1

Fixed per Node: Partial Dyadic V2 & V3



RAHT vs Dyadic RAHT



Results: V2

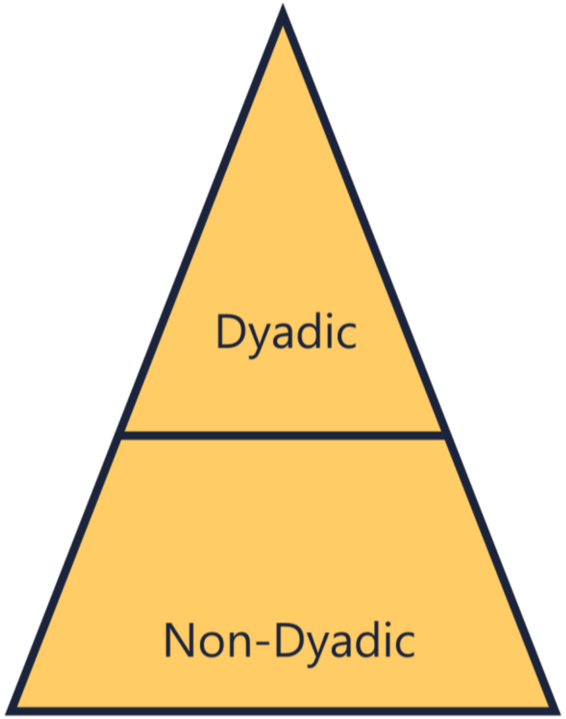
Reference:	TMC13v10.0_octree_dyadic_raht
Tested:	TMC13v10.0_octree_partial_dyadic_raht_V2

All Intra

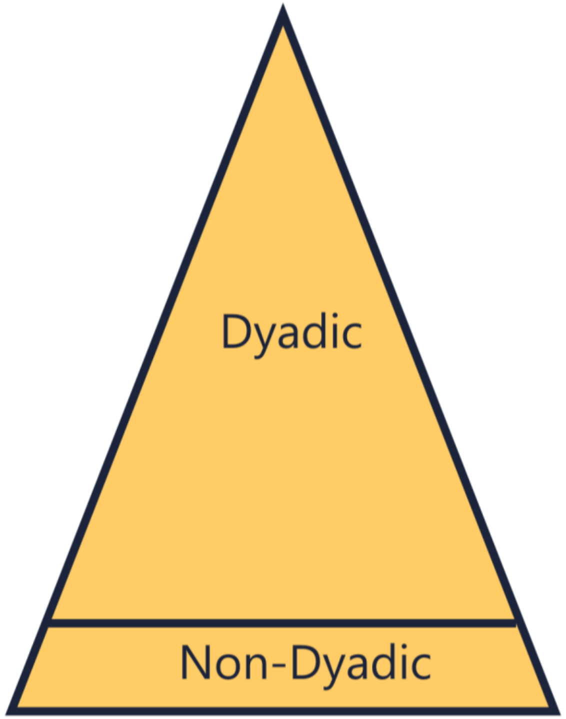
C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	0.2%	-0.2%	-0.1%	
Cat1-B average	0.4%	0.3%	0.4%	
Cat3-fused average	0.3%	0.2%	0.2%	0.7%
Cat3-frame average				0.3%
Overall average	0.3%	0.1%	0.2%	0.4%
Avg. Enc Time [%]	96%			
Avg. Dec Time [%]	96%			
Avg. Enc Time Colour [%]	98%			
Avg. Dec Time Colour[%]	98%			
Avg. Enc Time Reflec [%]	94%			
Avg. Dec Time Reflec [%	94%			
Avg. Enc Time Geom [%]	95%			
Avg. Dec Time Geom[%]	95%			

C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	0.5%	0.3%	0.2%	
Cat1-B average	0.6%	0.7%	0.6%	
Cat3-fused average	0.9%	0.2%	0.3%	1.2%
Cat3-frame average				0.3%
Overall average	0.6%	0.5%	0.4%	0.5%
Avg. Enc Time [%]	99%			
Avg. Dec Time [%]	99%			
Avg. Enc Time Colour [%]	98%			
Avg. Dec Time Colour[%]	99%			
Avg. Enc Time Reflec [%]	96%			
Avg. Dec Time Reflec [%	96%			
Avg. Enc Time Geom [%]	97%			
Avg. Dec Time Geom[%]	99%			

Fixed per Level



1. Half and Half



2. Last level

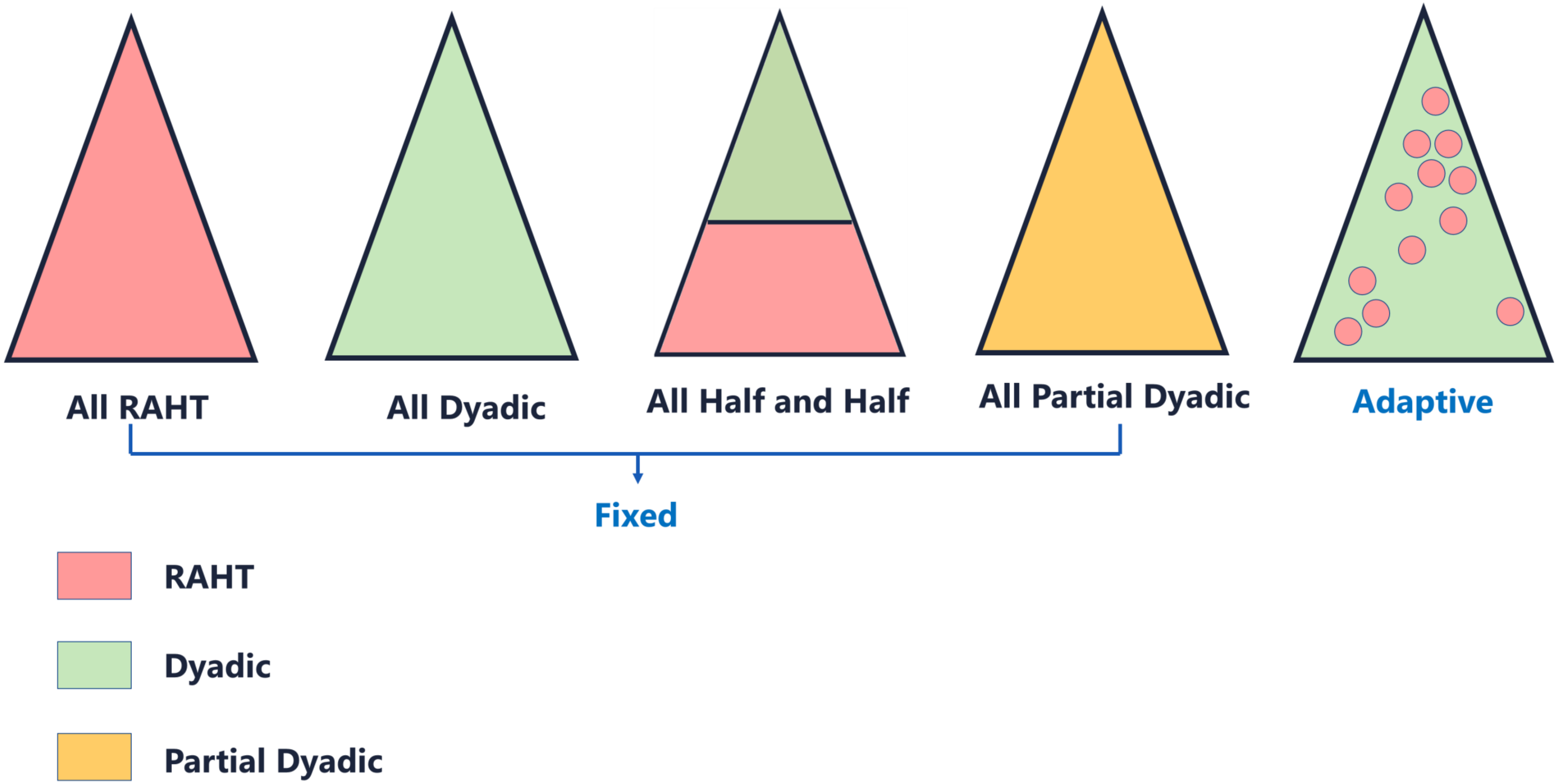
Results: Fixed per Level

Reference:	TMC13v10.0_octree_dyadic_raht			
Tested:	TMC13v10.0_octree_dyadic_raht_level_50%			
All Intra				

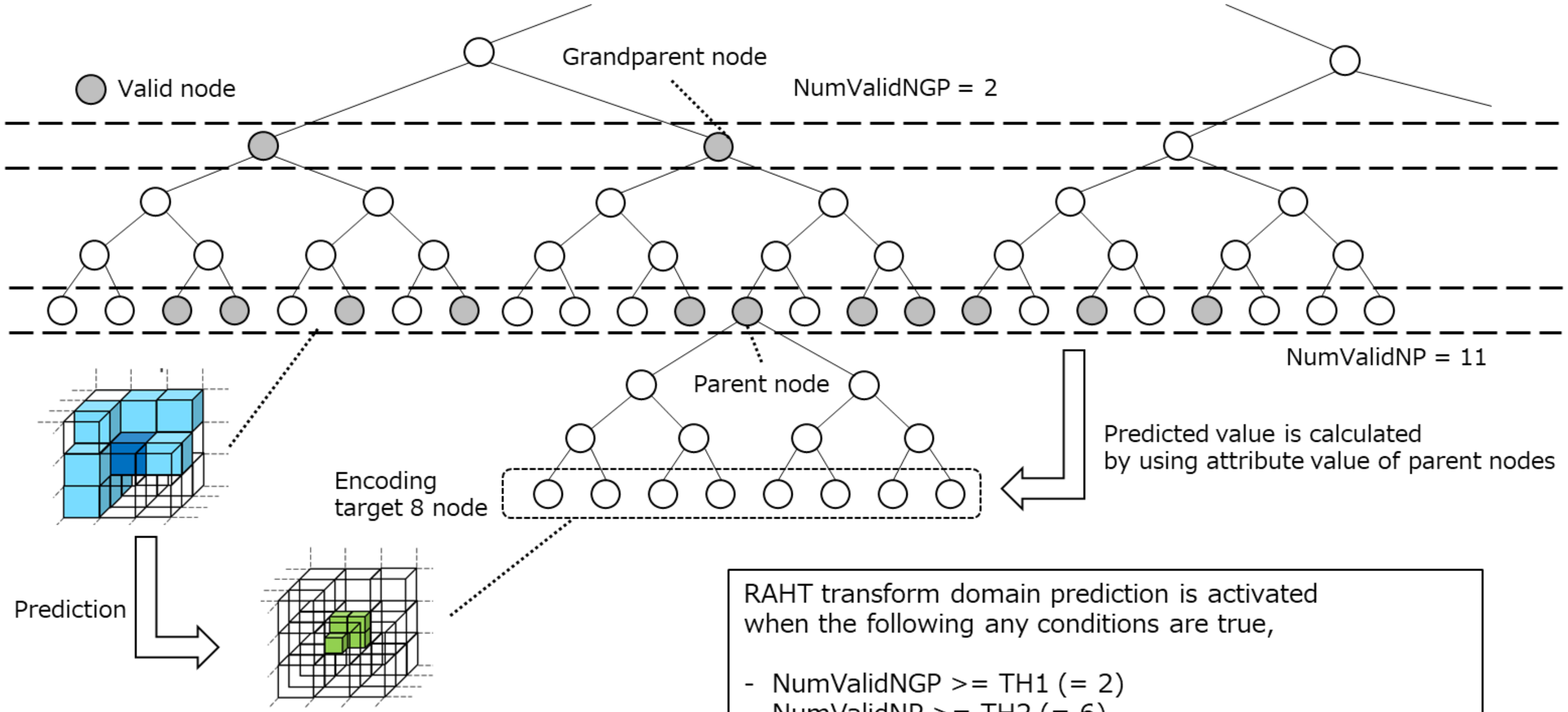
C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%]			
	Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	1.5%	1.3%	1.5%	
Cat1-B average	0.8%	1.0%	1.2%	
Cat3-fused average	0.2%	-0.4%	-0.4%	1.0%
Cat3-frame average				0.7%
Overall average	1.1%	1.1%	1.2%	0.8%
Avg. Enc Time [%]	97%			
Avg. Dec Time [%]	97%			
Avg. Enc Time Colour [%]	98%			
Avg. Dec Time Colour[%]	99%			
Avg. Enc Time Reflec [%]	96%			
Avg. Dec Time Reflec [%	96%			
Avg. Enc Time Geom [%]	97%			
Avg. Dec Time Geom[%]	97%			

C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%]			
	Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	2.8%	1.9%	2.7%	
Cat1-B average	1.9%	2.7%	3.0%	
Cat3-fused average	1.0%	-0.3%	-0.3%	2.0%
Cat3-frame average				0.8%
Overall average	2.3%	2.1%	2.7%	1.2%
Avg. Enc Time [%]	97%			
Avg. Dec Time [%]	97%			
Avg. Enc Time Colour [%]	96%			
Avg. Dec Time Colour[%]	99%			
Avg. Enc Time Reflec [%]	97%			
Avg. Dec Time Reflec [%	98%			
Avg. Enc Time Geom [%]	97%			
Avg. Dec Time Geom[%]	97%			

Fixed Vs Adaptive



Adaptive: Based on Geometry



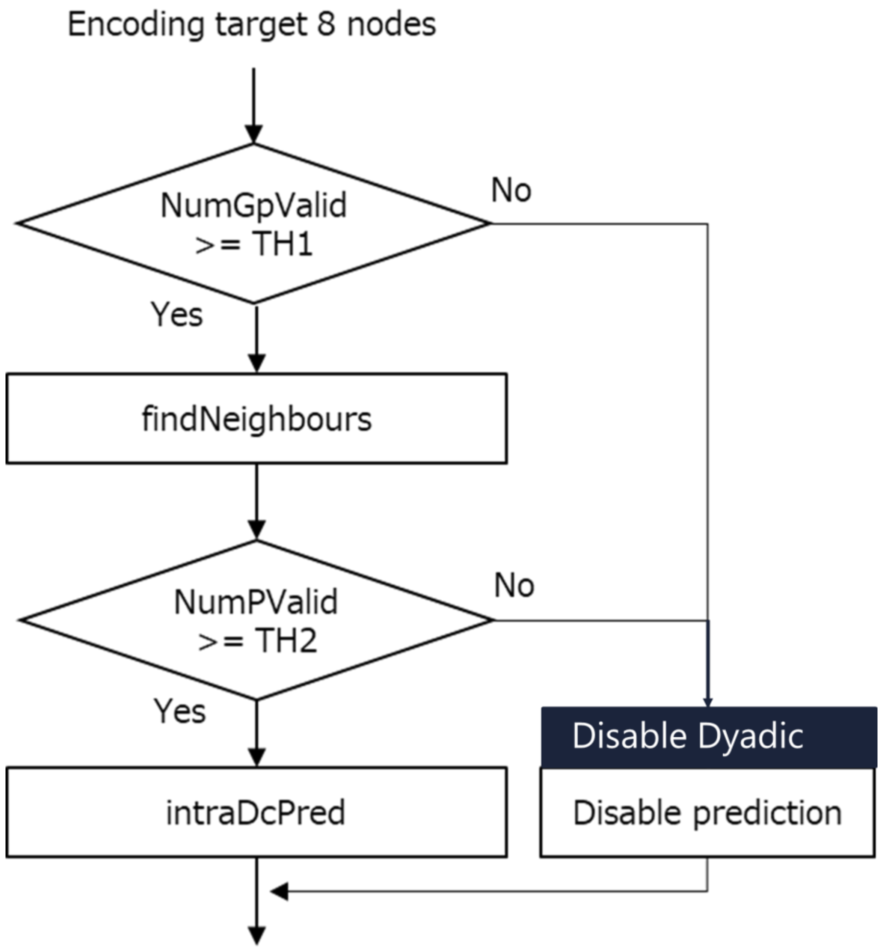
RAHT transform domain prediction is activated when the following any conditions are true,

- NumValidNGP >= TH1 (= 2)
- NumValidNP >= TH2 (= 6)

NumValidNP: total number of valid neighbour parent node

NumValidNGP: total number of valid neighbour grandparent node

Results: Based on Geometry



Reference:	TMC13v10.0_octree_dyadic_raht			
Tested:	TMC13v10.0_octree_dyadic_raht_geometry			
All Intra				

C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	0.0%	0.0%	0.0%	
Cat1-B average	0.0%	0.0%	0.0%	
Cat3-fused average	0.0%	0.0%	0.0%	0.0%
Cat3-frame average				0.1%
Overall average	0.0%	0.0%	0.0%	0.1%
Avg. Enc Time [%]	97%			
Avg. Dec Time [%]	98%			
Avg. Enc Time Colour [%]	99%			
Avg. Dec Time Colour[%]	100%			
Avg. Enc Time Reflec [%]	95%			
Avg. Dec Time Reflec [%	96%			
Avg. Enc Time Geom [%]	96%			
Avg. Dec Time Geom[%]	96%			

C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	0.0%	0.6%	0.3%	
Cat1-B average	0.0%	0.4%	-0.3%	
Cat3-fused average	0.2%	-0.1%	0.0%	0.1%
Cat3-frame average				0.1%
Overall average	0.0%	0.4%	0.0%	0.1%
Avg. Enc Time [%]	98%			
Avg. Dec Time [%]	99%			
Avg. Enc Time Colour [%]	98%			
Avg. Dec Time Colour[%]	100%			
Avg. Enc Time Reflec [%]	100%			
Avg. Dec Time Reflec [%	102%			
Avg. Enc Time Geom [%]	97%			
Avg. Dec Time Geom[%]	98%			

Adaptive: Naïve Approach

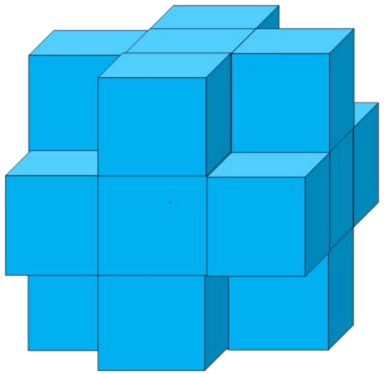
Title : **RAHT upsampled prediction improvement**

Author : Wei Zhang, Na Dai, Mary-Luc Champel

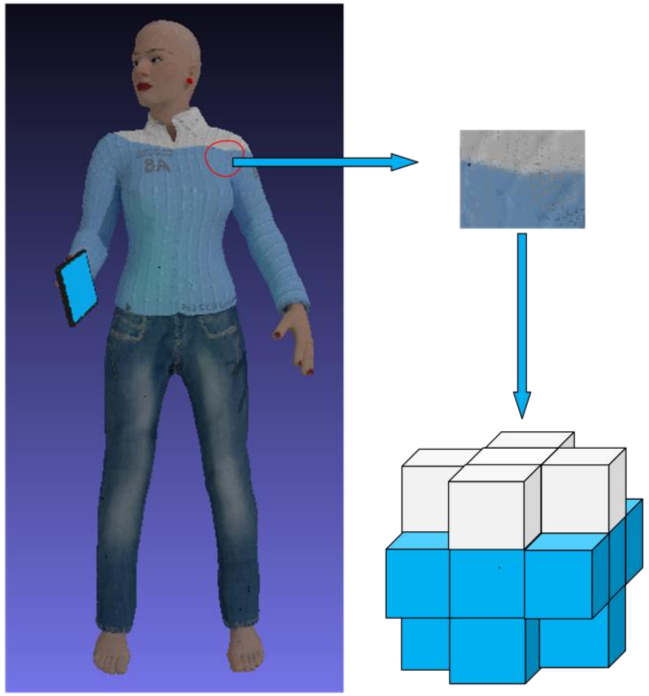
Source : Xidian University, Xiaomi

Abstract : Screen the parent neighbours used for the upsampled prediction in RAHT.

- Neighbors may have different attribute value compared with the node to be predicted.
- Using all 7 neighbors -> large prediction residual.
- Gain up to 4.7% on luma and up to 1.4% on reflectance with less than 3% increase of runtime.



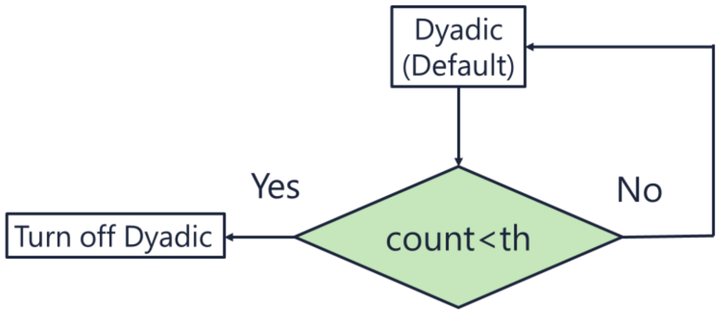
$$Ratio_i = \frac{A_i}{A_c}$$



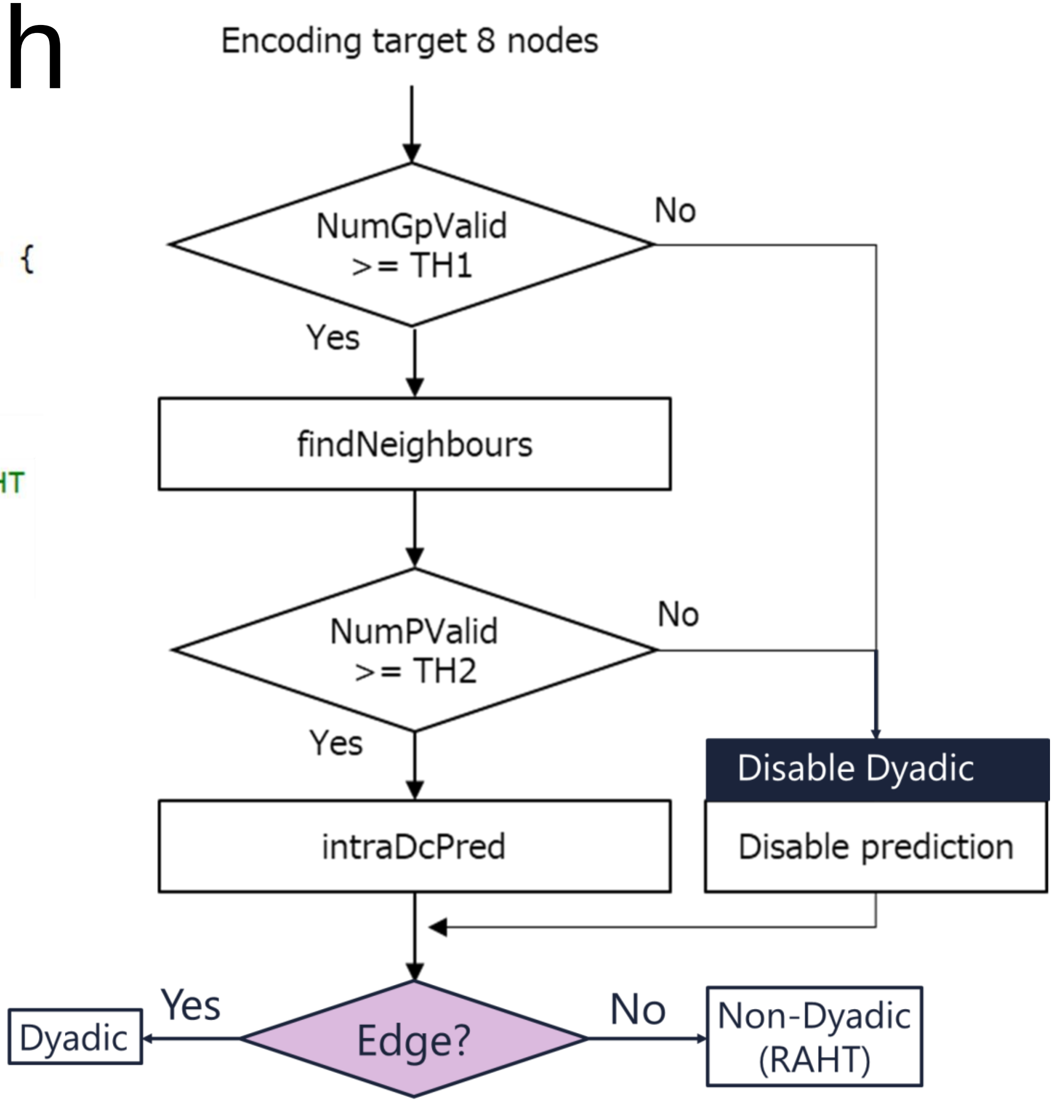
Adaptive: Naïve Approach

```
// check if the attribute value falls out of limit i.e., edge
if (10 * reconNeighValue[0] <= value1 || 10 * reconNeighValue[0] >= value2) {
  counter += 1;
  continue;
}

// Did not fall too much out of range --> uniform area (no edge) --> RAHT
if (counter < 3)
    enableDy = false;
```



Note: Counter-> counts the number of attributes out of 18 has fallen out of range.



Results: Naïve Approach

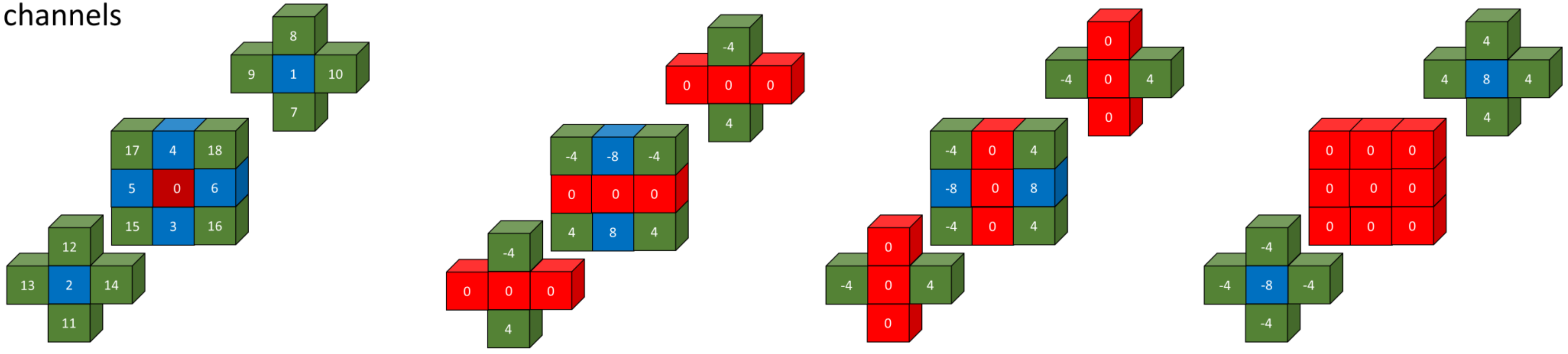
Reference:	TMC13v10.0_octree_dyadic_raht			
Tested:	TMC13v10.0_octree_dyadic_raht_geom_attr_th3			
All Intra				

C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	0.6%	0.1%	0.2%	
Cat1-B average	0.4%	1.2%	1.4%	
Cat3-fused average	-4.4%	-3.6%	-3.7%	0.3%
Cat3-frame average				-0.6%
Overall average	0.2%	0.4%	0.6%	-0.3%
Avg. Enc Time [%]	101%			
Avg. Dec Time [%]	101%			
Avg. Enc Time Colour [%]	101%			
Avg. Dec Time Colour[%]	101%			
Avg. Enc Time Reflec [%]	101%			
Avg. Dec Time Reflec [%	102%			
Avg. Enc Time Geom [%]	101%			
Avg. Dec Time Geom[%]	102%			

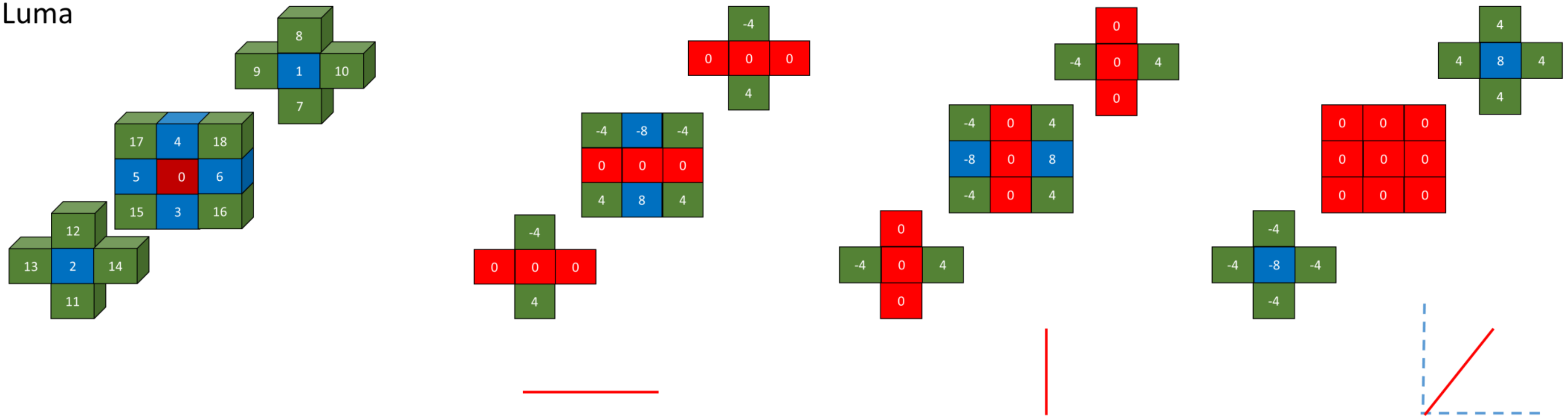
C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-2.0%	-0.5%	-1.3%	
Cat1-B average	-1.2%	-1.8%	-2.3%	
Cat3-fused average	2.1%	3.1%	3.0%	-1.4%
Cat3-frame average				0.0%
Overall average	-1.4%	-0.9%	-1.5%	-0.4%
Avg. Enc Time [%]	97%			
Avg. Dec Time [%]	98%			
Avg. Enc Time Colour [%]	99%			
Avg. Dec Time Colour[%]	98%			
Avg. Enc Time Reflec [%]	99%			
Avg. Dec Time Reflec [%	100%			
Avg. Enc Time Geom [%]	96%			
Avg. Dec Time Geom[%]	96%			

Adaptive: 3D edge filter

All the channels



Only Luma



Adaptive: 3D edge filter (Relative Threshold)

3D Sobel Filter

$$G_x : \begin{bmatrix} -2 & -4 & -2 \\ 0 & 0 & 0 \\ 2 & 4 & 2 \end{bmatrix}, \begin{bmatrix} -4 & -8 & -4 \\ 0 & 0 & 0 \\ 4 & 8 & 4 \end{bmatrix}, \begin{bmatrix} -2 & -4 & -2 \\ 0 & 0 & 0 \\ 2 & 4 & 2 \end{bmatrix}$$

$$G_y : \begin{bmatrix} -2 & 0 & 2 \\ -4 & 0 & 4 \\ -2 & 0 & 2 \end{bmatrix}, \begin{bmatrix} -4 & 0 & 4 \\ -8 & 0 & 8 \\ -4 & 0 & 4 \end{bmatrix}, \begin{bmatrix} -2 & 0 & 2 \\ -4 & 0 & 4 \\ -2 & 0 & 2 \end{bmatrix}$$

$$G_z : \begin{bmatrix} -2 & -4 & -2 \\ -4 & -8 & -4 \\ -2 & -4 & -2 \end{bmatrix}, \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \begin{bmatrix} 2 & 4 & 2 \\ 4 & 8 & 4 \\ 2 & 4 & 2 \end{bmatrix}$$

Gradient of a 3D image

$$\nabla \mathbf{f} = \begin{bmatrix} G_x & G_y & G_z \end{bmatrix}^T = \begin{bmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} & \frac{\partial f}{\partial z} \end{bmatrix}^T$$

Magnitude of the gradient

$$Mag = \nabla f = |\nabla F| = |G_x| + |G_y| + |G_z|$$

$$Avg = \frac{sum\ of\ available\ attributes}{no.of\ available\ nodes}$$

$$\boxed{k = \frac{Mag}{Avg}}$$

Thresholded edge image

$$g(x,y,z) = \begin{cases} RAHT & if\ k > threshold \\ Dyadic & otherwise \end{cases}$$

Adaptive: 3D edge detection

Reference: TMC13v10.0_octree_dyadic_raht
Tested: TMC13v10.0_octree_dyadic_raht_geom_attr_Y_Rel_th025

All Intra

C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	0.0%	-0.3%	-0.4%	
Cat1-B average	-0.2%	0.4%	0.6%	
Cat3-fused average	-4.5%	-3.5%	-3.7%	0.0%
Cat3-frame average				-1.0%
Overall average	-0.4%	-0.1%	-0.1%	-0.7%
Avg. Enc Time [%]	94%			
Avg. Dec Time [%]	94%			

C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-0.9%	-0.1%	-0.7%	
Cat1-B average	-0.8%	-1.0%	-1.2%	
Cat3-fused average	-0.3%	0.2%	0.0%	-0.7%
Cat3-frame average				-0.3%
Overall average	-0.8%	-0.5%	-0.9%	-0.4%
Avg. Enc Time [%]	96%			
Avg. Dec Time [%]	97%			

Reference: TMC13v10.0_octree_dyadic_raht
Tested: TMC13v10.0_octree_dyadic_raht_geom_attr_Y_Rel_th037

All Intra

C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-0.3%	-0.4%	-0.7%	
Cat1-B average	-0.4%	0.0%	0.2%	
Cat3-fused average	-4.5%	-3.4%	-3.5%	-0.2%
Cat3-frame average				-1.1%
Overall average	-0.6%	-0.4%	-0.4%	-0.9%
Avg. Enc Time [%]	95%			
Avg. Dec Time [%]	95%			

C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-1.6%	-0.7%	-1.1%	
Cat1-B average	-1.2%	-1.5%	-1.7%	
Cat3-fused average	-0.3%	0.4%	0.1%	-1.1%
Cat3-frame average				-0.5%
Overall average	-1.3%	-1.0%	-1.3%	-0.7%
Avg. Enc Time [%]	97%			
Avg. Dec Time [%]	98%			

Reference: TMC13v10.0_octree_dyadic_raht
Tested: TMC13v10.0_octree_dyadic_raht_geom_attr_Y_Rel_th50

All Intra

C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-0.6%	-0.7%	-0.8%	
Cat1-B average	-0.6%	-0.3%	-0.3%	
Cat3-fused average	-4.5%	-3.2%	-3.4%	-0.5%
Cat3-frame average				-1.3%
Overall average	-0.8%	-0.6%	-0.7%	-1.1%
Avg. Enc Time [%]	94%			
Avg. Dec Time [%]	95%			

C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-2.3%	-1.4%	-1.9%	
Cat1-B average	-1.6%	-2.0%	-2.4%	
Cat3-fused average	-0.5%	0.5%	0.1%	-1.5%
Cat3-frame average				-0.7%
Overall average	-1.8%	-1.6%	-2.0%	-0.9%
Avg. Enc Time [%]	97%			
Avg. Dec Time [%]	99%			

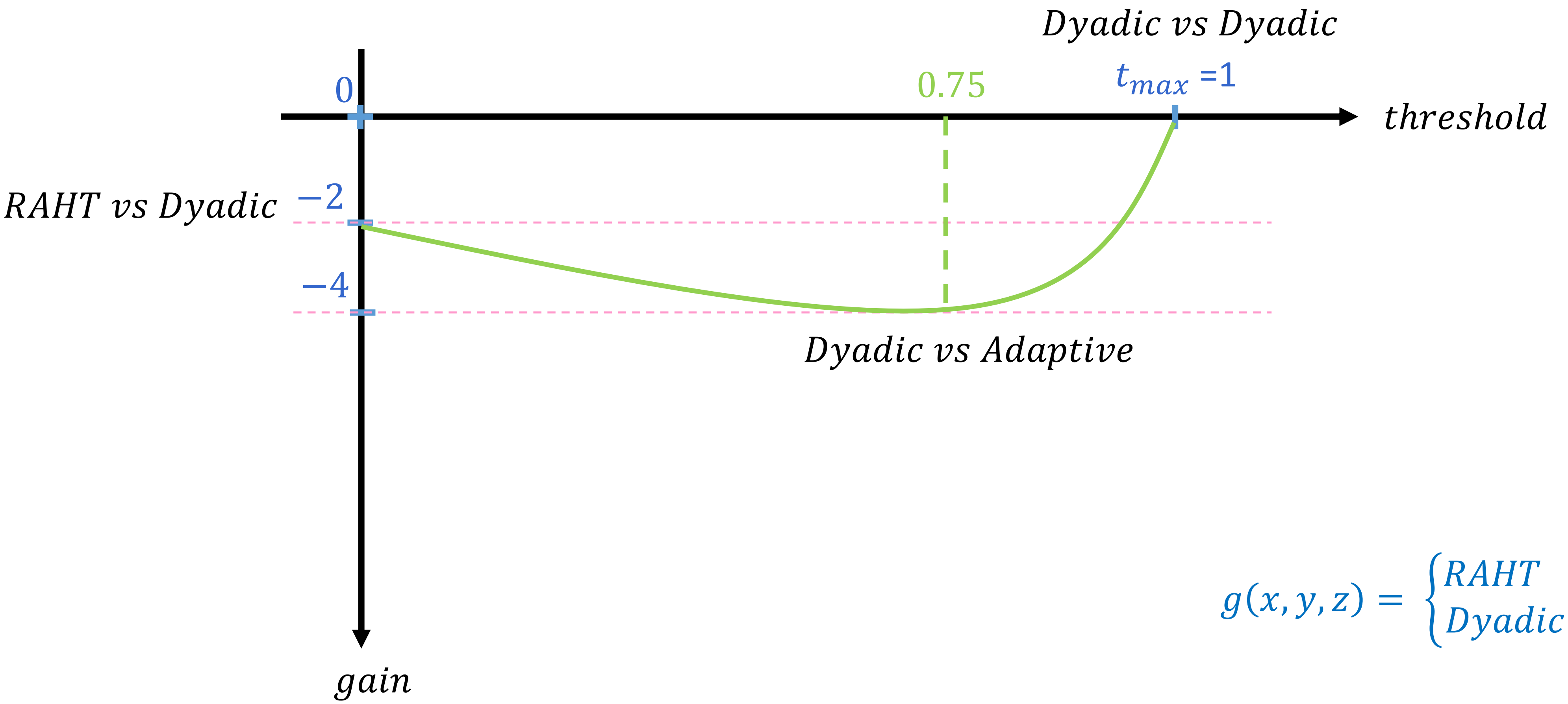
Reference: TMC13v10.0_octree_dyadic_raht
Tested: TMC13v10.0_octree_dyadic_raht_geom_attr_Y_Rel_th075

All Intra

C1_ai	lossless geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-0.7%	-0.5%	-0.8%	
Cat1-B average	-0.7%	-0.4%	-0.5%	
Cat3-fused average	-4.4%	-3.1%	-3.2%	-0.6%
Cat3-frame average				-1.4%
Overall average	-0.9%	-0.6%	-0.8%	-1.2%
Avg. Enc Time [%]	95%			
Avg. Dec Time [%]	95%			

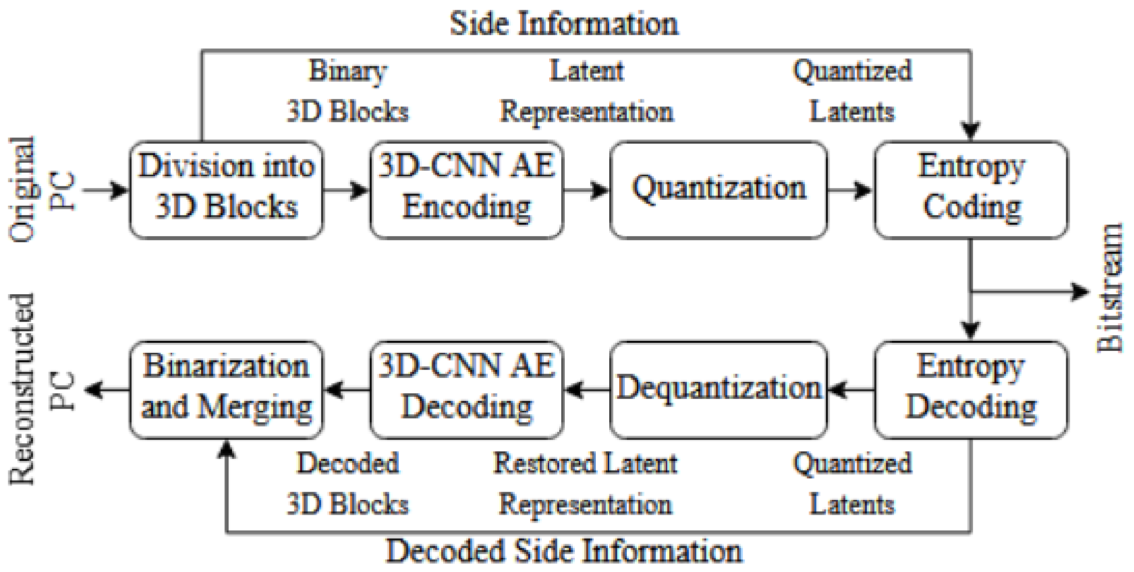
C2_ai	lossy geometry, lossy attributes [all intra] End-to-End BD-AttrRate [%] Luma	Chroma Cb	Chroma Cr	Reflectance
Cat1-A average	-2.6%	-1.0%	-1.8%	
Cat1-B average	-1.8%	-2.2%	-2.7%	
Cat3-fused average	-0.7%	0.5%	0.3%	-1.9%
Cat3-frame average				-0.7%
Overall average	-2.1%	-1.5%	-2.1%	-1.1%
Avg. Enc Time [%]	97%			
Avg. Dec Time [%]	98%			

Analysis (Fixed Vs Adaptive)

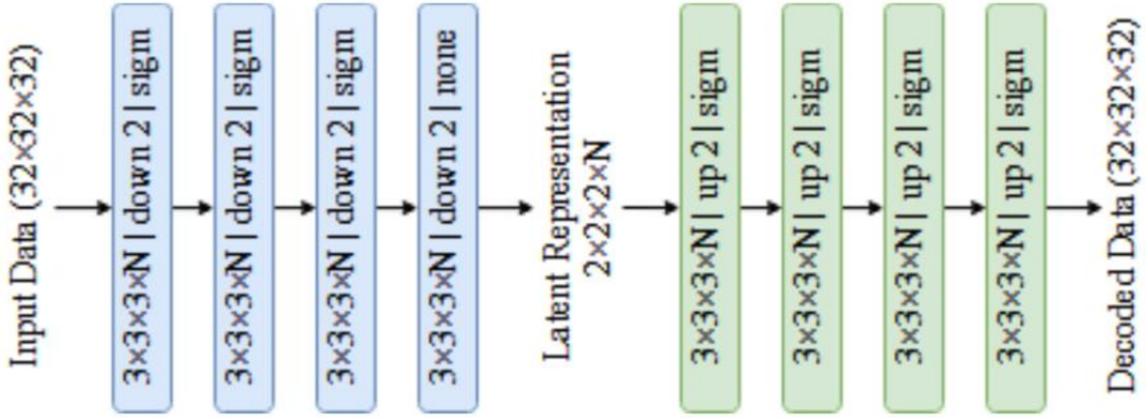


$$g(x,y,z) = \begin{cases} RAHT & if\ k > threshold \\ Dyadic & otherwise \end{cases}$$

Point cloud compression using DNN



Overall Architecture



Adaptive Transform

Point cloud geometry autoencoder

Conclusion

- Point cloud compression

- Study of different types of RAHT Transform

- Dyadic RAHT early termination experiments:
  - The results show that the proposed scheme has potential
  - However, further investigation must be done:
    (a) Adapting it to an integer implementation
    (b) Porting it to recently released TMC13V11

      -> New adoption were integrated after the MPEG 131 meeting and the behavior of the proposed technique must be evaluated on top of that having v11 release as anchor.

- Survey on PCC using Deep neural networks

Thank You!

Audience
and
Team members
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