Decoder-side Chroma Intra Mode Derivation in Video Coding

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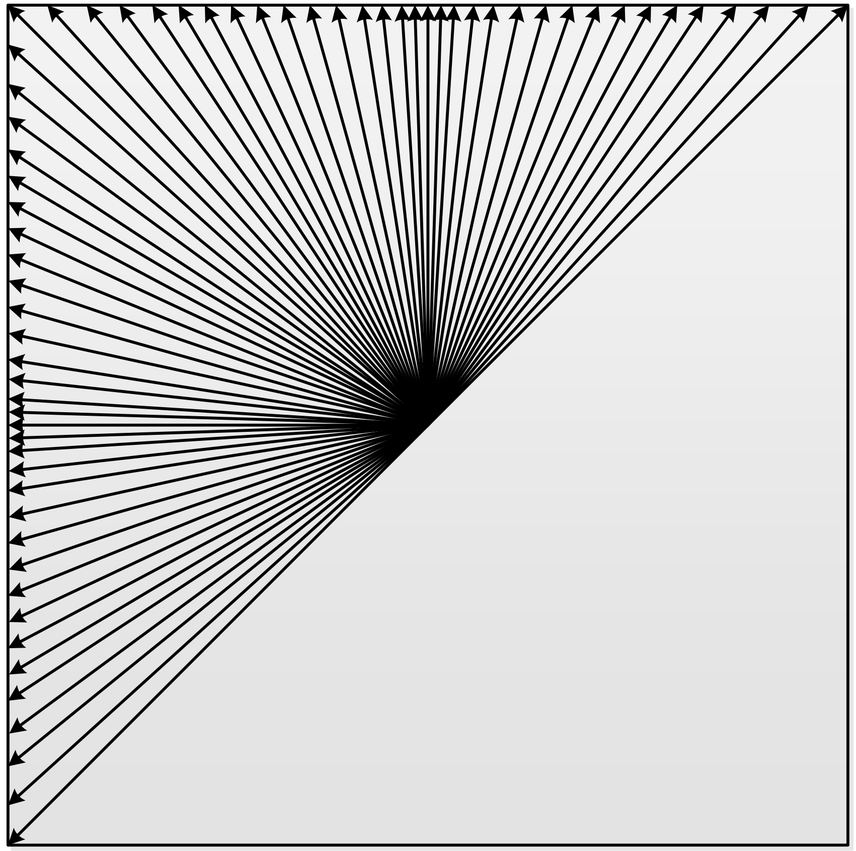
Introduction

- The latest video coding standard Versatile Video Coding (VVC) was finalized in July 2020 [1]
- Recent studies have provided evidence that some promising coding tools can still further improve the coding efficiency on top of VVC [3]
- An enhanced compression model (ECM) was established to explore coding technologies beyond VVC capability [4]
  - Improves some coding tools in VVC
  - Introduces some new coding tools with significant coding gain

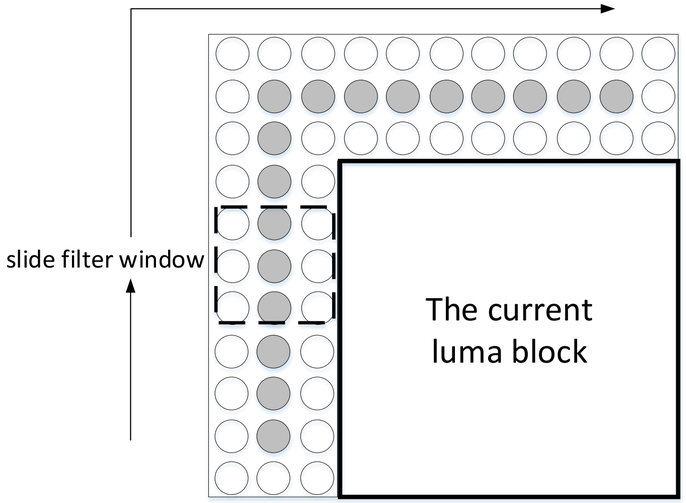
Decoder-side intra mode derivation (DIMD) in ECM



- Decoder-side intra mode derivation (DIMD) [13][14] is a promising coding tool newly adopted in ECM
- 67 intra prediction modes for luma
  - Planar mode
  - DC mode
  - 65 angular modes
- A significant number of bits are transmitted in the bitstream
- DIMD derives the intra prediction mode based on the gradients at encoder and decoder in the same way to save the bit overhead

Decoder-side intra mode derivation (DIMD) in ECM

1. Calculate gradients of neighboring samples



1	0	-1
2	0	-2
1	0	-1

G_{hor}

-1	-2	-1
0	0	0
1	2	1

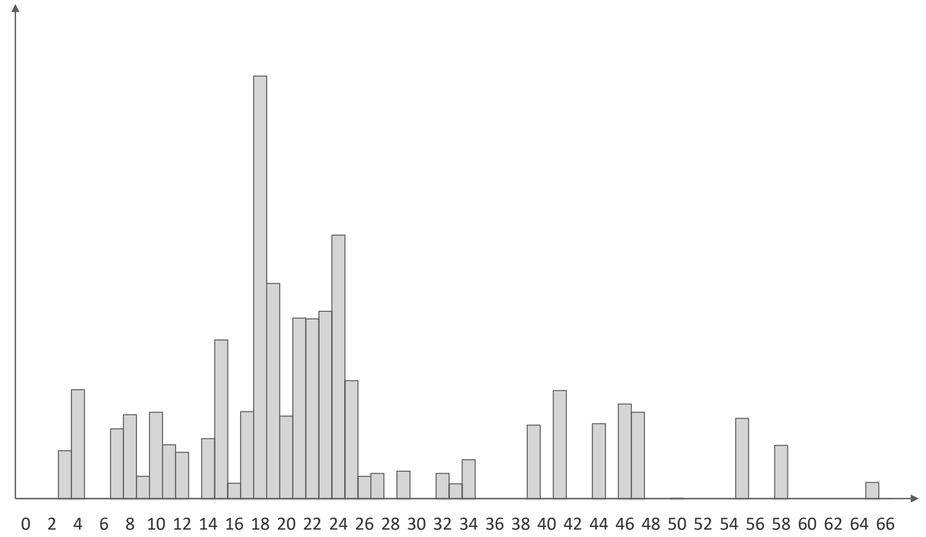
G_{ver}

2. Map to angular modes

$$\theta = \arctan\left(\frac{G_{ver}}{G_{hor}}\right)$$

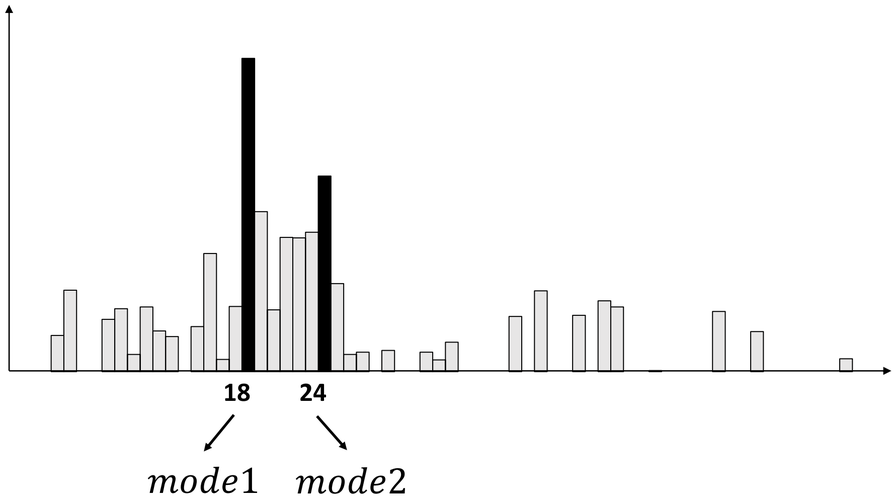
$$G = |G_{hor}| + |G_{ver}|$$

3. Build a histogram of gradients



Decoder-side intra mode derivation (DIMD) in ECM

- A fusion method is applied to improve the coding efficiency of DIMD:



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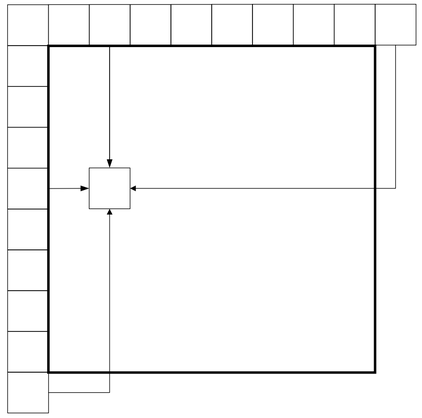

planar mode

$$pred = w_{planar} \cdot pred_{planar} + w_{mode1} \cdot pred_{mode1} + w_{mode2} \cdot pred_{mode2}$$

$$w_{planar} = \frac{21}{64}$$

$$w_{mode1} = \frac{43}{64} \cdot \frac{amp(mode1)}{amp(mode1) + amp(mode2)}$$

$$w_{mode2} = \frac{43}{64} \cdot \frac{amp(mode2)}{amp(mode1) + amp(mode2)}$$

- The weight of planar mode w_{planar} is fixed to 21/64
- The remaining weight of 43/64 is then shared between $mode1$ and $mode2$, proportionally to their histogram amplitude values

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Motivation

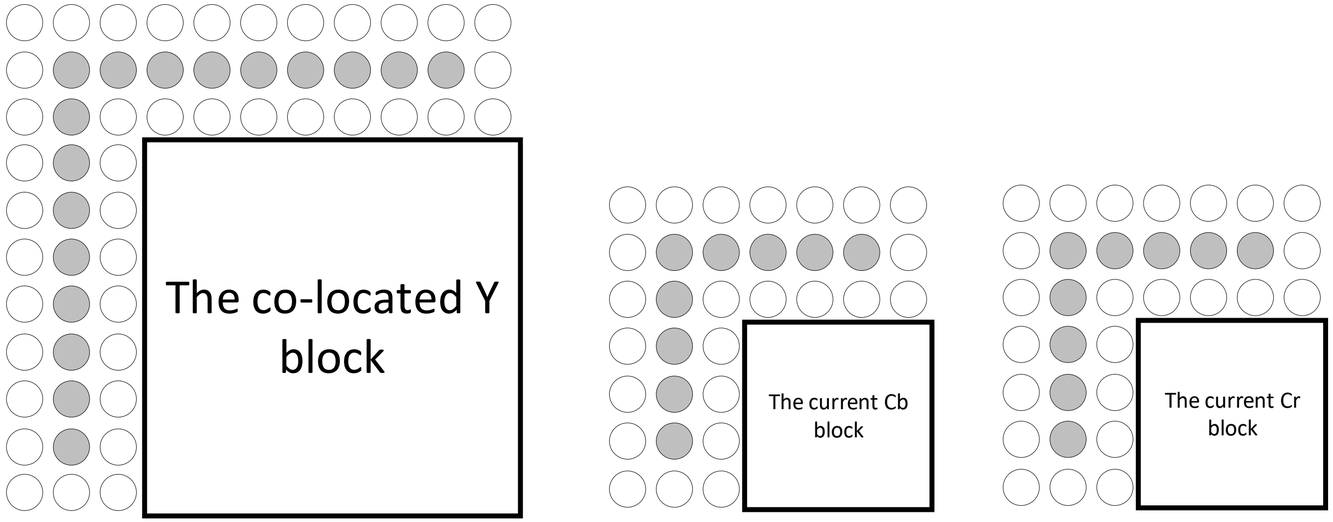
- DIMD is not applied to chroma because it is specially designed for the characteristics of luma intra prediction

- The chroma intra prediction modes in ECM are limited:
  - DM mode, four default modes (planar mode, vertical mode, horizontal mode and DC mode), cross-component linear model modes (CCLM) and multi-model cross-component linear model modes (MMLM) are supported
  - The encoder choices are not as flexible as luma intra prediction
  - Enabling more angular intra modes for chroma may not cover the increased bit overhead since the texture of the chroma components is generally simpler

- A decoder-side chroma intra mode derivation (DCIMD) is proposed in this paper to improve the prediction accuracy while avoiding expensive bit overhead

Decoder-side chroma intra mode derivation (DCIMD)

- The DCIMD mode considers the correlation between different components to improve the matching degree of the derived angular intra mode with the texture of the chroma block
  - The corresponding adjacent luma samples and chroma samples are utilized to derive the angular intra mode
  - The gradients for each luma and chroma sample are calculated
  - All the gradients are combined to build one histogram of the gradients
  - The angular intra mode (the one with the largest amplitude value) will be selected for predicting



Decoder-side chroma intra mode derivation (DCIMD)

- The angular intra mode derived by DCIMD is used as an additional chroma intra prediction mode, which extends the number of modes supported for chroma intra prediction by one

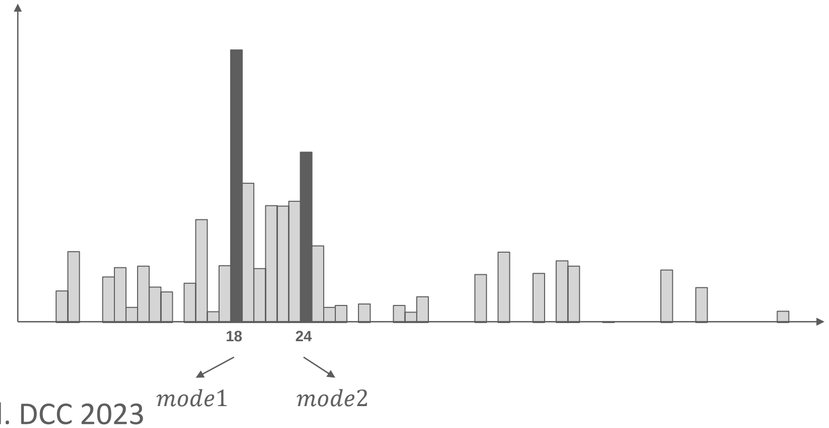
- A context-based CU level flag is signaled to indicate whether the DCIMD is applied to the current chroma block or not

- To avoid redundancy, a pruning method is proposed:
  - When the angular intra mode derived from the DCIMD is the same as the DM mode, another angular mode with the second largest amplitude value in the histogram constructed by the DCIMD derivation process will be selected to replace the original angular intra mode.

For example:

If $mode1$ ≠ *DM mode,*
$mode1$ *will be used for prediction*

If $mode1$ = *DM mode,*
$mode2$ *will be used for prediction*



Chroma intra mode fusion (CIMF)

- The DIMD mode for luma fuses two angular modes and planar mode to further improve prediction
- However, since chroma blocks have relatively simple texture features compared to luma blocks, the method by fusing these spatial correlation-based modes has almost no positive effect on chroma intra prediction
- The chroma intra prediction modes can be divided into two categories:

spatial correlation-based modes

- DM mode
- Default modes
- DCIMD mode

cross-component correlation-based modes

- CCLM mode
- MMLM mode

- Cross-component correlation-based modes predict chroma samples from reconstructed luma samples by a linear model derived by adjacent samples
- One linear model in CCLM, while two linear models in MMLM
- Three sub-modes: LT mode, L mode, and T mode

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Chroma intra mode fusion (CIMF)

- Since the spatial correlation-based modes and the cross-component correlation-based modes have different characteristics, the combination of these two types of prediction modes can improve the prediction accuracy

- A chroma intra mode fusion method (CIMF) is proposed in this paper:
  - The DCIMD mode can be fused with a cross-component correlation-based intra mode
  - Furthermore, the CIMF method is extended to all prediction modes based on spatial correlation

$$pred = \left(w_{spatial} \cdot pred_{spatial} + w_{component} \cdot pred_{component} + offset\right) \gg shift$$

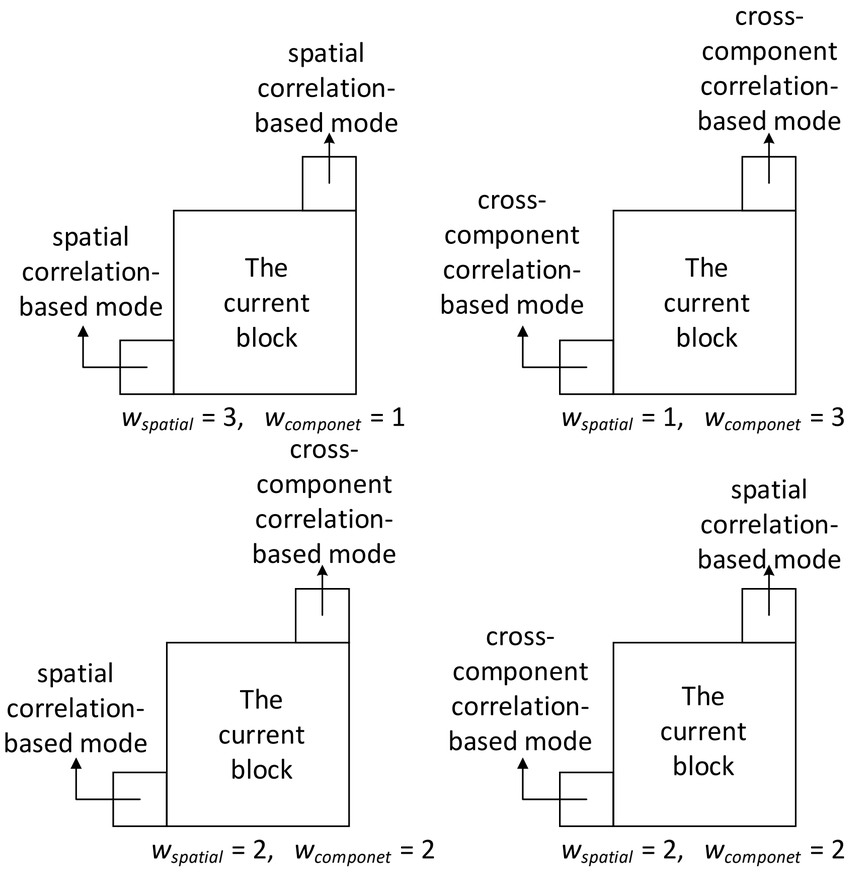
- the current chroma block is predicted using a spatial correlation-based mode and a cross-component correlation-based mode respectively to obtain the predicted values $pred_{spatial}$ and $pred_{component}$
- $w_{spatial}$ and $w_{component}$ are two weights
- $offset$ is a round factor
- $shift$ is a normalization factor

Chroma intra mode fusion (CIMF)

- When CIMF is integrated into ECM, due to the trade-off between encoder complexity and coding efficiency:
  - The mode based on spatial correlation can be one of the following modes: DM mode, DCIMD mode and the four default modes
  - The mode based on cross-component correlation is fixed to MMLM_LT mode since it is more efficient than other cross-component correlation-based modes
- A context-based CU level flag is signaled to indicate whether CIMF is applied after signaling a spatial correlation-based mode for a CU

Chroma intra mode fusion (CIMF)

An adaptive weight derivation method is proposed: the weights are determined according to the prediction modes of top and left adjacent blocks of the current chroma block

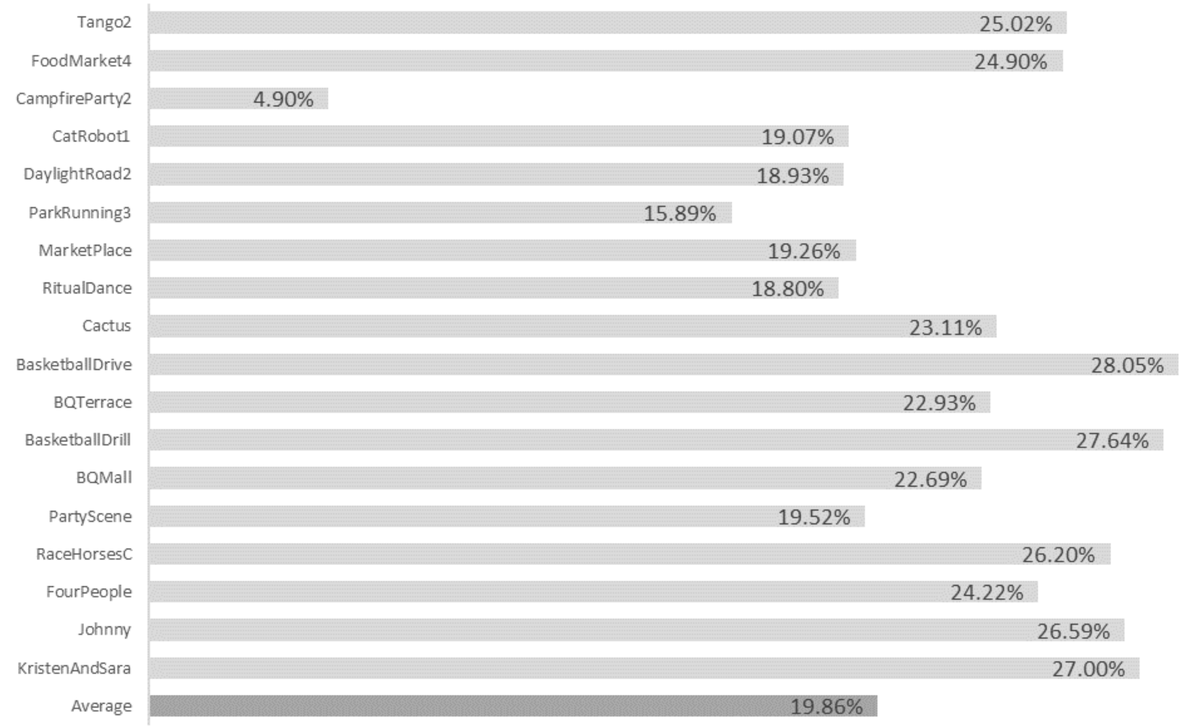


Experimental Results

Class	Sequence	DCIMD			DCIMD + CIMF		
		Y	U	V	Y	U	V
A1	Tango2	-0.06%	-0.60%	-0.50%	-0.15%	-1.96%	-1.49%
	FoodMarket4	-0.06%	-0.31%	-0.36%	-0.07%	-0.92%	-0.96%
	Campfire	0.01%	-0.27%	0.32%	0.02%	-0.62%	0.21%
A2	CatRobot1	-0.11%	-1.00%	-0.87%	-0.11%	-1.55%	-1.48%
	DaylightRoad2	-0.02%	-0.75%	-0.71%	-0.03%	-1.46%	-0.98%
	ParkRunning3	0.01%	-0.34%	-0.39%	0.00%	-0.37%	-0.43%
B	MarketPlace	-0.01%	-0.16%	-0.26%	-0.04%	-0.43%	-0.50%
	RitualDance	-0.04%	-0.21%	-0.18%	-0.04%	-0.74%	-0.35%
	Cactus	-0.09%	-0.46%	-0.77%	-0.12%	-0.97%	-1.42%
	BasketballDrive	-0.11%	-0.79%	-0.80%	-0.16%	-1.63%	-1.79%
	BQTerrace	-0.03%	-0.55%	-0.74%	-0.02%	-1.22%	-1.09%
C	BasketballDrill	-0.10%	-0.73%	-0.62%	-0.12%	-2.18%	-1.58%
	BQMall	-0.04%	-0.32%	-0.57%	-0.05%	-0.55%	-0.80%
	PartyScene	0.00%	-0.30%	-0.20%	-0.01%	-0.55%	-0.32%
	RaceHorses	-0.10%	-0.38%	-0.64%	-0.11%	-0.74%	-1.07%
E	FourPeople	-0.13%	-0.68%	-0.68%	-0.02%	-1.01%	-0.79%
	Johnny	-0.15%	-1.10%	-0.90%	-0.13%	-2.15%	-2.08%
	KristenAndSara	-0.09%	-1.12%	-0.87%	-0.09%	-1.93%	-1.38%
Class Summary	Class A1	-0.03%	-0.39%	-0.18%	-0.07%	-1.17%	-0.75%
	Class A2	-0.04%	-0.69%	-0.66%	-0.05%	-1.13%	-0.96%
	Class B	-0.06%	-0.43%	-0.55%	-0.08%	-1.00%	-1.03%
	Class C	-0.06%	-0.43%	-0.51%	-0.07%	-1.01%	-0.94%
	Class E	-0.13%	-0.96%	-0.81%	-0.08%	-1.70%	-1.42%
Overall Summary	**Average**	**-0.06%**	**-0.56%**	**-0.54%**	**-0.07%**	**-1.17%**	**-1.02%**
	EncT		**101%**			**102%**	
	DecT		**100%**			**100%**	

- Implemented on top of ECM-4.0 [5]
- Performed following the common test conditions and evaluation procedures for enhanced compression tool testing [19]
- 0.07%, 1.17% and 1.02% BD-rate savings for Y, Cb and Cr components on average
- Negligible encoder and decoder runtime changes

Experimental Results



- Selected percentage of the proposed new chroma intra modes
- On average 19.86% of the chroma blocks use the two proposed modes

Summary

- A decoder-side chroma intra mode derivation (DCIMD) method is proposed for chroma intra prediction
- A chroma intra mode fusion (CIMF) method is proposed to further improve the coding efficiency of the DCIMD
- Average BD rate savings of 0.07%, 1.17% and 1.02% for Y, Cb and Cr components, respectively, compared to the ECM-4.0
- Both the DCIMD and CIMF methods have been adopted in ECM-5.0 by JVET

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Thank you!