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# Cross Residual DPCM for HEVC lossless coding

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# Contents

- 1. Introduction**
- 2. Proposed method**
- 3. Experimental results**
- 4. Conclusion**

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# Abstract

- This contribution proposes a Cross Residual DPCM (CR-DPCM) for the HEVC intra lossless coding
- The CR-DPCM is only applied to on the top of RDPCM
  - when the intra prediction modes are vertical and horizontal directions
  - needs one bit flag for the CR-DPCM in the horizontal and vertical prediction modes after RDPCM
- The average coding gain
  - 1.4% in class B and F sequences compared with RDPCM in “AI-Main”
  - 2.31% in class A, B, C, D, E, and F sequences compared with H.264/MPEG-4 AVC lossless coding (RDPCM) in Intra Main configuration of HM9.0 reference software

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# 1. Introduction

- This contribution proposes a method to improve the performance of the RDPCM (Residual DPCM) and SAP (Sample-based Angular Prediction)
  - by applying DPCM one more time to 90 degree (cross) direction on the RDPCM samples by computing RDO.
- The proposed CR-DPCM (Cross Residual DPCM) is only applied to the RDPCM signals with one bit flag in the horizontal and vertical prediction modes in lossless intra case

## 2. Proposed method

- Residual DPCM (CR-DPCM)

### Vertical RDPCM

Encoder

$$r'_{i,j} = \begin{cases} r_{i,j} & , i = 0, 0 \leq j \leq (N-1) \\ r_{i,j} - r_{(i-1),j} & , 1 \leq i \leq (M-1), 0 \leq j \leq (N-1) \end{cases}$$

Decoder

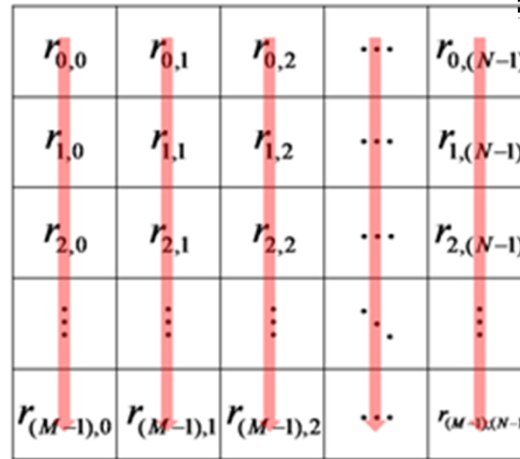
$$r_{i,j} = \sum_{k=0}^i r'_{k,j} \quad , 0 \leq i \leq (M-1), 0 \leq j \leq (N-1)$$

### Horizontal RDPCM

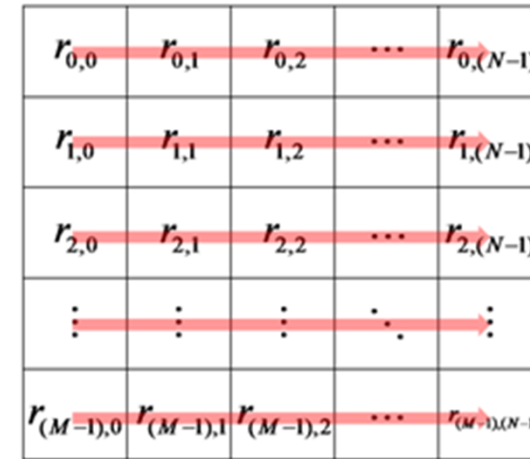
$$r'_{i,j} = \begin{cases} r_{i,j} & , 0 \leq i \leq (M-1), j = 0 \\ r_{i,j} - r_{i,(j-1)} & , 0 \leq i \leq (M-1), 1 \leq j \leq (N-1) \end{cases}$$

$$r_{i,j} = \sum_{k=0}^j r'_{i,k} \quad , 0 \leq i \leq (M-1), 0 \leq j \leq (N-1)$$

$r'_{i,j}$  : RDPCM samples  
 $r_{i,j}$  : prediction residual



(a)



(b)

Fig. 1 The MxN RDPCM when intra prediction mode is (a) vertical and (b) horizontal mode.

## 2. Proposed method

### Cross Residual DPCM (CR-DPCM)

#### Vertical RDPCM

Encoder

$$r'_{i,j} = \begin{cases} r_{i,j} & , i = 0, 0 \leq j \leq (N-1) \\ r_{i,j} - r_{(i-1),j} & , 1 \leq i \leq (M-1), 0 \leq j \leq (N-1) \end{cases}$$

Decoder

$$r_{i,j} = \sum_{k=0}^i r'_{k,j} \quad , 0 \leq i \leq (M-1), 0 \leq j \leq (N-1)$$

#### Horizontal RDPCM

$$r'_{i,j} = \begin{cases} r_{i,j} & , 0 \leq i \leq (M-1), j = 0 \\ r_{i,j} - r_{i,(j-1)} & , 0 \leq i \leq (M-1), 1 \leq j \leq (N-1) \end{cases}$$

$$r_{i,j} = \sum_{k=0}^j r'_{i,k} \quad , 0 \leq i \leq (M-1), 0 \leq j \leq (N-1)$$

#### CR-DPCM on RDPCM signals with one flag

#### Horizontal DPCM

Encoder

$$r''_{i,j} = \begin{cases} r'_{i,j} & , 0 \leq i \leq (M-1), j = 0 \\ r'_{i,j} - r'_{i,(j-1)} & , 0 \leq i \leq (M-1), 1 \leq j \leq (N-1) \end{cases}$$

Decoder

$$r'_{i,j} = \sum_{k=0}^j r''_{i,k} \quad , 0 \leq i \leq (M-1), 0 \leq j \leq (N-1)$$

#### Vertical DPCM

$$r''_{i,j} = \begin{cases} r'_{i,j} & , i = 0, 0 \leq j \leq (N-1) \\ r'_{i,j} - r'_{(i-1),j} & , 1 \leq i \leq (M-1), 0 \leq j \leq (N-1) \end{cases}$$

$$r'_{i,j} = \sum_{k=0}^i r''_{k,j} \quad , 0 \leq i \leq (M-1), 0 \leq j \leq (N-1)$$

$r''_{i,j}$  : CR-DPCM samples

## 2. Proposed method

- Encoding process

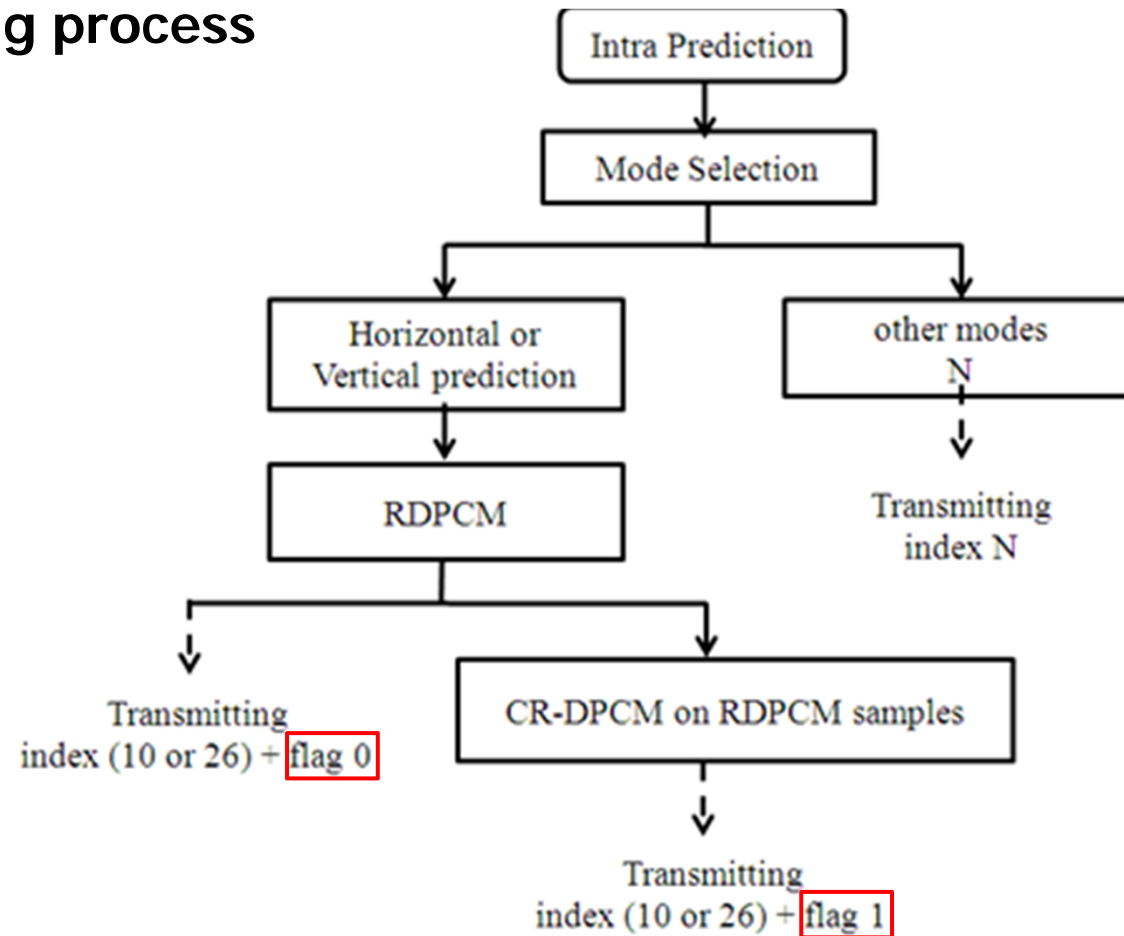


Fig. 2 The proposed lossless intra block encoding

## 2. Proposed method

- Decoding process

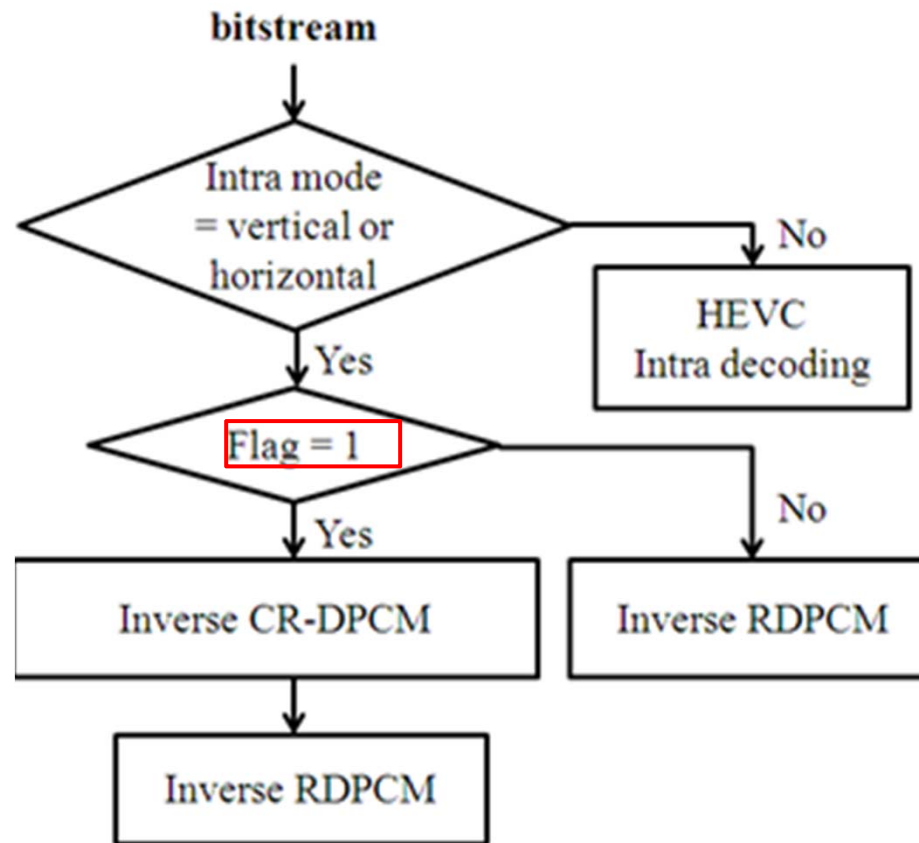


Fig. 3 The proposed lossless intra block decoding



### 3. Experimental results

- CR-DPCM is implemented on the top of RDPCM on HEVC range extension SW
  - **HM10.0\_RExt2.0 software**

Table 1. Performance of the CR-DPCM

Class \ Config.	All Intra Bit-rate saving		Random Access Bit-rate saving		Low Delay B Bit-rate saving	
	RDPCM	CRDPCM	RDPCM	CRDPCM	RDPCM	CRDPCM
Class F	-9.3%	-10.5%	-5.7%	-6.0%	-4.6%	-4.9%
Class B	-4.5%	-6.1%	-0.9%	-1.1%	-0.6%	-0.8%
SC (GBR)	%	%	%	%	%	%
RangeExt	%	%	%	%	%	%
Overall (w/o SC)	%	%	%	%	%	%
Overall (w/ SC)	%	%	%	%	%	%
Enc Time[%]	101%	112%	101%	101%	101%	100%
Dec Time[%]	96%	90%	103%	96%	96%	97%

### 3. Experimental results

- Additional information
  - Implemented HM9.0 reference SW
  - Experimental condition : Intra Main, "Common test conditions in JCTVC-K1003[3]"

Table 2. Results of bit saving of the CR-DPCM

	Saving bit(%)		Compression ratio	
	HM9.0 vs. <i>RDPCM</i>	HM9.0 vs. <i>CR-DPCM</i>	JPEG 2000	CR-DPCM
Class A	7.19	11.3	3.71	3.61
Class B	3.54	3.91	2.02	2.07
Class C	4.46	4.76	2.01	2.00
Class D	6.30	6.91	1.88	1.88
Class E	8.32	9.72	2.93	2.89
Class F	9.82	10.11	3.49	4.22
Overall	6.12	8.43	2.70	2.78

RDPCM (H.264/MPEG-4 AVC lossless coding) vs. CR-DPCM

### 3. Experimental results

- Additional information
  - Mode selection ratios in HM9.0 of the major four intra prediction modes

Table 3. Mode Selection Ratios of HEVC lossless coding and CR-DPCM method

	HM 9.0 (%)				CR-DPCM (%)			
	Planar	DC	Vertical	Horizontal	Planar	DC	Vertical	Horizontal
<b>Class A</b>	9.19	7.28	5.68	7.19	2.37	1.83	35.64	31.18
<b>Class B</b>	12.24	8.78	6.60	5.23	8.97	8.56	22.46	17.94
<b>Class C</b>	9.49	6.52	3.28	6.11	5.86	5.06	13.14	15.05
<b>Class D</b>	10.60	7.58	6.20	8.69	5.00	4.50	26.87	16.49
<b>Class E</b>	11.57	9.19	7.36	5.99	5.76	7.54	51.52	10.97
<b>Class F</b>	7.59	4.20	9.92	12.08	5.86	2.52	23.47	19.80
<b>Average</b>	10.25	7.58	6.42	6.92	5.81	5.25	29.49	20.82

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## 4. Conclusion

- In this contribution, the partial test results on the CR-DPCM are demonstrated
- The CR-DPCM (RDPCM+CR-DPCM) can improve the coding efficiency
  - With additional one bit flag
- The CR-DPCM can be taken into account in the next version of the test model and the draft text for HEVC range extension