# AHG7: Residual DPCM for HEVC Lossless Coding

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# Introduction

## Motivation

- Lossless coding has many applications, e.g. medical image compression.
- HEVC lossless coding is enabled by bypassing transform, quantization and in-loop filters.
- However, the performance of the current HEVC lossless coding (HM9.1) is not satisfactory and needs to be further improved.

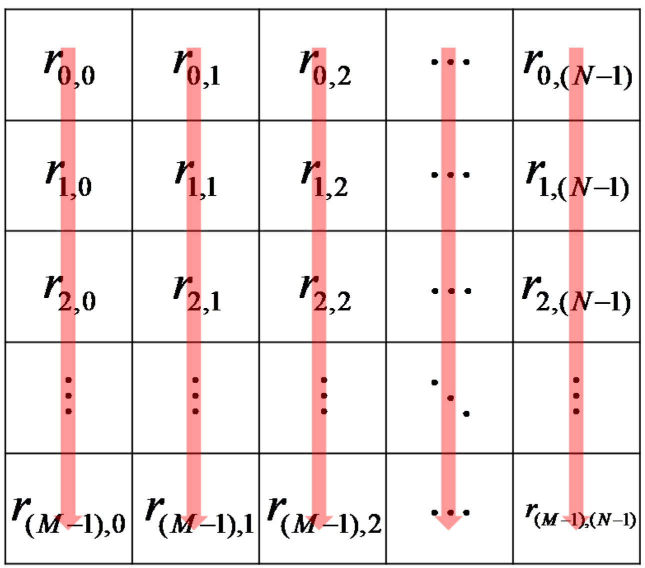
## What we propose

- The goal of this contribution is to propose a residual DPCM method for HEVC lossless coding.
- A simple DPCM is applied to the residual samples of intra-predicted PUs, when the intra prediction mode is either vertical or horizontal.
- The proposed method does not suffer from the throughput problem of sample-based prediction methods.
- The proposed coding tool is a part of H.264/AVC standard (8.5.15).

# Algorithm description (1/2)

- The proposed method is invoked when *cu_transquant_bypass_flag* is equal to 1, the prediction mode is intra, and the applicable intra prediction mode is equal to either vertical or horizontal mode.

## Vertical mode




- Encoding

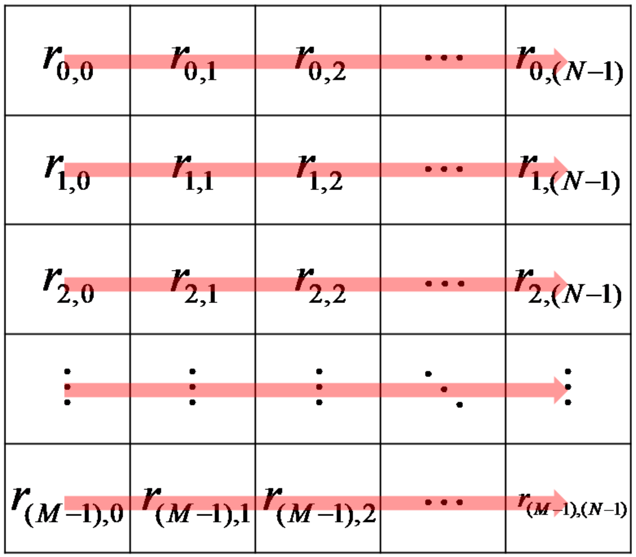
$$\tilde{r}_{i,j} = \begin{cases} r_{i,j} & ,i = 0,\ j = 0..(N-1) \\ r_{i,j} - r_{(i-1),j} & ,i = 1..(M-1),\ j = 0..(N-1) \end{cases}$$

- Decoding

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

# Algorithm description (2/2)

## Horizontal mode




- Encoding

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

- Decoding

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

- The reconstruction of the current residual sample does not depend on the availability of the previous residual sample.
- The proposed method is exactly the same as “Intra residual transform-bypass decoding process” specified in 8.5.15 of H.264/AVC standard specification.

# Test Results (1/2)

- Test condition
  - Implemented on top of HEVC Range Extension S/W
  - Common test condition of HEVC range extension (JCTVC-K1006) with lossless coding options enabled.
- Summary of the results
  - Coding gain is -8.0% in AI, -1.5% in RA, and -1.0% in LDB
  - No increase in both encoding and decoding time in all configurations.

| | AI | RA | LDB |
|---|---|---|---|
| RGB 4:4:4 | -9.9% | -1.8% | -1.2% |
| YCbCr 4:4:4 | -7.5% | -1.5% | -1.0% |
| YCbCr 4:2:2 | -6.2% | -1.2% | -0.7% |
| **Overall** | **-8.0%** | **-1.5%** | **-1.0%** |
| Enc Time[%] | 98% | 100% | 100% |
| Dec Time[%] | 89% | 97% | 97% |

# Test Results (2/2)

- Test condition
  - Implemented on top of HM 9.1 S/W
  - Common test condition of HEVC (JCTVC-K1100) with lossless coding enabled.
- Summary of the results
  - Coding gain in Main is -5.2% in AI, -1.3% in RA, -1.1% in LB, and -1.2% in LP.
  - Encoding time ranges 99% ~ 102%, decoding time ranges 93% ~ 101%.

| Config. / Class | Main | | | | HE10 | | | |
|---|---|---|---|---|---|---|---|---|
| | AI | RA | LB | LP | AI | RA | LB | LP |
| A | -6.7 | -2.4 | | | -6.7 | -2.6 | | |
| B | -3.2 | -0.6 | -0.5 | -0.7 | -4.0 | -1.4 | -1.2 | -1.4 |
| C | -3.9 | -1.0 | -0.8 | -0.9 | -4.6 | -1.5 | -1.4 | -1.4 |
| D | -5.9 | -1.3 | -1.0 | -1.1 | -6.8 | -1.9 | -1.6 | -1.6 |
| E | -7.6 | | -2.4 | -3.0 | -10.0 | | -4.7 | -4.7 |
| **Overall (w/o F)** | **-5.2** | **-1.3** | **-1.1** | **-1.2** | **-6.1** | **-1.8** | **-2.0** | **-2.1** |
| Overall (w/ F) | -5.9 | -2.1 | -1.8 | -2.0 | -7.0 | -2.9 | -2.9 | -2.9 |
| F | -9.2 | -5.7 | -4.8 | -4.9 | -11.4 | -7.6 | -6.4 | -6.4 |
| Enc Time [%] | 99 | 101 | 100 | 101 | 99 | 102 | 101 | 102 |
| Dec Time [%] | 96 | 100 | 99 | 101 | 93 | 98 | 97 | 98 |

# Conclusion

- A residual DPCM method for HEVC lossless coding is proposed.
- Coding gain
  - The coding gain in range extension software is -8.0% in AI, -1.5% in RA, and -1.0% in LDB, respectively.
  - The coding gain in HM 9.1 software is -5.2% in AI, -1.3% in RA, -1.1% in LDB, and -1.2% in LDP of Main configuration.
  - The coding gain in HM 9.1 software is -6.1% in AI, -1.8% in RA, -2.0% in LDB, and -2.1% in LDP of Main configuration.
- The intra prediction process and all the syntax elements remain unchanged.
- The proposed coding tool is exactly the same as "Intra residual transform-bypass decoding process" specified in 8.5.15 of H.264/AVC standard specification.
- It is suggested to adopt this tool into HEVC lossless coding.

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# THANK YOU

# Appendix – Details of HM-based test (1/2)

| | All Intra Main | | | All Intra HE10 | | |
|---|---|---|---|---|---|---|
| | compression ratio | | Bit-rate saving | compression ratio | | Bit-rate saving |
| | Reference | Tested | | Reference | Tested | |
| Class A | 2.1 | 2.3 | -6.7% | 1.4 | 1.5 | -6.7% |
| Class B | 2.1 | 2.1 | -3.2% | 1.3 | 1.4 | -4.0% |
| Class C | 2.0 | 2.0 | -3.9% | 1.3 | 1.4 | -4.6% |
| Class D | 1.8 | 2.0 | -5.9% | 1.2 | 1.3 | -6.8% |
| Class E | 2.7 | 2.9 | -7.6% | 1.7 | 1.9 | -10.0% |
| **Overall (w/o F)** | **2.1** | **2.2** | **-5.2%** | **3.1** | **3.6** | **-6.1%** |
| **Overall (w/ F)** | **2.5** | **2.7** | **-5.9%** | **1.4** | **1.5** | **-7.0%** |
| Class F | 4.6 | 5.2 | -9.2% | 3.1 | 3.6 | -11.4% |
| Enc Time[%] | 99% | | | 99% | | |
| Dec Time[%] | 96% | | | 93% | | |

| | Random Access Main | | | Random Access HE10 | | |
|---|---|---|---|---|---|---|
| | compression ratio | | Bit-rate saving | compression ratio | | Bit-rate saving |
| | Reference | Tested | | Reference | Tested | |
| Class A | 2.4 | 2.5 | -2.4% | 1.5 | 1.5 | -2.6% |
| Class B | 2.4 | 2.4 | -0.6% | 1.5 | 1.5 | -1.4% |
| Class C | 2.5 | 2.5 | -1.0% | 1.5 | 1.6 | -1.5% |
| Class D | 2.6 | 2.7 | -1.3% | 1.6 | 1.6 | -1.9% |
| **Overall (w/o F)** | **2.5** | **2.5** | **-1.3%** | **1.5** | **1.5** | **-1.8%** |
| **Overall (w/ F)** | **7.5** | **8.0** | **-2.1%** | **4.9** | **5.2** | **-2.9%** |
| Class F | 29.1 | 31.1 | -5.7% | 19.3 | 21.0 | -7.6% |
| Enc Time[%] | 101% | | | 102% | | |
| Dec Time[%] | 100% | | | 98% | | |

# Appendix – Details of HM-based test (2/2)

| | Low delay B Main | | | Low delay B HE10 | | |
|---|---|---|---|---|---|---|
| | compression ratio | | Bit-rate saving | compression ratio | | Bit-rate saving |
| | Reference | Tested | | Reference | Tested | |
| Class B | 2.4 | 2.4 | -0.5% | 1.5 | 1.5 | -1.2% |
| Class C | 2.5 | 2.5 | -0.8% | 1.5 | 1.6 | -1.4% |
| Class D | 2.6 | 2.7 | -1.0% | 1.6 | 1.6 | -1.6% |
| Class E | 3.2 | 3.3 | -2.4% | 1.9 | 2.0 | -4.7% |
| **Overall (w/o F)** | **2.6** | **2.7** | **-1.1%** | **1.6** | **1.6** | **-2.0%** |
| **Overall (w/ F)** | **11.5** | **12.0** | **-1.8%** | **7.5** | **7.9** | **-2.9%** |
| Class F | 47.1 | 49.4 | -4.8% | 31.2 | 33.0 | -6.4% |
| Enc Time[%] | 100% | | | 101% | | |
| Dec Time[%] | 99% | | | 97% | | |

| | Low delay P Main | | | Low delay P HE10 | | |
|---|---|---|---|---|---|---|
| | compression ratio | | Bit-rate saving | compression ratio | | Bit-rate saving |
| | Reference | Tested | | Reference | Tested | |
| Class B | 2.3 | 2.3 | -0.7% | 1.4 | 1.5 | -1.4% |
| Class C | 2.4 | 2.5 | -0.9% | 1.5 | 1.6 | -1.4% |
| Class D | 2.6 | 2.6 | -1.1% | 1.6 | 1.6 | -1.6% |
| Class E | 3.1 | 3.2 | -3.0% | 1.9 | 2.0 | -4.7% |
| **Overall (w/o F)** | **2.6** | **2.6** | **-1.2%** | **1.6** | **1.6** | **-2.1%** |
| **Overall (w/ F)** | **11.4** | **11.9** | **-2.0%** | **7.5** | **7.9** | **-2.9%** |
| Class F | 46.7 | 48.9 | -4.9% | 31.0 | 32.9 | -6.4% |
| Enc Time[%] | 101% | | | 102% | | |
| Dec Time[%] | 101% | | | 98% | | |