# Mode Dependent 2-step Transform
# for Intra Coding

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# Introduction

▶ The KLT which is designed for intra prediction residual is an effective technology in terms of coding efficiency.

▶ However, its complexity is higher than DCT's in terms of number of operation and encoder/decoder software runtime.

▶ This contribution presents an approach for the unification of MDDT and ROT, which encoding/decoding runtimes are comparable with those of TMuC0.9-hm software

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# Proposed Method (1)

▶ **2-step Transform**

- First Transform is either of Chen-DCT or AVC transform.

- $2^{nd}$ 4x4 KLT is applied for low frequency component.

- For T8, norm adjusting is done before 4x4 KLT

→ Reduction of number of operation

▶ **Mode Dependent**

- $2^{nd}$ KLT is controlled according to the table on intra prediction mode.

- No explicit signaling to select $2^{nd}$ KLT matrix.

- No need for additional test in encoder

→ Reduction of encoding run time

# Proposed Method (2)

▶ DDST model based 2$^{nd}$ transform matrix

- The matrix of 2$^{nd}$ KLT is one for each size.

- The covariance matrix for 2$^{nd}$ KLT is derived by $M^2 = T M^1 T^T$

  - $M^1$ is the covariance matrix presented in JCTVC-B24 (I2R) and JCTVC-C108(Samsung)

- $M^1$ with gentle sloop is used. 50% for T8, 25% for T16 and T32.

  → Utilization of the study of optimal transform for intra residual

▶ 1 step MDDT is used for 4x4 block

- 2-step transform is not used

  - The number of operation / block is $O(N^3)$. $N$ is transform block width.

  - The number of operation / pixel is $O(N)$

  - Its for 4x4 block is smallest in all transform block sizes

- DDST could be applied for complexity reduction if necessary.

# Proposed Method (3)

▸ Disabled Mode Dependent Coefficient Scan

  ■ In order to evaluate transform only, the scanning is not changed.

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# Experimental Results

▸ Table below shows results of proposed method with reference to TMuC 0.9-hm (negative BD-rate value indicates gain).

| | Intra | | | Intra LoCo | | |
|---|---|---|---|---|---|---|
| | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -1.7 | -1.7 | -1.6 | -2.1 | -1.0 | -0.7 |
| Class B | -1.0 | -0.9 | -0.8 | -1.5 | -0.7 | -0.6 |
| Class C | -1.3 | -1.0 | -1.1 | -1.7 | -0.8 | -0.8 |
| Class D | -1.3 | -1.1 | -1.0 | -1.7 | -0.7 | -0.7 |
| Class E | -1.7 | -1.8 | -1.8 | -2.4 | -1.0 | -1.2 |
| All | -1.3 | -1.2 | -1.2 | -1.8 | -0.8 | -0.8 |
| Enc Time[%] | 103 % | | | 106 % | | |
| Dec Time[%] | 101 % | | | 108 % | | |

| | Random Access | | | Random Access LoCo | | |
|---|---|---|---|---|---|---|
| | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.8 | -0.3 | -0.1 | -0.8 | -0.1 | -0.1 |
| Class B | -0.5 | -0.2 | -0.3 | -0.6 | -0.2 | -0.2 |
| Class C | -0.7 | -0.5 | -0.4 | -0.6 | -0.3 | -0.2 |
| Class D | -0.6 | -0.2 | 0.1 | -0.5 | -0.1 | -0.1 |
| Class E | -1.7 | -1.8 | -1.8 | -2.4 | -1.0 | -1.2 |
| All | -0.6 | -0.3 | -0.2 | -0.6 | -0.2 | -0.1 |
| Enc Time[%] | 100 % | | | 101 % | | |
| Dec Time[%] | 100 % | | | 101 % | | |

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# Conclusions

▶ This contribution proposes low complexity unification of MDDT and ROT (2-step transform).

  ■ Mode Dependency make small the increase of encoding runtime

  ■ 2-step Transform make small the increase of the number of operation.

▶ It provides 1.3% and 0.6% gain for Intra HE and Random Access HE

▶ We recommend JCT-VC to:

  ■ Establish a CE on Transform itself for further study in the view point of trade off between coding gain and complexity (number of operation, encoder and decoder runtime).

  ■ Include this proposal into above CE.

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# Thank you

# Proposed Method (5)

- ▶ Bit-width
  - Bit-width of the matrix of 2$^{nd}$ KLT is 7 bit.
  - Decoding Flow (worst case)
    - Inverse 2nd Horizontal KLT: +7bit
    - Inverse 2nd Vertical KLT: + 7bit
    - Shift Down: -14bit
    - → No affect to following Inverse DCT.
    - Inverse Chen-DCT or AVC T8.

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## ▶ Number of Operation

| | | Proposal | | | |
|---|---|---|---|---|---|
| | | 1 step MDDT 4T | AVC 8T + KLT 4T | Chen 16T + KLT 4T | Chen 32T + KLT 4T |
| Ops. / Block | Addition (+) | 96 | 624 | 2,488 | 12,536 |
| | Multiplication (*) | 128 | 144 | 1,536 | 7,552 |
| | Shift (>>, <<) | 32 | 208 | 864 | 4,256 |
| | Total | 256 | 976 | 4,888 | 24,344 |
| Ops. / Pixel | Addition (+) | 6.00 | 9.75 | 9.72 | 12.24 |
| | Multiplication (*) | 8.00 | 2.25 | 6.00 | 7.38 |
| | Shift (>>, <<) | 2.00 | 3.25 | 3.38 | 4.16 |
| | Total | **16.00** | **15.25** | **19.09** | **23.77** |
| Difference of Ops./ Pixel against TMuC 0.9 | Addition (+) | 2.00 | 1.75 | 0.47 | 0.12 |
| | Multiplication (*) | 8.00 | 2.25 | 0.50 | 0.13 |
| | Shift (>>, <<) | 1.00 | 0.75 | 0.13 | 0.03 |
| | Total | 11.00 | 4.75 | 1.09 | 0.27 |

Table 2. Number of operations of transforms in this proposal

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# Proposed Method (7)

▶ **Memory Requirement**

- ■ 7bit 4x4 Transform Matrix for T8,T16,T32
  - ● → 7bit * 4*4*3 = 48 byte

- ■ 7bit and 9 mode, Row and Column 4x4 Transform Matrix
  - ● → 7bit * 4*4*18 = 288 byte
  - ● Can be reduced to 7 bit * 4 * 4 = 16 byte If DDST is used.

- ■ No additional dequantization/quantization table
  - ● Elements are equal to HM's one. Just Indexing only.

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