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CE7: Mode-dependent transform, residual reordering and coefficient scanning for intra prediction residue

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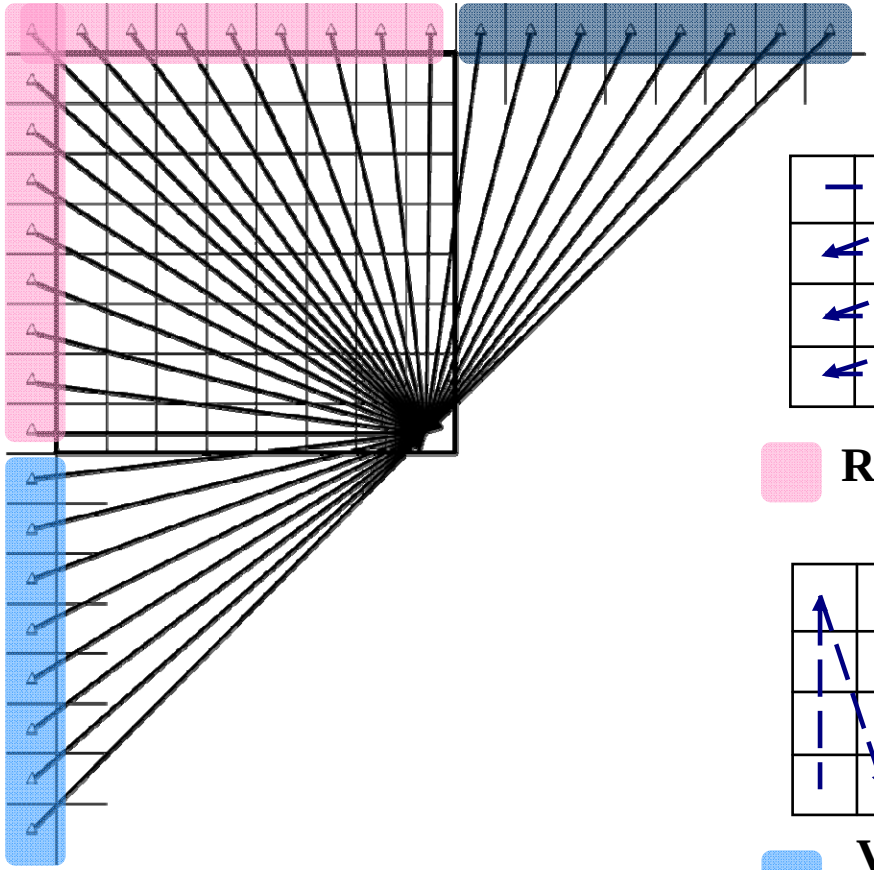
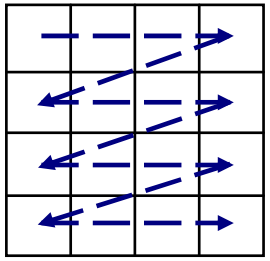
Outline

- Algorithm
- Simulation results
- Complexity
- Summary

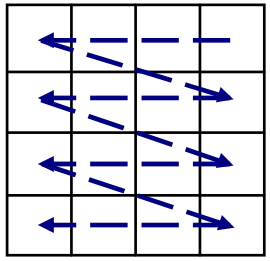
Algorithm

- Mode-dependent residual reordering

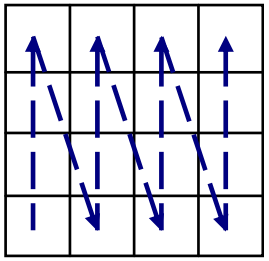




Raster Scan



Horizontal Flipping



Vertical Flipping

Algorithm

- Mode-dependent transform

$$\boldsymbol{F=D\cdot X\cdot D^{T}}$$

	Transform matrix $\boldsymbol{D}$	
	DC prediction	Others
4x4 modes (0~17)	DCT (TMuC 0.9)	S_4
8x8 modes (0~33)	DCT (TMuC 0.9)	S_8

Algorithm

- Mode-dependent transform

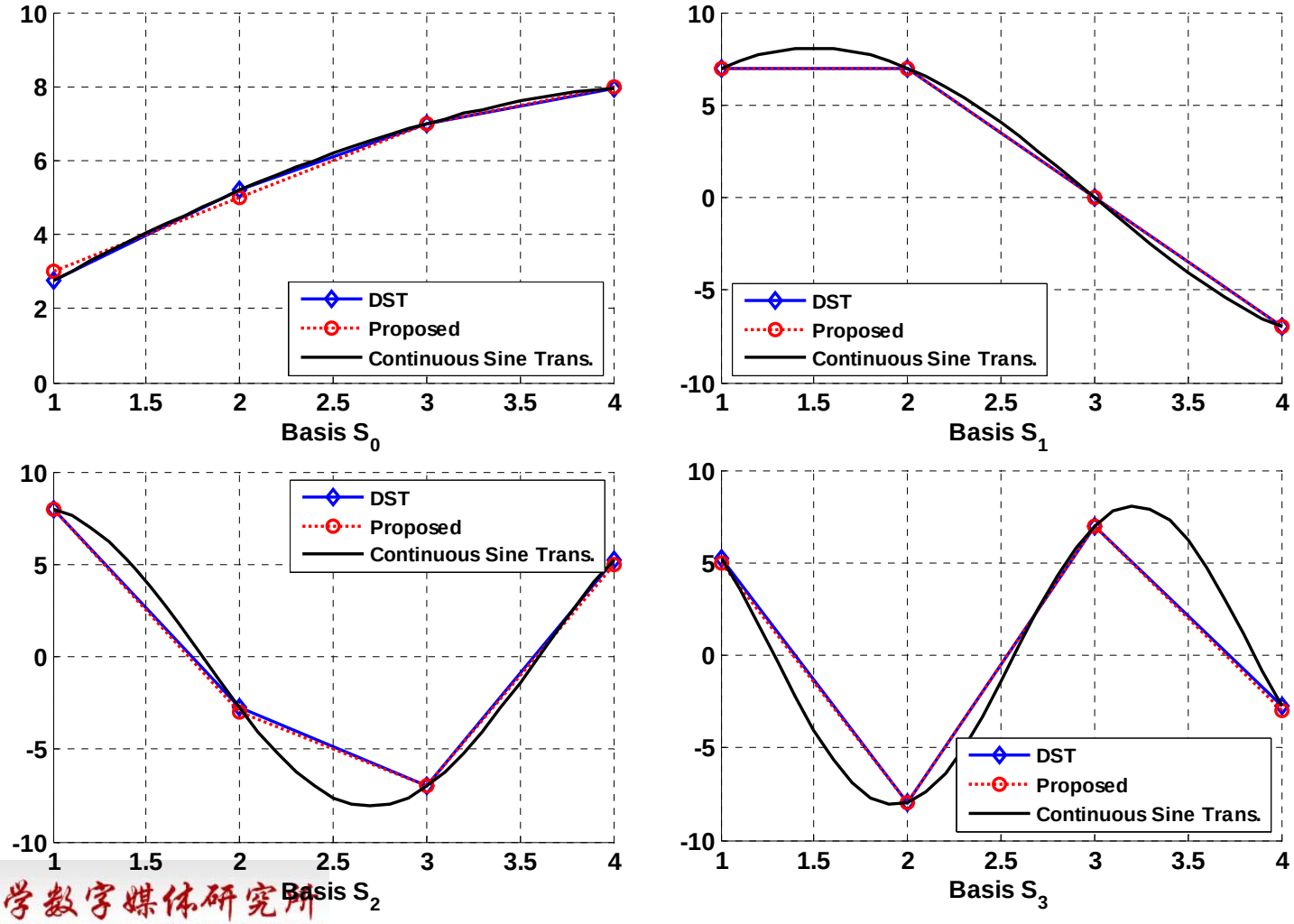
$$S_4 = \begin{bmatrix} 3 & 5 & 7 & 8 \\ 7 & 7 & 0 & -7 \\ 8 & -3 & -7 & 5 \\ -5 & 8 & -7 & 3 \end{bmatrix} \qquad S_4 \bullet S_4^T = \begin{bmatrix} 147 & 0 & 0 & 0 \\ 0 & 147 & 0 & 0 \\ 0 & 0 & 147 & 0 \\ 0 & 0 & 0 & 147 \end{bmatrix}$$

- The proposed 4x4 matrix is actually an approximation of 4x4 DST proposed by I^{2}R and Samsung

$$C_{i,j} = \frac{2}{\sqrt{2N+1}} \sin\left(\frac{(2i-1)j\pi}{2N+1}\right)$$

Algorithm

- Mode-dependent transform



Algorithm

- Mode-dependent transform
  - 4-point forward transform

$$\begin{bmatrix} f_0 \\ f_1 \\ f_2 \\ f_3 \end{bmatrix} = \begin{bmatrix} 3 & 5 & 7 & 8 \\ 7 & 7 & 0 & -7 \\ 8 & -3 & -7 & 5 \\ -5 & 8 & -7 & 3 \end{bmatrix} \cdot \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

$$\begin{aligned} a_0 &= x_0 - x_1 \\ a_1 &= x_1 + x_3 \\ a_2 &= (x_2 << 3) - x_2 \\ a_3 &= x_0 + x_1 - x_3 \\ b_0 &= a_0 << 2 \\ b_1 &= a_1 << 2 \end{aligned}$$

$$\begin{aligned} c_0 &= b_0 + a_2 \\ f_0 &= -a_0 + c_0 + (a_1 << 3) \\ f_1 &= (a_3 << 3) - a_3 \\ f_2 &= (a_0 << 3) - a_2 + b_1 + a_1 \\ f_3 &= -a_0 - c_0 + b_1 - a_1 \end{aligned}$$

  - 4-point inverse transform

$$\begin{bmatrix} f_0 \\ f_1 \\ f_2 \\ f_3 \end{bmatrix} = \begin{bmatrix} 3 & 7 & 8 & -5 \\ 5 & 7 & -3 & 8 \\ 7 & 0 & -7 & -7 \\ 8 & -7 & 5 & 3 \end{bmatrix} \cdot \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

$$\begin{aligned} a_0 &= x_0 + x_2 \\ a_1 &= x_2 - x_3 \\ a_2 &= (x_1 << 3) - x_1 \\ a_3 &= x_0 - x_2 - x_3 \\ b_0 &= a_0 << 2 \\ b_1 &= a_1 << 2 \end{aligned}$$

$$\begin{aligned} c_0 &= b_0 + a_2 \\ f_0 &= -a_0 + c_0 + b_1 + a_1 \\ f_1 &= a_0 + c_0 - (a_3 << 3) \\ f_2 &= (a_3 << 3) - a_3 \\ f_3 &= (a_0 << 3) - a_2 - b_1 + a_1 \end{aligned}$$

Algorithm

- Mode-dependent transform
  - S_8 is analytically obtained as

$$S_8 = \begin{bmatrix} 19 & 31 & 40 & 47 & 52 & 54 & 54 & 51 \\ 47 & 60 & 56 & 35 & 5 & -26 & -49 & -56 \\ 58 & 48 & 1 & -47 & -60 & -29 & 24 & 58 \\ 62 & 12 & -53 & -45 & 27 & 62 & 12 & -53 \\ 56 & -30 & -53 & 36 & 48 & -42 & -44 & 47 \\ 46 & -58 & 3 & 56 & -49 & -14 & 62 & -37 \\ 33 & -61 & 55 & -20 & -27 & 59 & -58 & 26 \\ -17 & 38 & -54 & 62 & -62 & 52 & -35 & 13 \end{bmatrix}$$

Algorithm

- Mode-dependent Coefficient Scanning

	Logical prediction modes (0~33)
Scanning Method #0	7~11
Scanning Method #1	23~27
Scanning Method #2	DC
Scanning Method #3	1~2, 16~18, 32~33
Scanning Method #4	3~6, 12~15
Scanning Method #5	19~22, 28~31

Simulation results

- Intra

	Intra HE			Intra Loco		
Class A	-2.5	-2.3	-2.3	-2.3	-0.6	-0.2
Class B	-1.3	-1.4	-1.4	-2.1	-1.6	-1.7
Class C	-2.1	-1.7	-1.6	-2.5	-1.8	-1.8
Class D	-2.2	-1.8	-1.8	-2.5	-1.9	-1.9
Class E	-2.7	-2.3	-2.1	-3.4	-1.1	-1.4
All average	**-2.0**	**-1.8**	**-1.7**	**-2.5**	**-1.5**	**-1.5**

Simulation results

- Random Access

	RA HE			RA Loco		
Class A	-1.1	-0.4	-0.0	-0.9	-0.0	-0.2
Class B	-0.7	-0.3	-0.3	-1.0	-0.5	-0.6
Class C	-1.0	-0.5	-0.7	-1.0	-0.6	-0.8
Class D	-0.9	-0.4	-0.3	-0.8	-0.5	-0.5
Class E						
All average	**-0.9**	**-0.4**	**-0.4**	**-0.9**	**-0.5**	**-0.5**

Complexity

Complexity Metric	4×4 Transform	8×8 Transform
Operation counts for transform a *N*-point 1-D vector	DC: no change Others: 15 adds, 6 shifts	DC: no change Others: 64 muls, 56 adds
Memory requirements for transforms	no change	no change
Memory requirements for coefficient scanning	6×4×16/8=48 byte (4 bits for one scan position, 2 for *x*, *2 for y)*	6×6 ×64/8=288 byte (6 bits for one scan position, 3 for *x*, *3 for y)*
Minimum bit-precision (9-bit input)	DC: no change Others: 19bits	DC: no change Others: 27bits
Other operations and memory requirements	Mode 1~8, 26~33: residual reordering process Others: no change	Mode 1~8, 26~33: residual reordering process Others: no change

Complexity

- Encoding and decoding running time

Encoding Config.	Encoding		Decoding	
	Ours (D284)	CC MediaTek (D290)	Ours (D284)	CC MediaTek (D290)
Intra HE	104%	103%	104%	105%
Intra Loco	106%	106%	103%	114%
RA HE	107%	101%	108%	108%
RA Loco	99%	99%	115%	114%

Conclusion

- The coding efficiency is promoted using the proposed algorithm with applicable additional complexity.
- Recommend adoption into the development of HM test model.

Acknowledgement

- We would like to thank MediaTek Inc. for doing Cross-verification of our proposal

Thanks!