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JCTVC-D107

CE7: Experimental results of One-Dimensional Directional Unified Transform

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Summary

- **CE7: Alternative transforms in HEVC**
  - 1DDUT (1 Dimensional Directional Unified Transform)
    - JCTVC-A119, JCTVC-B042, JCTVC-C080
    - Related Doc: JCTVC-D392

      (Joint proposal with Qualcomm/I2R/Toshiba/Hauwei)

- **Experimental results**
  - BD-rate gain compared with common conditions
    - I slice only : 2.12% (HE) 2.31% (LoCo)
    - Random access : 0.93% (HE) 0.76% (LoCo)
    - Low delay : 0.30% (HE) 0.24% (LoCo)
  - Encoding time and decoding time
    - Almost same as the anchor

One-Dimensional Directional Unified Transform (1DDUT)

- **4/8-point mode dependent directional transform**
  - Unified two 1D transform matrices (DCT:$\mathbf{T}^2$ and Directional Transform:$\mathbf{T}^1$)
  - Selecting four combinations of 1D transform matrices each prediction mode
  - Applied for block sizes of 4x4 and 8x8 only

Transform Index	1st 1D Transform	2nd 1D Transform
0	$\mathbf{T}^1$	$\mathbf{T}^2$
1	$\mathbf{T}^2$	$\mathbf{T}^1$
2	$\mathbf{T}^{2*}$	$\mathbf{T}^{2*}$
3	$\mathbf{T}^1$	$\mathbf{T}^1$

- **Coefficient Scan scheme (update part of this proposal)**
  - Eight fixed scan based on MDDT initial scan
  - For DCT (DC prediction), default scan is applied
    (HE: HHI-based scan, LC: Zigzag scan)

*: Note that DCT for DC prediction is same as one of TMuC software.

Proposed transform matrix (same as previous contribution)

- DCT and Directional transform for 4x4 block

DCT:T^1 DT:T^2

$$T^1_{N=4} = \begin{bmatrix} 64 & 64 & 64 & 64 \\ 84 & 35 & -35 & -84 \\ 65 & -64 & -64 & 64 \\ 35 & -84 & 84 & -35 \end{bmatrix}, \quad T^2_{N=4} = \begin{bmatrix} 40 & 60 & 73 & 76 \\ 75 & 64 & -10 & -81 \\ -79 & 32 & 77 & -57 \\ 54 & -87 & 71 & -27 \end{bmatrix}$$

- DCT and Directional transform for 8x8 block

DCT:T^1 DT:T^2

$$T^1_{N=8} = \begin{bmatrix} 45 & 45 & 45 & 45 & 45 & 45 & 45 & 45 \\ 63 & 53 & 36 & 12 & -12 & -36 & -53 & -63 \\ 59 & 24 & -24 & -59 & -59 & -24 & 24 & 59 \\ 53 & -12 & -63 & -36 & 36 & 63 & 12 & -53 \\ 45 & -45 & -45 & 45 & 45 & -45 & -45 & 45 \\ 36 & -63 & 12 & 53 & -53 & -12 & 63 & -36 \\ 24 & -59 & 59 & -24 & -24 & 59 & -59 & 24 \\ 12 & -36 & 53 & -63 & 63 & -53 & 36 & -12 \end{bmatrix}, \quad T^2_{N=8} = \begin{bmatrix} 17 & 27 & 35 & 44 & 51 & 55 & 57 & 57 \\ 38 & 56 & 60 & 45 & 16 & -20 & -46 & -58 \\ -49 & -55 & -19 & 38 & 66 & 38 & -18 & -55 \\ 59 & 28 & -40 & -56 & 12 & 63 & 20 & -54 \\ 61 & -9 & -63 & 17 & 54 & -35 & -47 & 44 \\ 53 & -50 & -15 & 61 & -39 & -24 & 62 & -34 \\ 42 & -63 & 45 & -4 & -35 & 59 & -57 & 24 \\ 23 & -46 & 58 & -62 & 57 & -47 & 30 & -10 \end{bmatrix}$$

IntraPredMode and TransformIdx

IntraPredMode [puParIdx]	IntraPredType [puParIdx]	IntraPredAngleID [puParIdx]	TransformIdx [puParIdx]
0	Intra_Vertical	0	**0**
1	Intra_Horizontal	0	**1**
2	Intra_DC	-	**2**
3	Intra_Vertical	-8	**3**
4	Intra_Vertical	-4	**3**
5	Intra_Vertical	4	**0**
6	Intra_Vertical	8	**0**
7	Intra_Horizontal	-4	**3**
8	Intra_Horizontal	4	**1**
9	Intra_Horizontal	8	**1**
10	Intra_Vertical	-6	**3**
11	Intra_Vertical	-2	**0**
12	Intra_Vertical	2	**0**
13	Intra_Vertical	6	**0**
14	Intra_Horizontal	-6	**3**
15	Intra_Horizontal	-2	**1**
16	Intra_Horizontal	2	**1**

IntraPredMode [puParIdx]	IntraPredType [puParIdx]	IntraPredAngleID [puParIdx]	TransformIdx [puParIdx]
17	Intra_Horizontal	6	**1**
18	Intra_Vertical	-7	**3**
19	Intra_Vertical	-5	**3**
20	Intra_Vertical	-3	**3**
21	Intra_Vertical	-1	**0**
22	Intra_Vertical	1	**0**
23	Intra_Vertical	3	**0**
24	Intra_Vertical	5	**0**
25	Intra_Vertical	7	**0**
26	Intra_Horizontal	-7	**3**
27	Intra_Horizontal	-5	**3**
28	Intra_Horizontal	-3	**3**
29	Intra_Horizontal	-1	**1**
30	Intra_Horizontal	1	**1**
31	Intra_Horizontal	3	**1**
32	Intra_Horizontal	5	**1**
33	Intra_Horizontal	7	**1**

Transform Index is mapped to IntraPredMode Table for UIP.

Experimental Conditions

- TMuC software version 0.9
- Test conditions follow common conditions completely (JCTVC-C500).
- Coding structures are based on CE7 condition:
  - I slice only coding structure
    - High efficiency and Low complexity
  - Random access coding structure
    - High efficiency and Low complexity
  - Low delay coding structure
    - High efficiency and Low complexity

Experimental results for I slice only

*Negative value means gain

	High efficiency (HE)			Low complexity (LoCo)		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-2.70	-2.97	-2.86	-2.97	-1.35	-0.94
Class B	-1.36	-1.76	-1.69	-1.66	-1.58	-1.51
Class C	-2.19	-1.96	-1.94	-2.37	-1.87	-1.91
Class D	-2.18	-1.93	-1.92	-2.15	-1.86	-1.84
Class E	-2.84	-2.74	-2.45	-3.12	-0.91	-1.50
All	**-2.12**	**-2.14**	**-2.05**	**-2.31**	**-1.57**	**-1.60**
Enc Time[%]	**106%**			**105%**		
Dec Time1[%]	**104% (without ouputting yuv file)**			**107% (without ouputting yuv file)**		
Dec Time2[%]	**103% (with ouputting yuv file)**			**104% (with ouputting yuv file)**		

- The BD-rate gain of 1DDUT is 2.2% on average.
- The encoding time and the decoding time is almost same as the anchor (about just 5% increase).

Experimental results for Random access

*Negative value means gain

	High efficiency (HE)			Low complexity (LoCo)		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-1.16	-0.51	-0.20	-1.03	-0.18	0.04
Class B	-0.77	-0.53	-0.55	-0.63	-0.48	-0.51
Class C	-0.99	-0.62	-0.61	-0.88	-0.68	-0.59
Class D	-0.95	-0.72	-0.33	-0.66	-0.37	-0.19
Class E						
All	**-0.93**	**-0.60**	**-0.46**	**-0.76**	**-0.47**	**-0.37**
Enc Time[%]	**100%**			**101%**		
Dec Time1[%]	**105% (without ouputting yuv file)**			**105% (without ouputting yuv file)**		
Dec Time2[%]	**104% (with ouputting yuv file)**			**92% (with ouputting yuv file)**		

- The BD-rate gain of 1DDUT is 0.8% on average.
- The encoding time and the decoding time is almost same as the anchor.

Experimental results for Low delay

*Negative value means gain

	High efficiency (HE)			Low complexity (LoCo)		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A						
Class B	-0.24	-0.35	-0.10	-0.20	-0.18	-0.25
Class C	-0.42	-0.41	-0.47	-0.35	-0.34	-0.41
Class D	-0.23	-0.84	-0.31	-0.23	-0.03	-0.25
Class E	-0.36	0.08	0.24	-0.15	0.40	-0.22
All	**-0.30**	**-0.41**	**-0.18**	**-0.24**	**-0.07**	**-0.29**
Enc Time[%]	**100%**			**100%**		
Dec Time1[%]	**101% (without ouputting yuv file)**			**102% (without ouputting yuv file)**		
Dec Time2[%]	**99% (with ouputting yuv file)**			**101% (with ouputting yuv file)**		

- The BD-rate gain of 1DDUT is 0.2% on average.
- The encoding time and the decoding time is almost same as the anchor.

Complexity analysis

- Complexity of N-point 1D transform
  - Operation counts and Memory sizes

	4x4 block	8x8 block
Operation counts	16 muls,12 adds (4-point transform)	64 muls,56 adds (8-point transform)
Memory sizes of additional transform matrices	16 byte (8x4x4 bits)	64 byte (8x8x8 bits)
Memory sizes of additional fixed scan order	16 byte (4x4x4x8 bits)	384 byte (6x8x8x8 bits)

  - Bit-precision: 32-bit (for inverse transform and quantization)
  - No internal rounding

→ Operation counts can be reduced by replacing add/shift operations.

Conclusion

- **Experimental results of 1DDUT on CE7**
  - BD-rate gain of 1DDUT compared with common anchor
    - I slice only : 2.12% (HE) 2.31% (LoCo)
    - Random access : 0.93% (HE) 0.76% (LoCo)
    - Low delay : 0.30% (HE) 0.24% (LoCo)
  - Encoding time and decoding time
    - Almost same as the anchor (up to 7% increase for I-only case)

- **Suggestion**
  - 1DDUT is a tool of improving BD-rate gain with minimum complexity increase for intra coding and is suggested to introduce it into HEVC test model.

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