CE 7 : Mode-dependent DCT/DST for intra prediction in video coding

JCTVC-D033

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Outline

- Prior and Related Work
- Background and Example
- Implementation in TMuC 0.9
- Experimental Results
- Conclusions

Prior & Related Work - 1

1. ICASSP, March 2010

(Jingning Han, Ankur Saxena and Prof. Kenneth Rose, University of California- Santa Barbara)

- Derived and proposed DST for Intra coding
- Implementation in JM 11.0

2. JCTVC-B024, July 2010

(C. Yeo, Y. H. Tan, Z. Li and S.Rahardja; I2R Singapore)

- Similar DST derived as the above ICASSP paper
- Implementation in JM11.0KTA2.6r1

3. JCTVC-C108, October 2010

(Ankur Saxena and Felix C. Fernandes, Samsung)

4. JCTVC-C037 , October 2010, (C. Yeo, Y. H. Tan, Z. Li and S.Rahardja; I2R Singapore)

Prior & Related Work - 2

- Low complexity-Integer DST at size 4*4
  - Jingning Han, Ankur Saxena, Vinay Melkote and Prof Kenneth Rose

$$
\begin{aligned}
T_S &\approx T_{IS} = \Lambda_S H_S \\
&= \left(\frac{1}{\sqrt{147}} \cdot I\right) \begin{pmatrix} 3 & 5 & 7 & 8 \\ 7 & 7 & 0 & -7 \\ 8 & -3 & -7 & 5 \\ 5 & -8 & 7 & -3 \end{pmatrix},
\end{aligned}
$$

  - Numerous other contributions related to mode-dependent DCT/DST at this JCTVC meeting

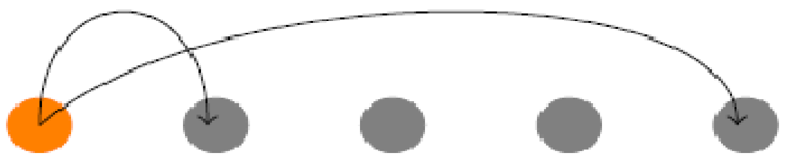
Block Diagram for Unified Intra Prediction

- DCT is used as the transform for all block sizes 4*4, 8*8, 16*16 and 32*32 following intra-prediction

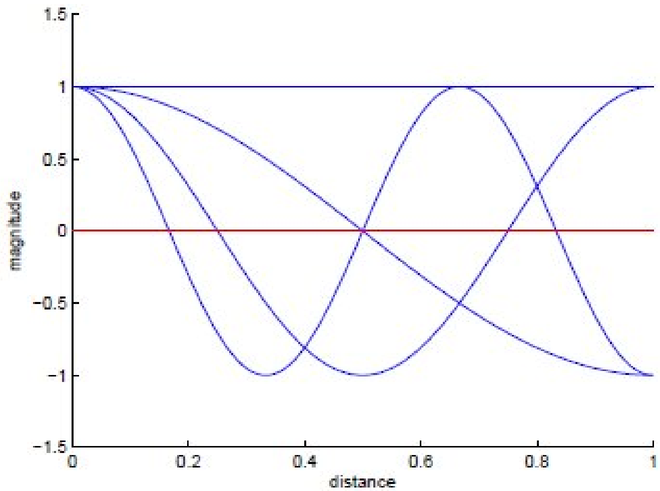
- ***Proposed*** : Mode-dependent DCT/DST for intra prediction

Motivation for DST: One-Sided Intra Prediction

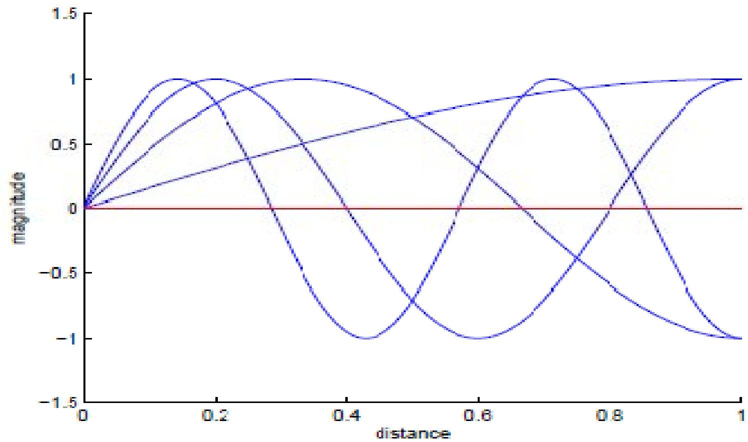
- When prediction is performed from one-side, the energy in prediction error residuals (gray pixels) increases as we go away from the boundary (orange pixel).



- A sine transform (with basis functions as shown below) is better adaptable to these prediction residual statistics.



- ***Orthogonal continuous cosine bases***

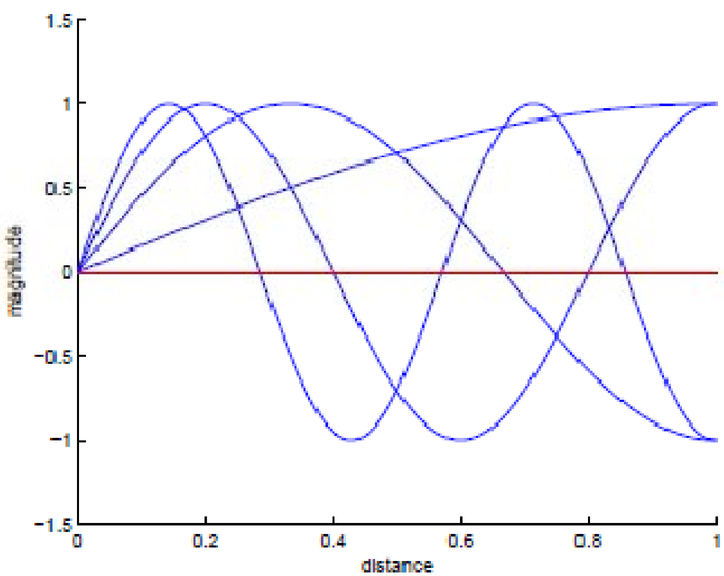


- ***Orthogonal continuous sine bases***

Optimal Residual Transform

- The KLT of the autocorrelation matrix $R_{\underline{yy}} = E(\underline{yy}^T)$ is a DST [Yueh, Applied Mathematics, 2005]:

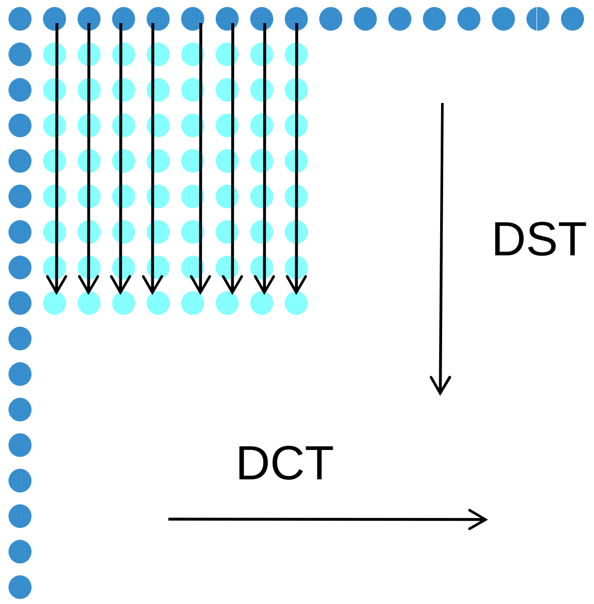
$$[T_S]_{j,i} = \left(\frac{2}{\sqrt{2N+1}} \sin \frac{(2j-1)i\pi}{2N+1} \right)$$



- Derivation and more details in the ICASSP paper and our proposal JCTVC-C108

Sine bases

Example : Vertical Mode



- Vertical Mode
- 1-d prediction in vertical direction

- DST in vertical direction
- DCT in horizontal direction

- **Implementation in TMuC 0.9**

Implementation in TMuC 0.9

- Experiments were performed for Intra HE, Intra LC, Random Access HE, Random Access LC configurations according to stipulated conditions in CE 7 description (JCTVC-C507, Robert Cohen et al.)

- **Scanning :** Uses TMuC 0.9 scanning for the transform coefficients ***without any modification***

- **DCT Matrices** Uses TMuC 0.9 DCT for both intra and inter slices ***without any modification***

- **Quantization & Inverse Quantization Tables:** Use TMuC 0.9 quantization and inverse quantization matrices for Intra and Inter slices ***without any modification***

More Details about implementation

- No new horizontal or vertical DCT kernels were introduced in our proposal
  - If new horizontal or vertical DCT kernels are used, then there will be 2 DCT's in the standard for intra slices
  - This will also require a new set of quantization and inverse quantization tables only for Intra –slices

- No new quantization/inverse quantization matrices were introduced
  - If new quantization/inverse quantization matrices are introduced for this **Intra tool**, this may require the storage of additional 960 elements for size 4*4 and 8*8

TMuC 0.9 quantization matrices storage for requirement at size 4 and 8

- There are 6 quantization and 6 inverse quantization tables at a block size.
- An example of one quantization table at size 4*4

```
{ 13107, 8066,13107, 8066,
   8066, 5243, 8066, 5243,
  13107, 8066,13107, 8066,
   8066, 5243, 8066, 5243
 },
```

Size	**Number of elements**	**Number of Quantization/Inverse Quantization elements**
4*4	16	16*6 * 2 = 192
8*8	64	64*6*2 = 768
Total		960

- Our proposal JCTVC-D033 **does not** require any additional storage
  - Re-Uses same quantization tables for DCT and DST.

Experiments for Mode-Dependent DCT/DST

	Anchor	Proposed Scheme	Comments	Cross-Checkers
1.	TMuC 0.9	DCT/DST at size 4*4 and 8*8 DCT only at size 16 and 32	TMuC 0.9 DCT kernels are used at all block sizes	BBC (JCTVC-D031), NHK (JCTVC-D088)
2.	TMuC 0.9	DCT/DST at all block sizes : 4*4 to 32*32	DCT kernels in DCT/DST part are exactly similar to TMuC. DCT is carried out via matrix multiplications.	BBC(JCTVC-D031), NHK(JCTVC-D088), Toshiba (JCTVC-D105)

- 2nd set of results is primarily for information purpose.

DCT/DST at 4*4 and 8*8. TMuC 0.9 DCT kernels are used.

	Intra			Intra LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-2.1	-2.3	-2.4	-3.0	-1.5	-1.1
Class B	-0.8	-1.1	-1.1	-1.5	-1.1	-1.0
Class C	-1.1	-1.1	-1.1	-1.7	-1.2	-1.2
Class D	-1.2	-1.1	-1.1	-1.7	-1.1	-1.1
Class E	-1.4	-1.7	-1.6	-2.5	-0.6	-1.0
All	-1.2	-1.3	-1.3	-1.9	-1.1	-1.1
Enc Time[%]	104%			97%		
Dec Time[%]	102%			99%		

	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	-0.9	-0.5	-0.4	-1.1	-0.3	0.1
Class B	-0.5	-0.3	-0.2	-0.5	-0.4	-0.4
Class C	-0.6	-0.5	-0.5	-0.6	-0.3	-0.3
Class D	-0.5	-0.5	-0.4	-0.5	-0.4	-0.3
Class E						
All	-0.6	-0.4	-0.4	-0.6	-0.4	-0.3
Enc Time[%]	100%			98%		
Dec Time[%]	103%			101%		

DCT/DST at all block sizes: 4*4 to 32*32. DCT via matrix multiplication

	Intra			Intra LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-2.4	-2.8	-3.0	-3.5	-2.6	-2.6
Class B	-1.0	-1.7	-1.8	-1.7	-1.9	-1.9
Class C	-1.2	-1.4	-1.4	-1.8	-1.6	-1.6
Class D	-1.2	-1.2	-1.2	-1.7	-1.3	-1.3
Class E	-1.5	-2.9	-2.8	-2.7	-2.8	-2.9
All	-1.3	-1.9	-1.9	-2.1	-2.0	-2.0
Enc Time[%]	113%			121%		
Dec Time[%]	117%			127%		

Complexity high because of **un-optimized** 32*32 matrix multiplication

	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	-1.0	-0.8	-0.8	-1.2	-0.5	-0.5
Class B	-0.6	-1.0	-0.9	-0.7	-0.6	-0.7
Class C	-0.7	-0.7	-0.6	-0.6	-0.5	-0.4
Class D	-0.6	-0.4	0.0	-0.5	-0.4	-0.3
Class E						
All	-0.6	-0.7	-0.6	-0.7	-0.5	-0.5
Enc Time[%]	105%			99%		
Dec Time[%]	104%			109%		

Comments

- If additional DCT matrices or quantization/inverse quantization matrices are introduced, our compression gains would increase
  - But this will require implementation of additional DCT
  - Storage of Additional Quantization tables only for I-slices
- Any mode-dependent scanning scheme for transform coefficients used in conjunction with DCT/DST will improve system performance
- If a low-complexity fast DST is ***directly*** used at a block size without scaling, it will require 3 additional set of quantization and inverse quantization tables for I-slices at a particular block size
  - Storage will increase from 960 to 960*4 = 3840 elements !
  - So, we have implemented DST as matrix multiplication after proper scaling in this contribution.

Conclusions

- Proposed mode-dependent DCT/DST as the transform for Intra coding
- Requires only 1 additional DST matrix at a particular block size in addition to conventional TMuC based DCT.
- No increase in encoding/decoding times.
- No additional storage required for quantization tables
- Recommend to adopt mode-dependent DCT/DST at block sizes 4*4 and 8*8 as the transform for Intra coding in HM.

Thank You