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SAMSUNG

***Jointly optimal intra prediction and
adaptive primary transform
JCTVC-C108***

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Outline

- ❑ Prior and Related Work
- ❑ Intra prediction and transform structure in TMuC
- ❑ Proposed “primary” transform
- ❑ Experimental Results
- ❑ Conclusions

Prior & Related Work

1. ICASSP, March 2010

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

Paper title: Towards jointly optimal spatial prediction and
adaptive transform in video/image coding

- ❑ Derived and proposed a new “Sine” transform for Intra coding
- ❑ Upto 10 % bit savings at high PSNR’s over DCT based
H.264/AVC for intra-coding in JM11.0

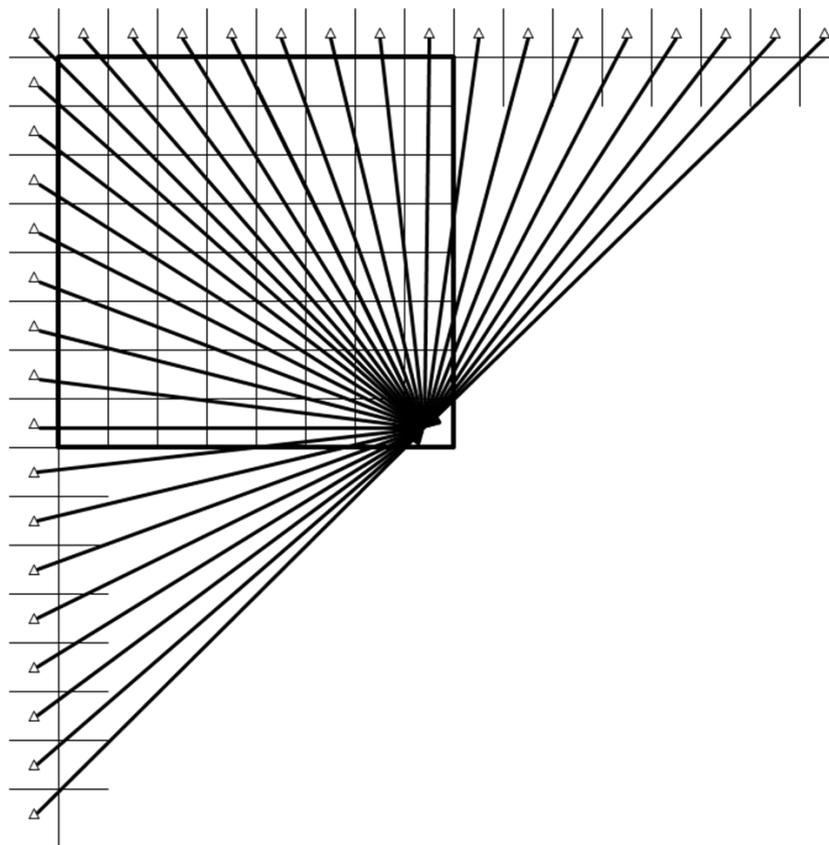
2. JCT-VC B-024, July 2010

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

- ❑ Similar transform derived as the ICASSP paper
- ❑ Implementation in JM11.0KTA2.6r1

3. JCT-VC C-037 and JCT-VC C-039; I2R Singapore

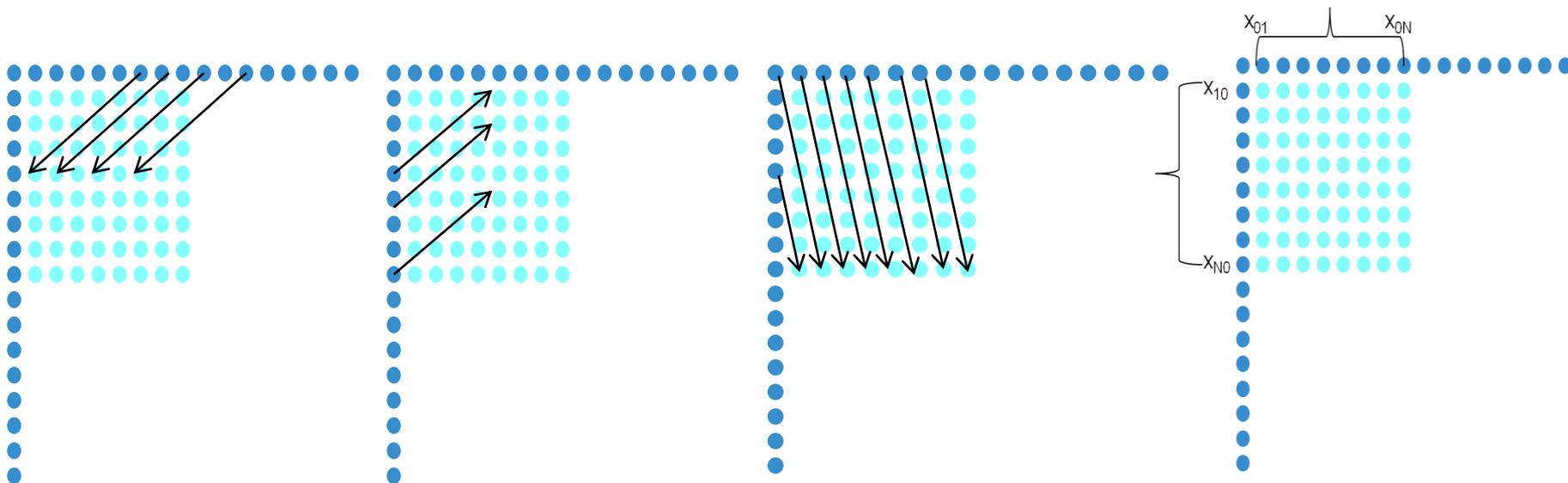
Unified Intra Prediction in TmuC 0.7



- Unified intra prediction in TmuC
- Upto 34 different intra prediction modes

Categorization of Intra Prediction Modes

- Prediction modes can broadly be divided into 3 categories



Category 1

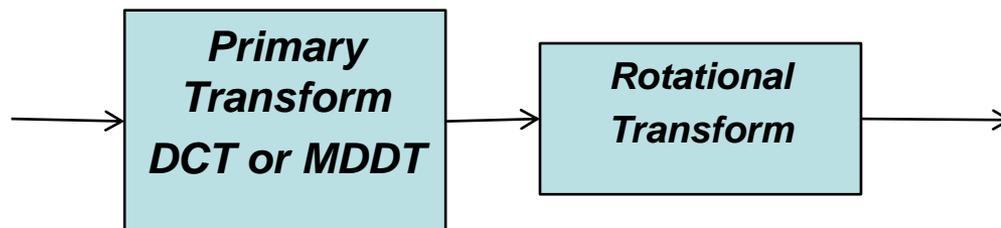
Prediction from either of the top row or left column

Category 2

Prediction from both top row and left column

DC Prediction Mode

Transform Structure in TMuC 0.7



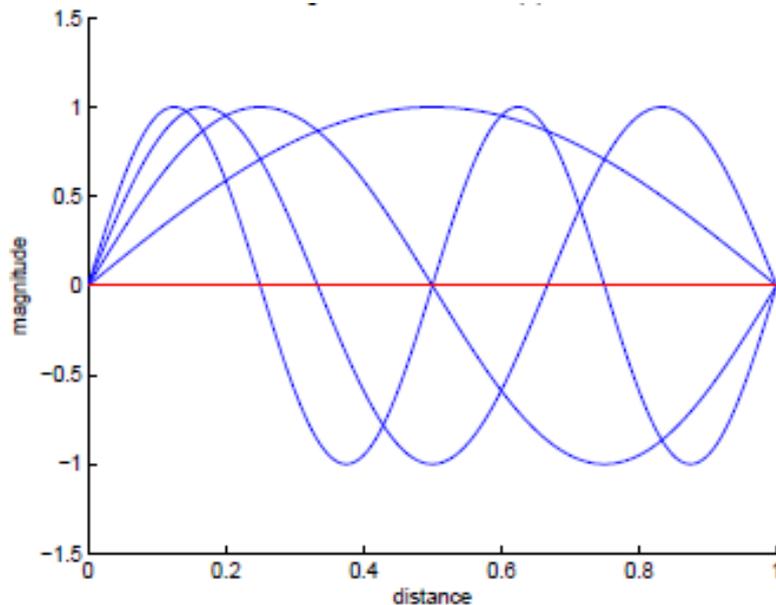
- ❑ DCT or MDDT is used as the 4*4 or 8*8 primary transform
- ❑ DCT only for blocks 16*16, 32*32 and 64*64
- ❑ Rotational Transform is used as the secondary transform

- ❑ **Proposed** : An adaptive combination of DCT and a DST for block sizes 16*16 and higher as the primary transform

Motivation : Jain's Theorem [Jain, 1976]

- Predicted from closed boundary, the optimal transform of the prediction residue is:

$$[T]_{ji} = \sin\left(\frac{ji\pi}{N+1}\right), \text{ where } j, i = 1, 2, \dots, N$$



□ 1- dimensional example

- Orange Pixels – Boundary

- Gray Pixels – To be encoded

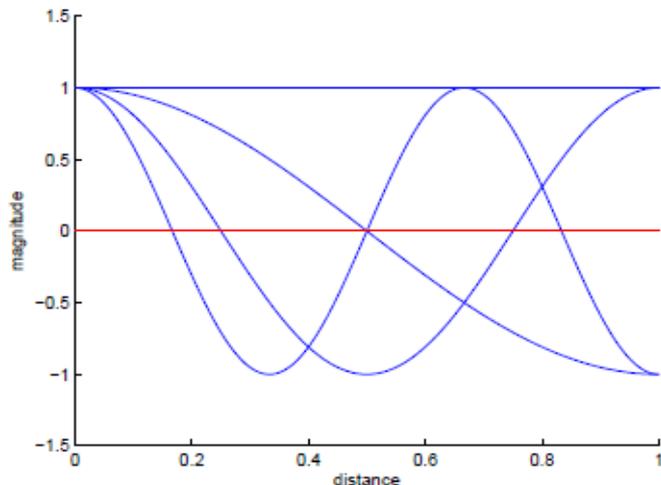
- Orthogonal continuous sine(1) bases

One-Sided Prediction Residual Transform

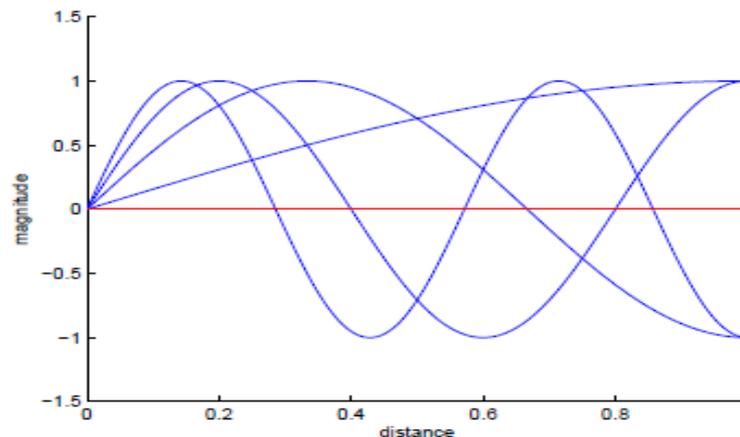
- When prediction is performed from one-side, the energy in prediction error residuals (gray pixels) increases as we go away from the boundary (orange pixel).



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



Orthogonal continuous cosine bases

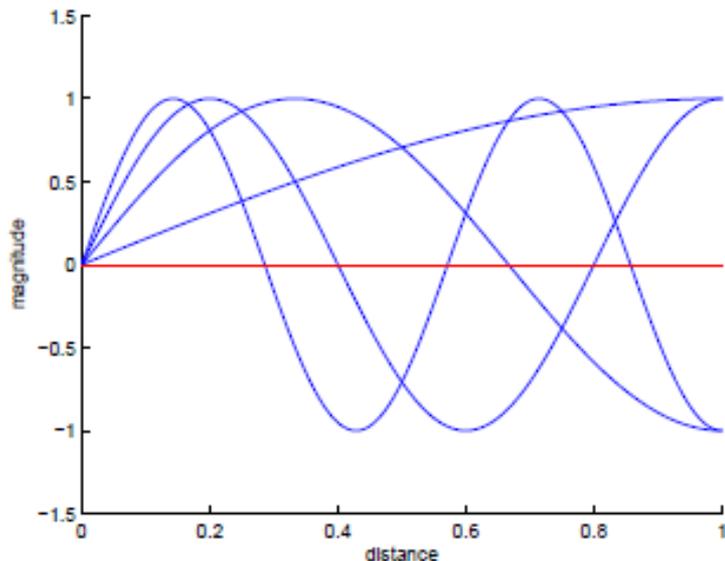


Orthogonal continuous sine(2) bases

Optimal Residual Transform

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

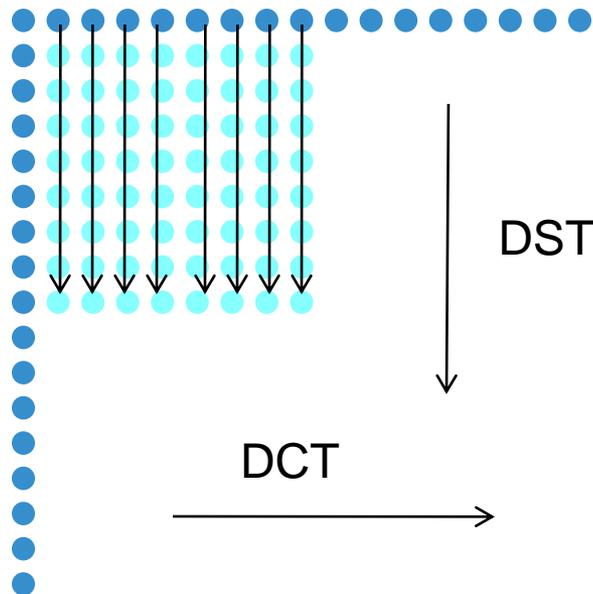
$$[T_s]_{j,i} = \left(\frac{2}{\sqrt{2N+1}} \sin \frac{(2j-1)i\pi}{2N+1} \right)$$



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

Sine (2) bases

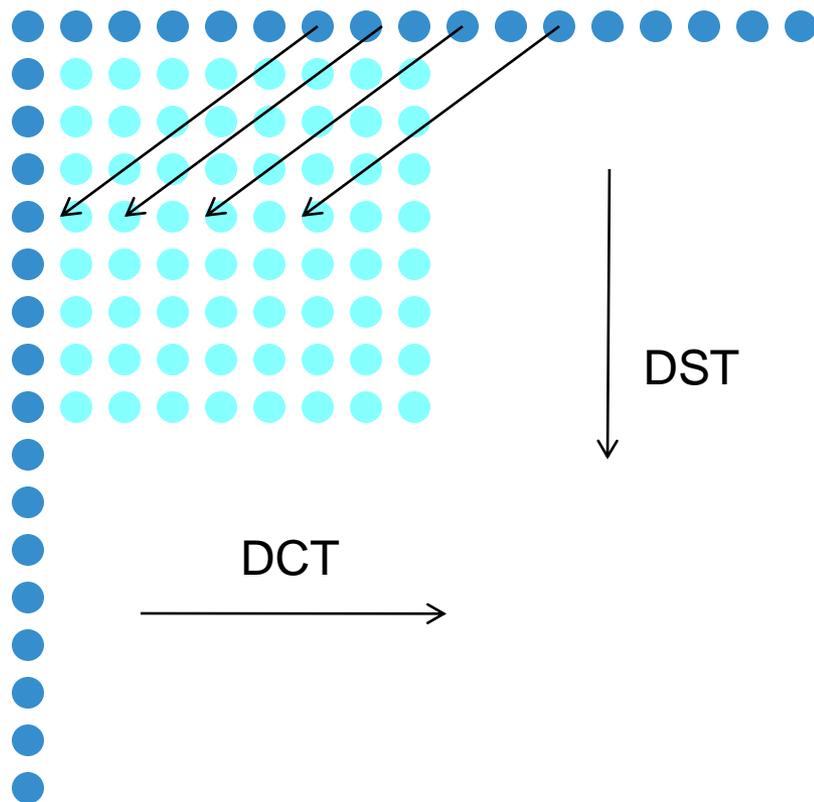
Example : Vertical Mode



- Vertical Mode
- 1-d prediction in vertical direction

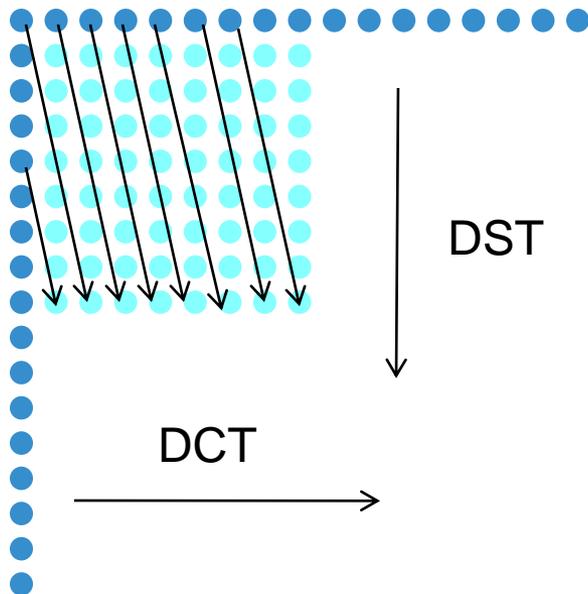
- DST in vertical direction
- DCT in horizontal direction

Example : Category 1 Mode



- ❑ Prediction from top row
- ❑ With some approximations, it can be shown that the optimal transforms are:
 - ❑ DST along vertical direction
 - ❑ DCT along horizontal direction
- ❑ Derivation and more details in proposal

Example: Category 2 Mode



- ❑ Prediction from both top row AND left column
- ❑ If a particular mode is near to vertical mode, use similar transform structure as vertical mode
- ❑ E.g., in the figure on left, for “Vertical-2” mode use :
 - DST in vertical direction
 - DCT in horizontal direction

Mode dependent transform assignment for unified intra prediction

IntraPredMode [puPartIdx]	IntraPredType [puPartIdx]	IntraPredAngleID [puPartIdx]	Category of Oblique Mode	Vertical Transform	Horizontal Transform
0	Intra_Vertical	0	1	DST	DCT
1	Intra_Horizontal	0	1:Prediction from Left Column	DCT	DST
2	Intra_DC	-	DC Mode	DCT	DCT
3	Intra_Vertical	-8	2	DST	DCT
4	Intra_Vertical	-4	2	DST	DCT
5	Intra_Vertical	+4	1	DST	DCT
6	Intra_Vertical	+8	1	DST	DCT
7	Intra_Horizontal	-4	2	DCT	DST
8	Intra_Horizontal	+4	1	DCT	DST
9	Intra_Horizontal	+8	1	DCT	DST
10	Intra_Vertical	-6	2	DST	DCT
11	Intra_Vertical	-2	2	DST	DCT
12	Intra_Vertical	+2	1	DST	DCT
13	Intra_Vertical	+6	1	DST	DCT
14	Intra_Horizontal	-6	2	DCT	DST
15	Intra_Horizontal	-2	2	DCT	DST
16	Intra_Horizontal	+2	1	DCT	DST
17	Intra_Horizontal	+6	1	DCT	DST
18	Intra_Vertical	-7	2	DST	DCT
19	Intra_Vertical	-5	2	DST	DCT
20	Intra_Vertical	-3	2	DST	DCT
21	Intra_Vertical	-1	2	DST	DCT
22	Intra_Vertical	+1	1	DST	DCT
23	Intra_Vertical	+3	1	DST	DCT
24	Intra_Vertical	+5	1	DST	DCT
25	Intra_Vertical	+7	1	DST	DCT
26	Intra_Horizontal	-7	2	DCT	DST
27	Intra_Horizontal	-5	2	DCT	DST
28	Intra_Horizontal	-3	2	DCT	DST
29	Intra_Horizontal	-1	2	DCT	DST
30	Intra_Horizontal	+1	1	DCT	DST
31	Intra_Horizontal	+3	1	DCT	DST
32	Intra_Horizontal	+5	1	DCT	DST
33	Intra_Horizontal	+7	1	DCT	DST

Implementation in TMuC 0.7

- ❑ First 25 frames of all the sequences were coded in intra high-efficiency mode
- ❑ Comparison Settings:

Block Size	Primary Transform	
	Anchor	Proposed
4*4 and 8*8	MDDT	MDDT
16*16 and higher	DCT	Adaptive DCT/DST

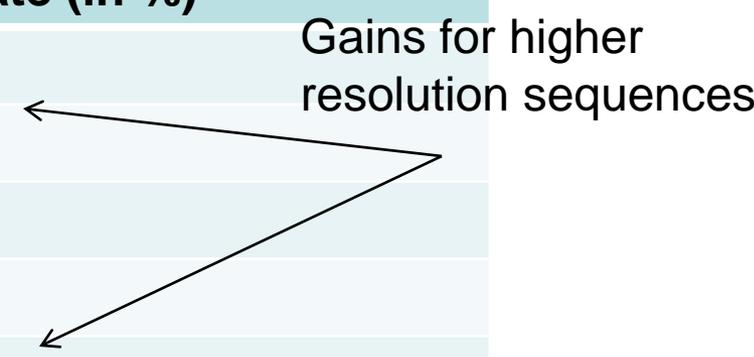
- ❑ Secondary Transform
 - Case 1 : ROT OFF
 - Case 2 : ROT ON

DCT vs. Proposed DCT/DST

- Rotational Transform is OFF

Class	BD Rate (in %)
Class A : 2560x1600	-0.3
Class B : 1920x1080	-0.4
Class C : 832x480	0.0
Class D : 416x240	0.1
Class E : 720p	-0.3
Overall Average	-0.2

Gains for higher resolution sequences

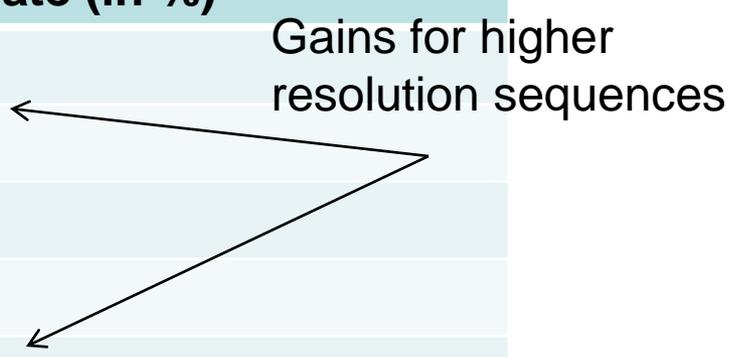


DCT vs. Proposed DCT/DST

- Rotational Transform is ON

Class	BD Rate (in %)
Class A : 2560x1600	-0.3
Class B : 1920x1080	-0.2
Class C : 832x480	0.0
Class D : 416x240	0.1
Class E : 720p	-0.1
Overall Average	-0.1

Gains for higher resolution sequences



Conclusions

- ❑ Adaptive DCT/DST proposed as primary transform
- ❑ Proposed transform is based on intra prediction modes
- ❑ Requires only 1 additional DST matrix at a particular block size in addition to DCT.
- ❑ Recommend to test adaptive DCT/DST as primary transform for all block sizes as part of a Tool/Core Experiment in TMuC/TM.

Thank You