

JVET-L0421 - CE6-related: fast implementation of MTS transforms using matrix multiplication



Problem

- MTS of VTM2 comprises DST7 / DCT8
- Cannot be decomposed into partial butterfly representation

Proposed solution

- inspired from K0096 proposing DFT-based implementation of DST7
- Main difference: L0421 performs matrix multiplication instead of specific implementation of each DFT stage

Approach

- decompose the MTS transforms basis into smaller matrices then
- perform matrix multiplication to implement the transforms
- Proposed solution is generic, independent from the transform size, and SIMD implementation friendly

N-DST7/DCT8 implemented via $(2N+1)$ -DFT

$(2N+1)$ -DFT implemented using prime factor algorithm

- $2N+1=N_1 \times N_2$, with N_1 and N_2 relatively prime

- $2N+1$ DFT implemented by a 2 stages DFT:
 1. N_2 DFTs of length N_1
 2. N_1 DFTs of size N_2

- 16-DCT8 using 33-DFT, decomposed into 3-DFTs and 11-DFTs
- 32-DCT8 using 65-DFT, decomposed into 5-DFTs and 13-DFTs

Algorithm description

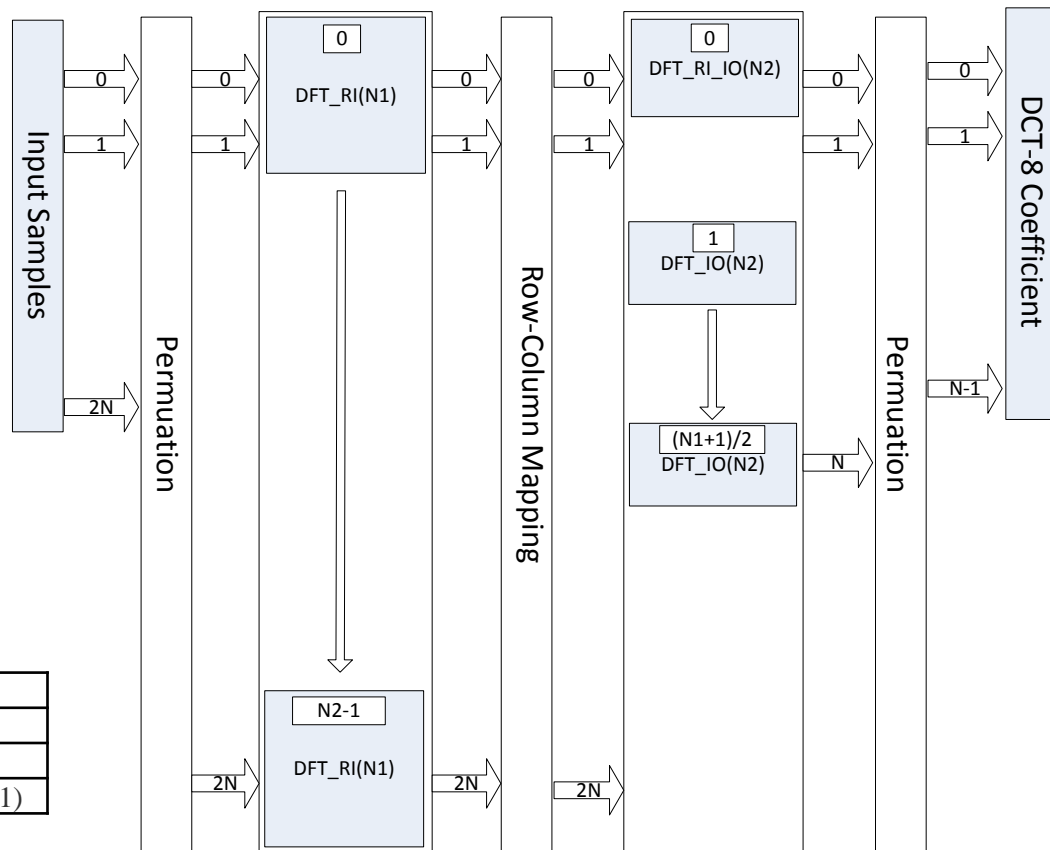
Generic design requiring 3 functions

- N_2 calls of DFT_RI involving N_1 -DFTs
- 1 call of DFT_RI_IO involving N_2 -DFTs
- $(N_1+1)/2$ calls of DFT_IO involving N_2 -DFTs
- Plus permutations of input/output

Implemented using matrix multiplications

Process	#Multiplications
$N_2 \text{ DFT_RI}(N_1)$	$N_2 * (N_1 - 1)^{2/2}$
1 $\text{DFT_RI_RO}(N_2)$	$(N_2 - 1)^{2/4}$
$(N_1-1)/2 \text{ DFT_RO}(N_2)$	$(N_1 - 1)/2 * ((N_1 - 1)^{2/2} / 2)$

Process	#Additions
$N_2 \text{ DFT_RI}(N_1)$	$N_2 * (N_1 - 1) * (1 + N_1/2)$
1 $\text{DFT_RI_RO}(N_2)$	$(N_2-1) * (N_2+5)/4$
$(N_1-1)/2 \text{ DFT_RO}(N_2)$	$(N_1 - 1)/2 * ((N_2 - 1) * (N_2/2+2) - 1)$



Performance over VTM2.0.1

AI	Y	U	V
Class A1	0.0%	0.0%	0.0%
Class A2	0.0%	0.0%	0.0%
Class B	0.0%	0.1%	0.1%
Class C	0.0%	0.1%	0.1%
Class E	0.0%	0.0%	0.0%
Overall	0.0%	0.0%	0.0%
Class D	0.0%	0.2%	-0.1%

RA	Y	U	V
Class A1	0.0%	0.0%	0.0%
Class A2	0.0%	-0.1%	-0.1%
Class B	0.0%	0.0%	0.1%
Class C	0.0%	0.2%	0.1%
Class E			
Overall	0.0%	0.0%	0.1%
Class D	0.0%	-0.3%	-0.1%

Mult / Additions saving / VTM design

Transform	DFT length	Decomposition	Multiplication saving	Additions saving
16x16 DCT8/DST7	33	3x11	49 / 256 = 0.19	154 / 240 = 0.64
32x32 DCT8/DST7	65	5x13	156 / 1024 = 0.15	421 / 992 = 0.42

This contribution proposes a fast implementation of MTS transforms using matrix multiplication

Generic process, non-size dependent, SIMD friendly

Compared to a full matrix multiplication,

- reduction of memory (5% of full matrices memory need)
 - overall number of coefficients = 2560 in VTM2 software → 132 in proposal
- reduction of nb of operations (nb of mult. reduced by 5 to 6)

No impact on coding performance