CTB directional gradient detection using 2D-DWT for Intra-picture prediction in HEVC

Presenter Information
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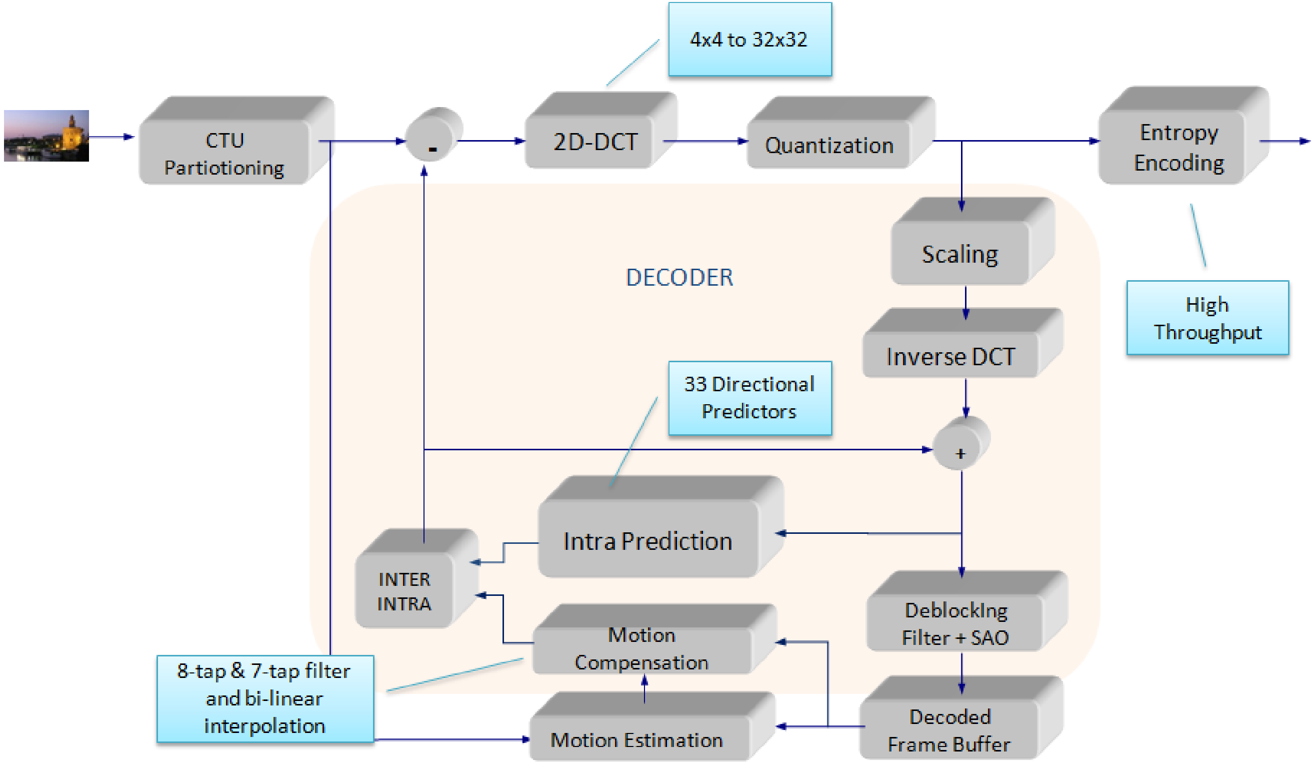
Agenda

- Motivation
- Intra Prediction in HEVC
- Proposal of gradient detection using wavelet transform
- 2D-DWT implementation on GPU
- Simulation results
- Conclusions

HEVC block diagram



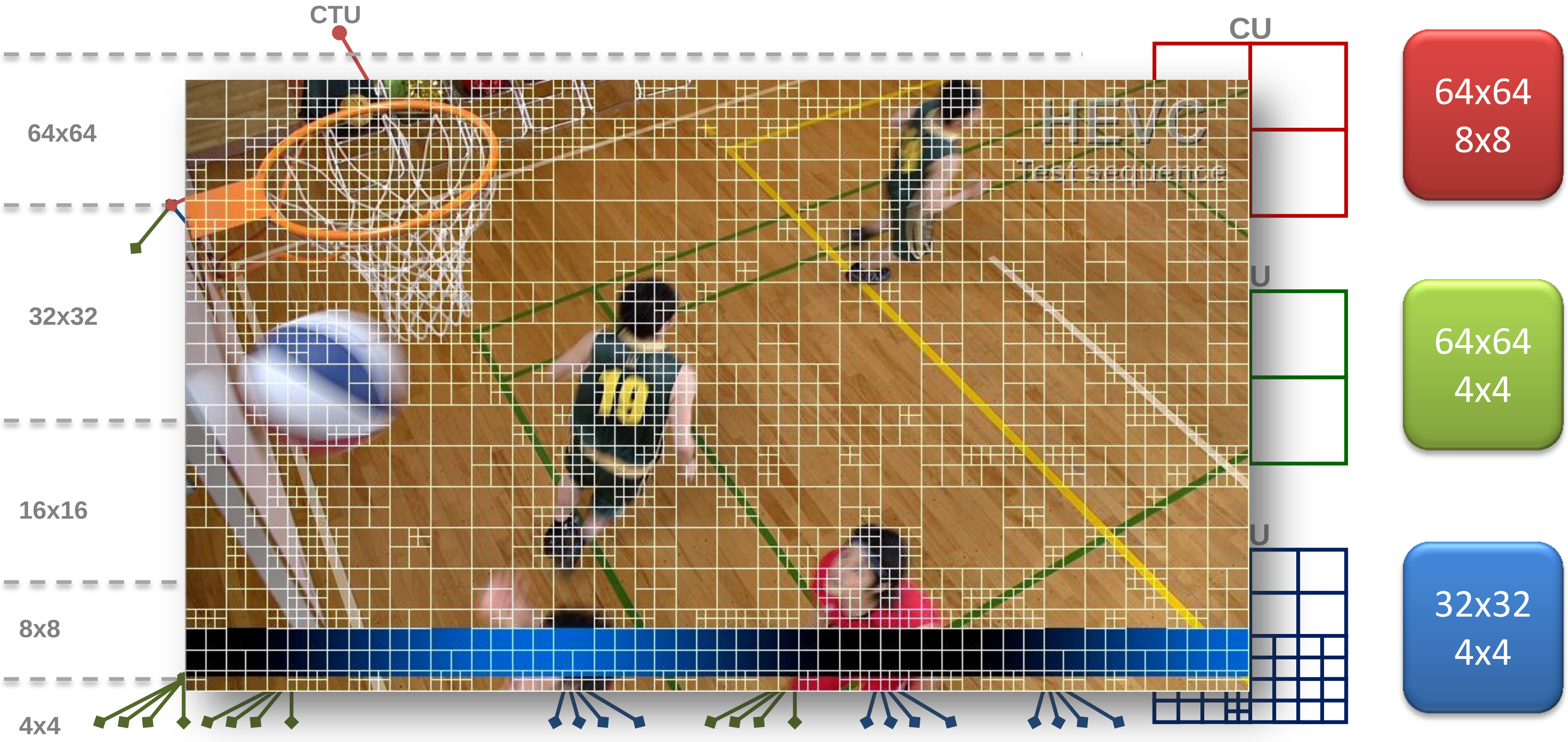
Motivation

- HEVC is the new video coding standard approved jointly by the ITU-T and ISO/MPEG, in January 2013
- HEVC allows a bit rate savings over 50% with respect to its predecessor, the H.264/AVC standard
- HEVC is expected to replace H.264/AVC especially for resolution formats beyond HD, UltraHD (4K and 8K)
- The new Intra-frame coding of HEVC outperforming the current state of the art in image coding, such as JPEG, JPEG2000 and JPEG XR
- However, these improvements are obtained at the expense of an increment in the encoder computational complexity

Motivation

- HEVC new hierarchical image partitioning, denoted as Coded Tree Block (CTB), with three new blocks units:
  - ✓ The Coding Units (CU) equivalent to Macroblock in H.264, in the range of 64x64 to 8x8.
  - ✓ The Prediction Units (PU) with sizes in the range of 64x64 to 4x4
  - ✓ The Transform Units (TU) with sizes from 32x32 to 4x4
- The decision of the optimal CTB partitioning is content depended, and it consumes most of the computational burden of HEVC encoder.

Motivation

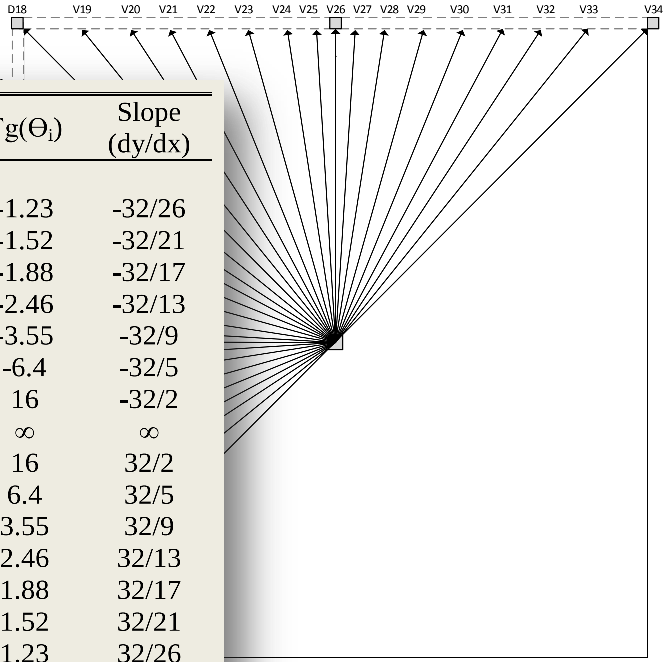


CTU
64x64
32x32
16x16
8x8
4x4
HEVC
Test sequence
CU
U
U
64x64
8x8
64x64
4x4
32x32
4x4

Intra Prediction in HEVC

- The intra-prediction in HEVC is five time more complex th
  - Increas
    from 9
  - Increas
    (4x4 ar

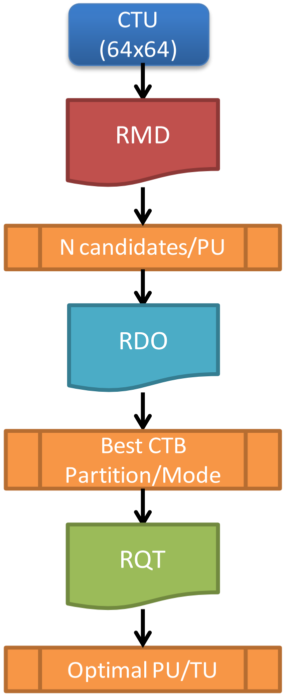
Mode M_i	Angle Θ_i	$Tg(\Theta_i)$	Slope (dy/dx)	Mode M_i	Angle Θ_i	$Tg(\Theta_i)$	Slope (dy/dx)
H2	225º	1	1				
H3	219.1º	0.81	26/32	V19	129.1º	-1.23	-32/26
H4	213.2º	0.65	21/32	V20	123.3º	-1.52	-32/21
H5	207.9º	0.53	17/32	V21	118.0º	-1.88	-32/17
H6	202.1º	0.40	13/32	V22	112.1º	-2.46	-32/13
H7	195.7º	0.28	9/32	V23	105.7º	-3.55	-32/9
H8	188.9º	0.15	5/32	V24	98.9º	-6.4	-32/5
H9	183.6º	0.06	2/32	V25	93.6º	16	-32/2
H10	180º	0	0	V26	90º	∞	∞
H11	176.4	-0.06	-2/32	V27	86.4º	16	32/2
H12	171.1º	-0.15	-5/32	V28	81.1º	6.4	32/5
H13	164.3º	-0.28	-9/32	V29	74.3º	3.55	32/9
H14	157.9º	-0.40	-13/32	V30	67.9º	2.46	32/13
H15	152.0º	-0.53	-17/32	V31	62.0º	1.88	32/17
H16	146.7º	-0.65	-21/32	V32	56.7º	1.52	32/21
H17	140.9º	-0.81	-26/32	V33	50.9º	1.23	32/26
D18	135º	-1	-1	V34	45º	1	1



	# PUs		
64x64	1		
32x32	4		
16x16	16		
8x8	64		
4x4	256		
TOTAL		15610	2944

Intra Prediction in HEVC

- The HEVC reference model implements a three steps algorithm:



1- Rough Mode Decision: computes fast Hadamard cost

->Selection of 8 mode candidates for each PU size

2- Rate Distortion Optimization: exhaustive cost of candidates

->Selection of Best Mode/PU size

3- Residual Quad Tree: full search of TU depths for Mode/PU

->Selection of Best TU size/ (Mode/PU)

Proposal of gradient detection using wavelet transform

- The RMD evaluates the 35 prediction modes, for each of five PU sizes, and in sequential order
- Our proposal replaces the RMD stage by using a directional wavelet (directionlet) transform, which allows to detect the dominant gradient of the PU.
- Our approach can be computed in parallel, and is specially suitable for multi-core graphic processors.
- The algorithm reduces also the number of candidates modes from 8 (RMD) to 3 modes (four modes for diagonal direction)

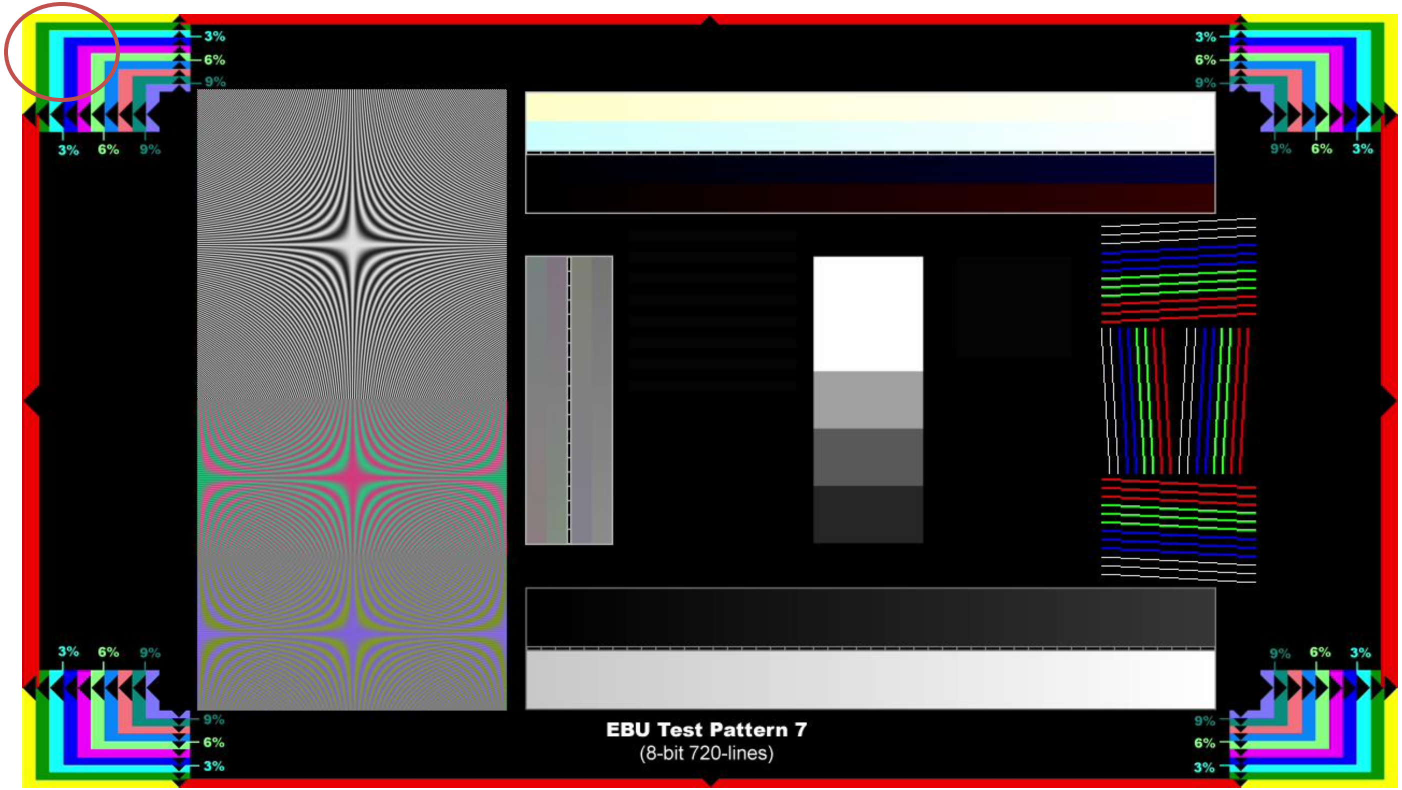
Proposal of gradient detection using wavelet transform

Traditional Wavelet Transforms (WT) has been shown to be an efficient tool for edge detection and textures classification

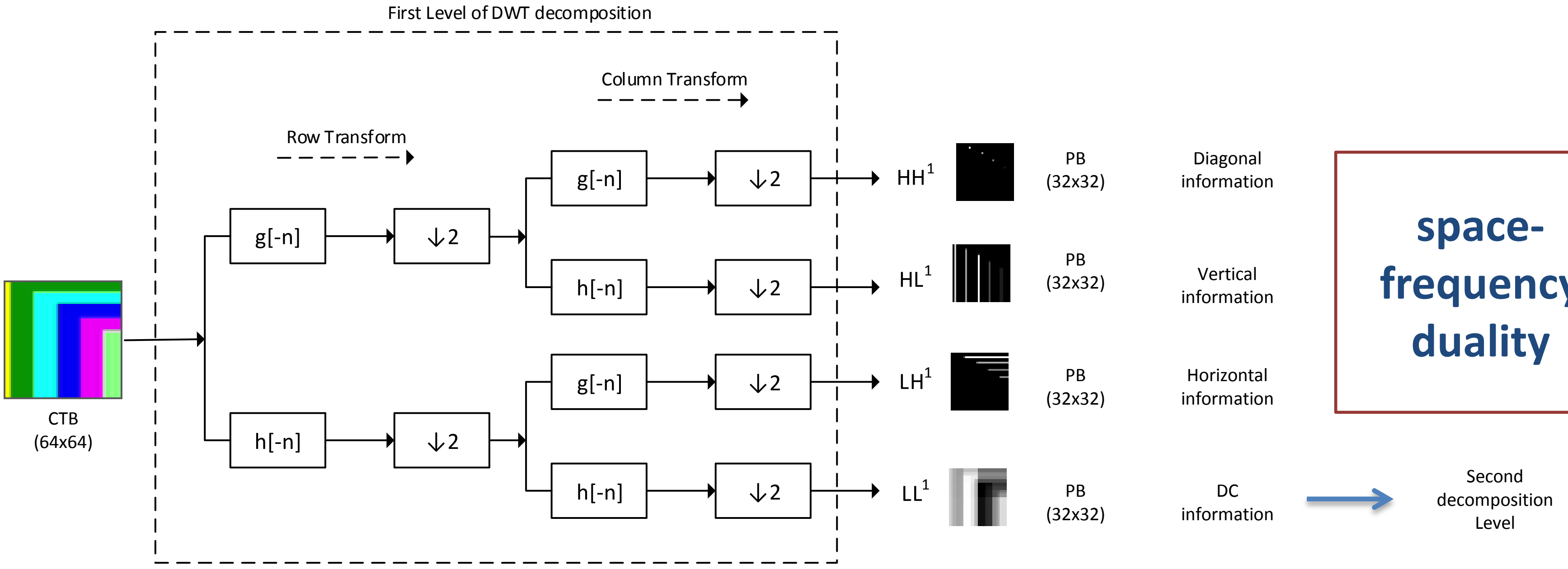
- Conventional 2D-Wavelets transform can be implemented as two separated 1D FIR filtering over the rows and columns of the image.
- The results are four sub-bands images achieving information of edge with Horizontal (LH^1), Vertical (HL^1), diagonal (HH^1) orientations, and DC (LL^1).
- The LL sub-band can be newly processed using 2D wavelet transform, achieving four sub-bands of the second decomposition level (LH^2,HL^2, HH^2, LL^2).

Proposal of gradient detection using wavelet transform

CTB
(64x64)



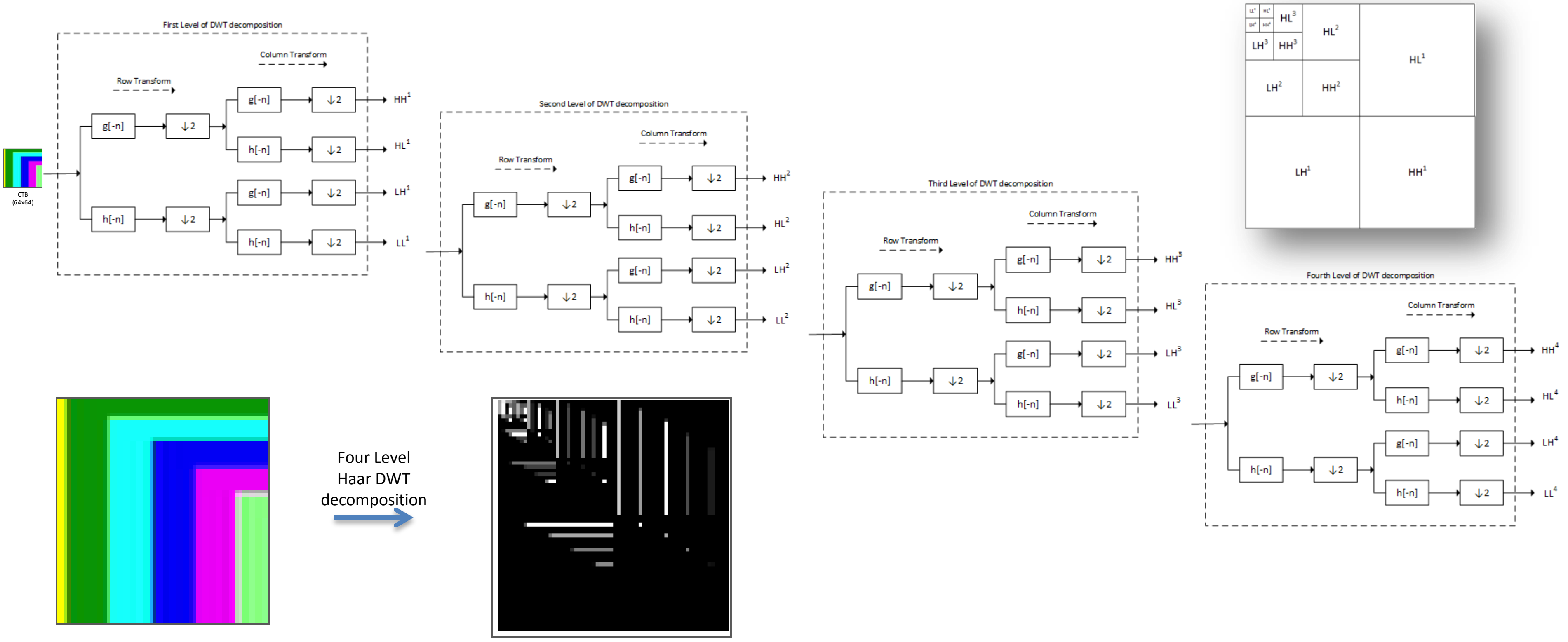
Proposal of gradient detection using wavelet transform



space-frequency duality

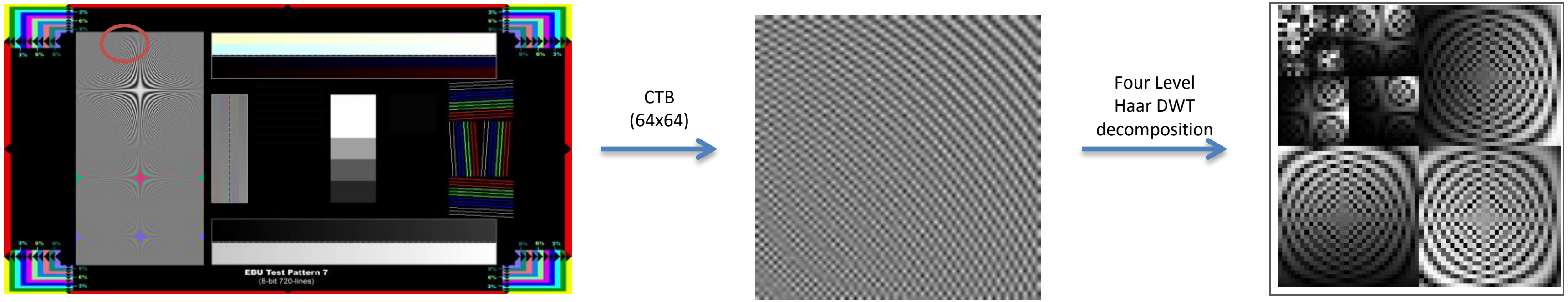
h[-h]: Low Pass Filter   g[-n]: High Pass Filter

Proposal of gradient detection using wavelet transform



Proposal of gradient detection using wavelet transform

Rows and column DWT provides poor information for gradients other than rows and columns transform directions (0º, 90º)

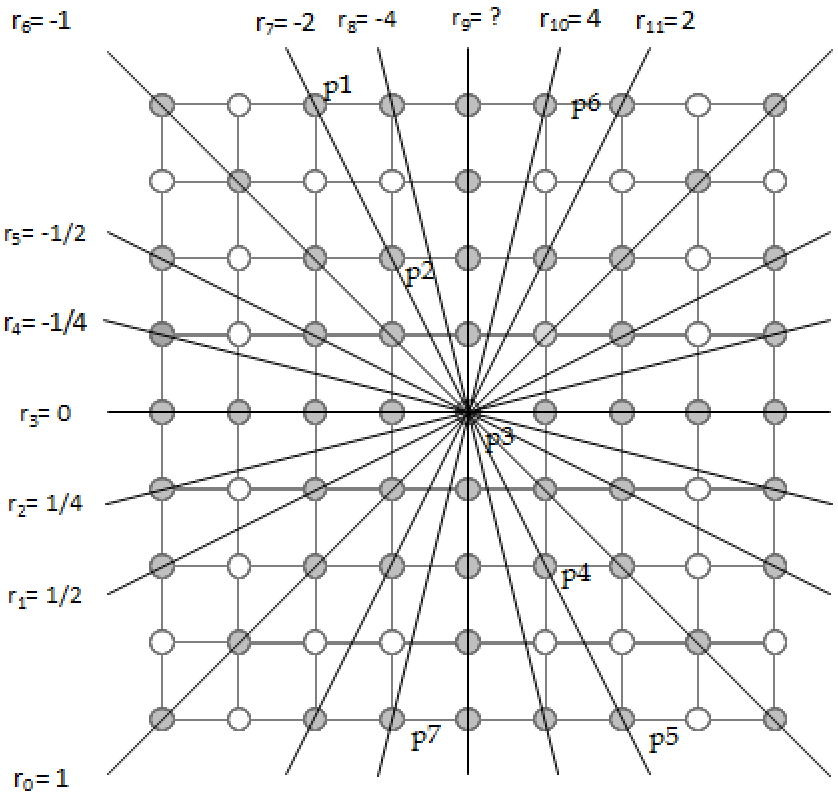


In order to estimate the 33 intra prediction directions in HEVC, we need to achieve a gradient information in additional directions.

Proposal of gradient detection using wavelet transform

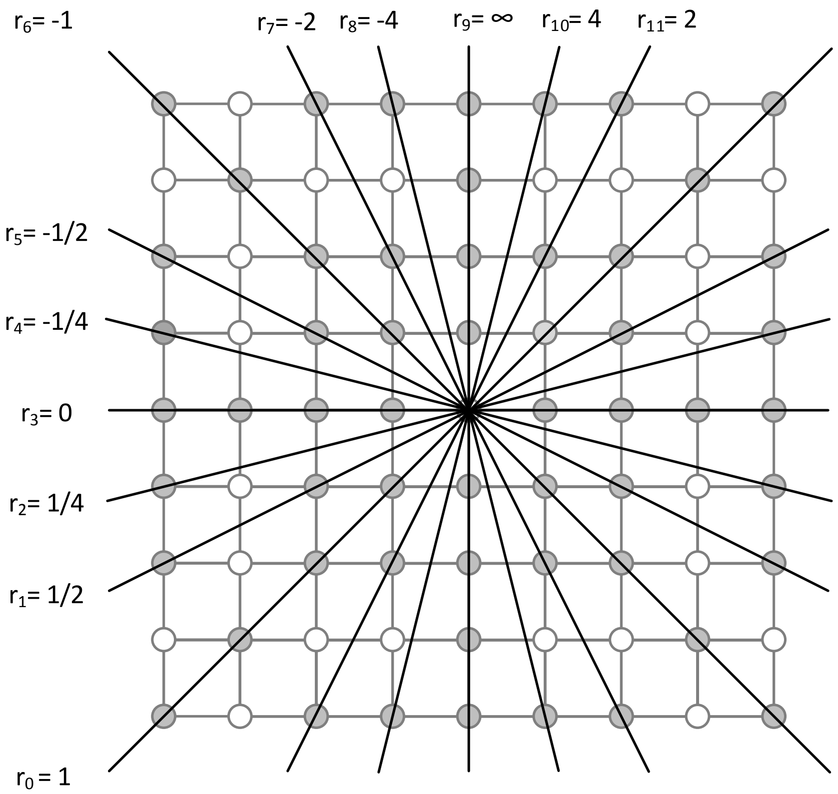
- We compute 10 additional 1D wavelet transform with rational directions (dy/dx)
- Example how to get the 10 additional 1D-DWT:

  1. 8x8 block is transformed into 10 lines each one of different length:
  R7=(p1,p2,p3,p4,p5)
  R10=(p6,p7)
  …
  2. Over this lines apply 1D-DWT
  get to sublines size N/2
  3. Measure the energy of the coefficients to see in which direction we have less high frequencies indicating that this direction is more homogeneous

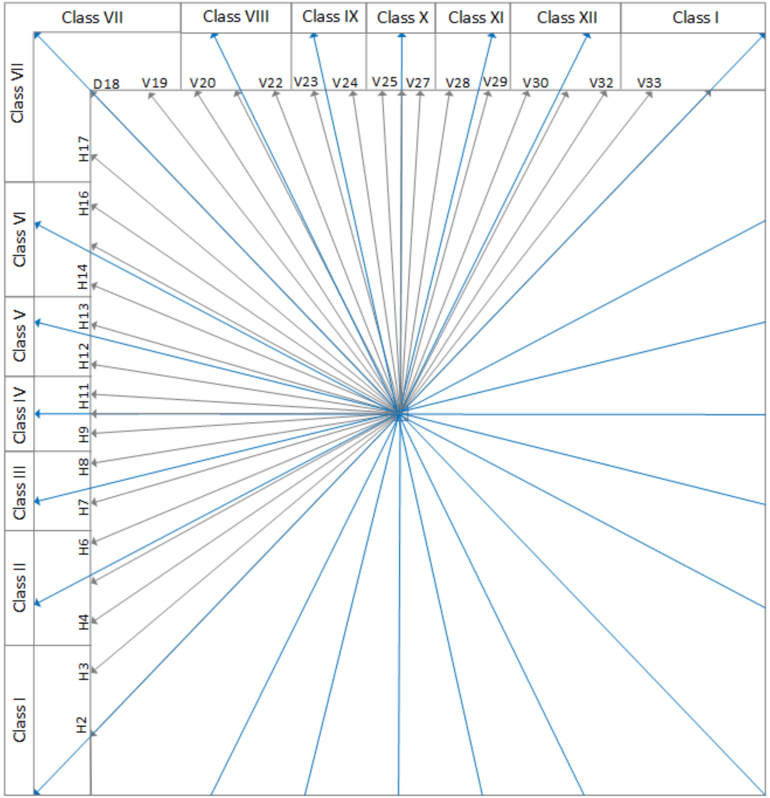


Proposal of gradient detection using wavelet transform

- The 10 directions were selected in a way so that all directions can be calculated for all PU sizes. Making sure that each line has at least two points so its well defined
- The conventional row and columns wavelets transform, in addition to this new directions, conform a set of 12 ´r_i´ gradient directions.
- But only three slopes match with the HEVC angular modes:
  - r_3 = H10
  - r_6 = D18
  - r_9 = V26



Proposal of gradient detection using wavelet transform



We define 12 Classes (C_i), defining a set of candidate modes to each Class according to directional transform with slope 'r_i'.

Class	Transform Direction	Slope (dy/dx)	ϕ	Candidate modes
I	r_0	1/1	225°	H2, H3, V33, V34
II	r_1	1/2	206.6°	H4, H5, H6
III	r_2	1/4	194°	H7, H8
IV	r_3	0	180°	H9, H10, H11
V	r_4	-1/4	166°	H12, H13
VI	r_5	-1/2	153.4°	H14, H15, H16
VII	r_6	-1/1	135°	H17, D18, V19
VIII	r_7	-2/1	116.6°	V20, V21, V22
IX	r_8	-4/1	104°	V23, V24
X	r_9	∞	90°	V25, V26, V27
XI	r_{10}	4/1	76°	V28, V29
XII	r_{11}	2/1	63.4°	V30, V31, V32

Proposal of gradient detection using wavelet transform

- Each wavelet coefficient $C^{\lambda}_{\phi}(i,j)$ in level λ and direction ϕ, provides frecuencial information related to co-located $(2^{\lambda} \times 2^{\lambda})$ pixels of CTB
  - Coeficients of $\lambda=2$ contain gradient information of PB_{4x4}
  - Coeficients of $\lambda=3$ contain gradient information of PB_{8x8}
  - Coeficients of $\lambda=4$ contain gradient information of PB_{16x16}
  - Coeficients of $\lambda=5$ contain gradient information of PB_{32x32}
  - Coeficients of $\lambda=6$ contain gradient information of PB_{64x64}

For each PU_{NxN} the dominant gradient ϕ is selected as the maximum $C^{\lambda}_{\phi}(i,j)$ at level $\lambda=\log_2 N$

implementation on GPU

1D-DWT Transform we use the implementation provided by the SDK.

1 thread computes the average and details for one thread of adjacent values

2D-DWT Transform we use the implementation provided by our SCU colleague Ed Karrels. He will explain this implementation on 3/20 at 13:30 room LL21A

Apply 1D-DWT to each row

Transpose Image

Apply 1D-DWT now to each column

Transpose the image to recover initial layout

The implementation combines the DWT and transpose steps using shared memory to ensure all read/writes are coalescent

implementation on GPU

get 1 frame

Repeat 6 times

1 kernel

tile image in blocks of size NxN (N starts at 64)

Apply the 2D-DWT transform

calculate energy of coefficients getting the H, V and D direction

2 kernel

reads the block creating the 10 lines and pass this as an input to the 1D-DWT transform

calculate energy of the 10 direction

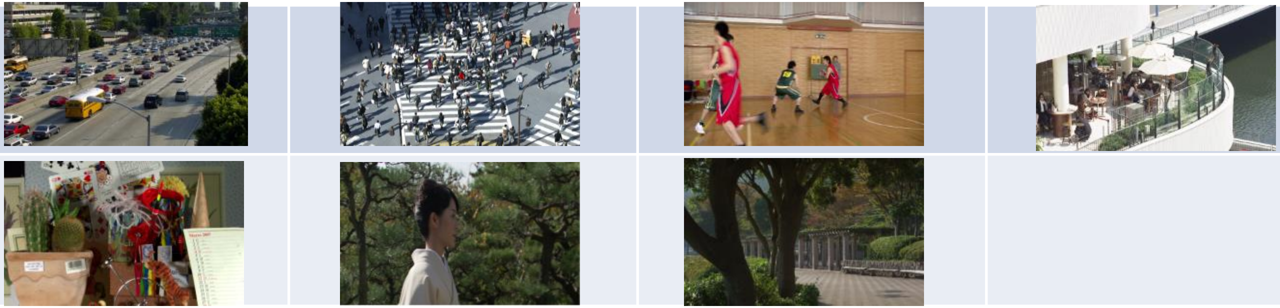
select the gradient for the NxN PU as the one with less high Frequency components of the 12

Simulation results

- We ha used two 4K sequences (Class A) and five HD sequences (Class B), recommended by the JCT-VC, according to:
  - JCT-VC, "Common test conditions and software reference configurations," Join collaborative Team on video Coding 9th meeting, Doc. JCTVC-I1100, 2012.

Class	Sequence	Frames	Horiz. Resolut.	Vertic. Resolut.	Number CTBs
Class A	Traffic PeopleOnStreet	150	2560	1600	1000
Class B	BasketballDrive BQTerrace Cactus Kimono ParkScene	500 600 500 240 240	1920	1080	578

4K and HD Test sequences



Processing a total of 1.502.240 CTBs

Simulation results of HEVC implementation

- ✓ PC with an Intel Core i7-2600 3.40 GHz processor, with 8GB RAM
- ✓ V. Studio 2013, and W7 O.S.
- ✓ Nvidia GTX 690 4096MB, 3072 CUDA cores
- ✓ Computed the average RMD time consumed by CTB, frame and sequence

	Sequence	Frames	RMD/CTB (ms)	RMD/Frame (sec)	RMD/Sequence (sec)
A	Traffic	150	6.053	6.047	907.050
	PeopleOnStreet	150	6.096	6.090	913.500
B	BasketballDrive	500	6.116	3.113	1556.560
	BQTerrace	600	6.083	3.096	1857.630
	Cactus	500	6.200	3.156	1578.120
	Kimono	240	5.961	3.034	728.160
	ParkScene	240	5.972	3.046	729.670

Time consuming of RMD in HM implementation

≈ 6ms/CTB

Our Implementation in GPU reach an average speedup of 30%

Conclusions

Presented a new approach for accelerating the CU angular decision of the HEVC intra prediction step based on the DWT transform

The approach is scalable and suitable for GPU architectures

Can be integrated with other algorithms

Reduces the time compared with the reference HM standard model

Thank you for your attention

Questions?

Presenter Information
(Name & Organization)