Performance Improvement of HEVC Using Adaptive Quantization

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Overview

Video Compression - Introduction

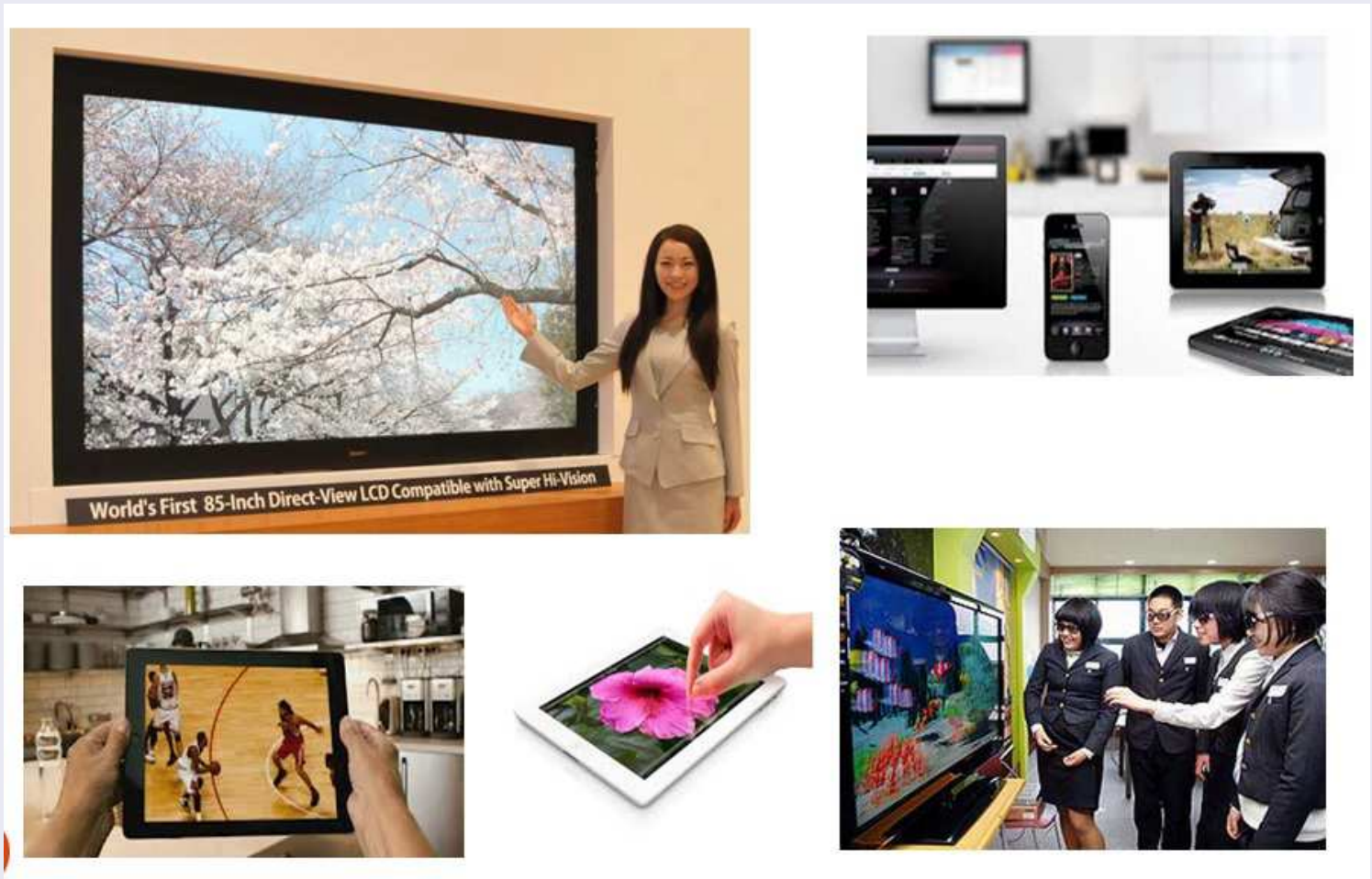


Figure : New Trends in Video

Video Coding - Standardisation Works

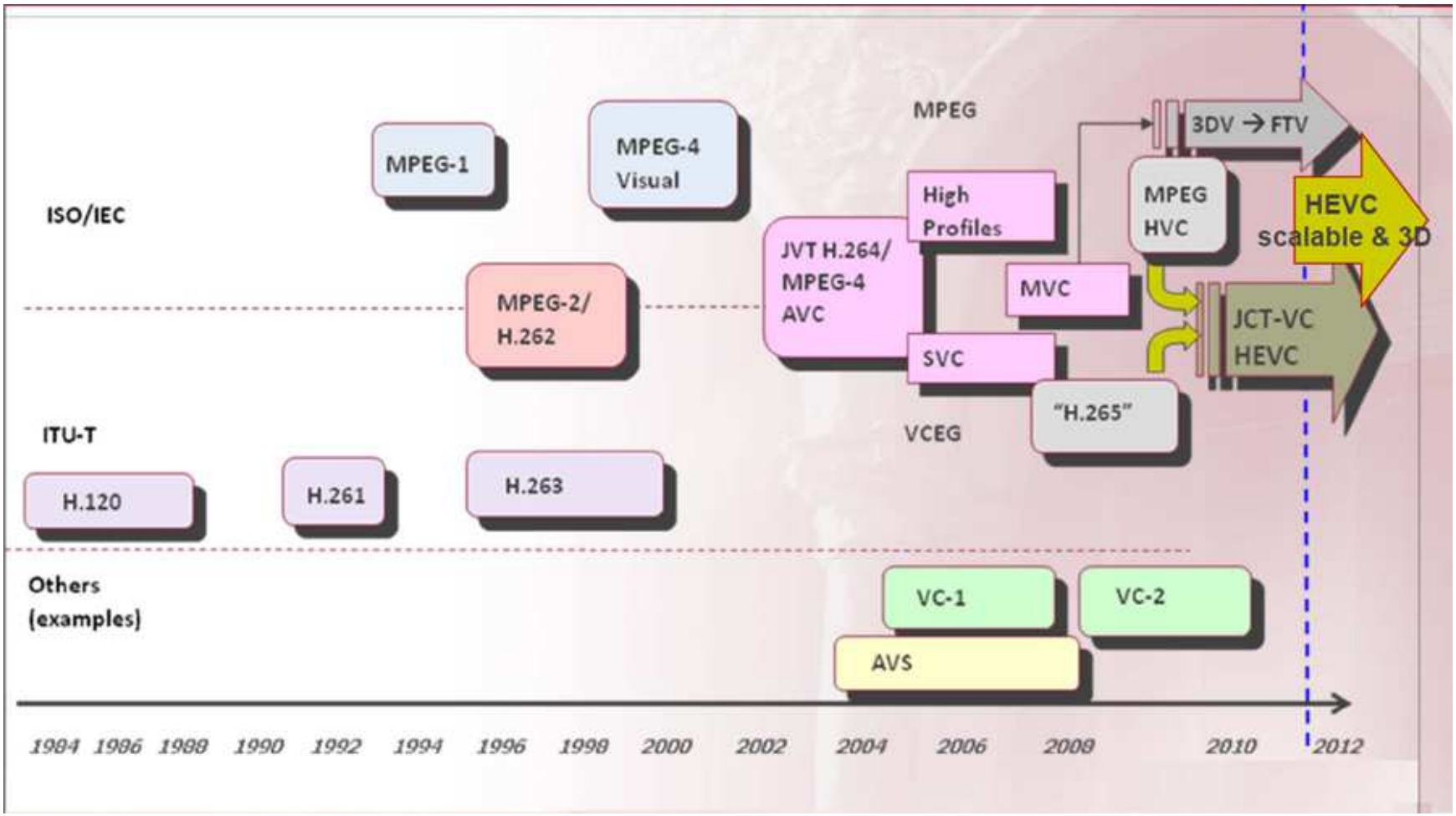


Figure : Popular Standards

Block based Hybrid Video Coding

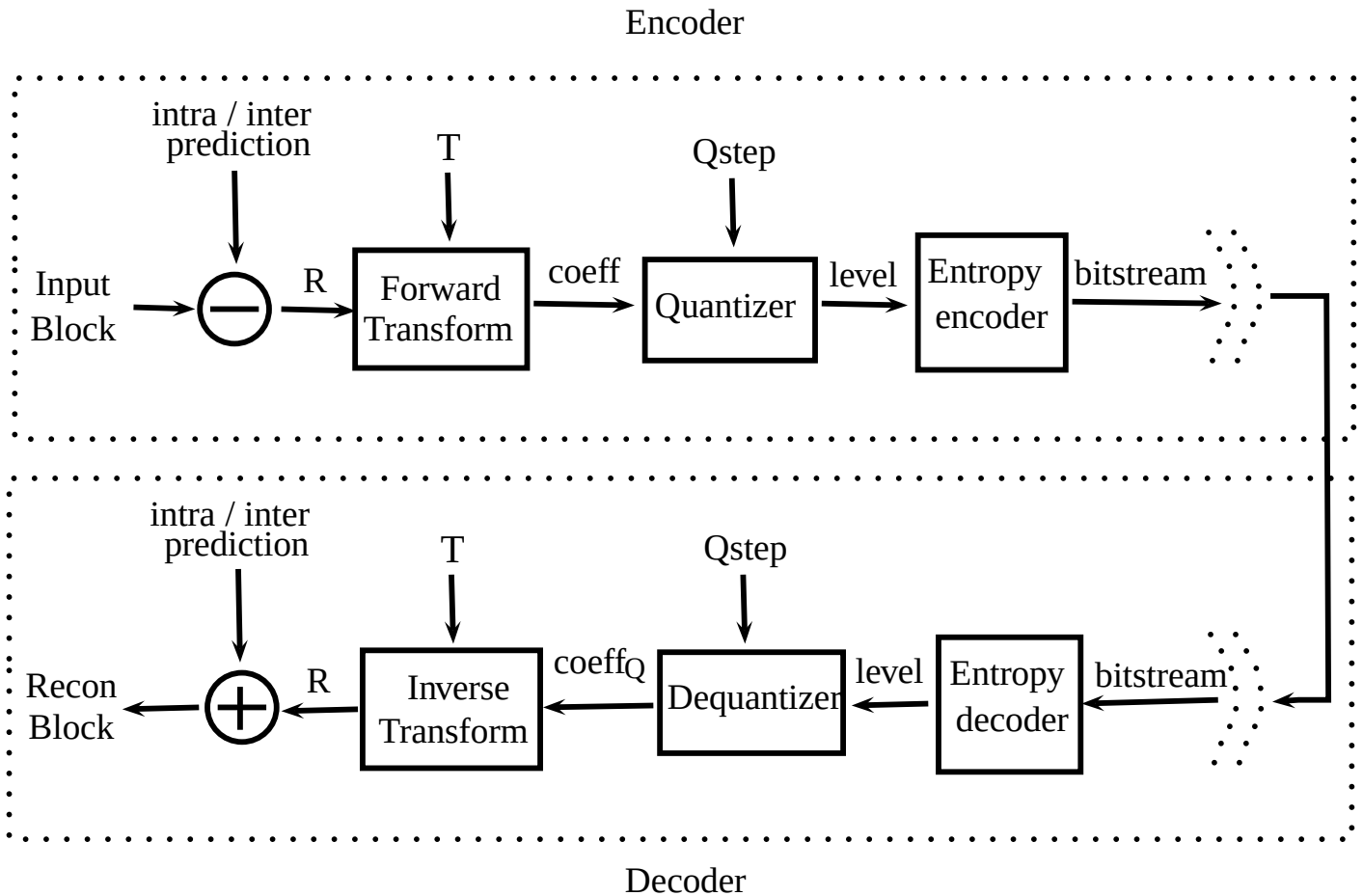


Figure : Block-based hybrid video coding. T is the transform matrix, R is the residue and Qstep is the quantization step size.

Motion Compensated Hybrid Video Coding

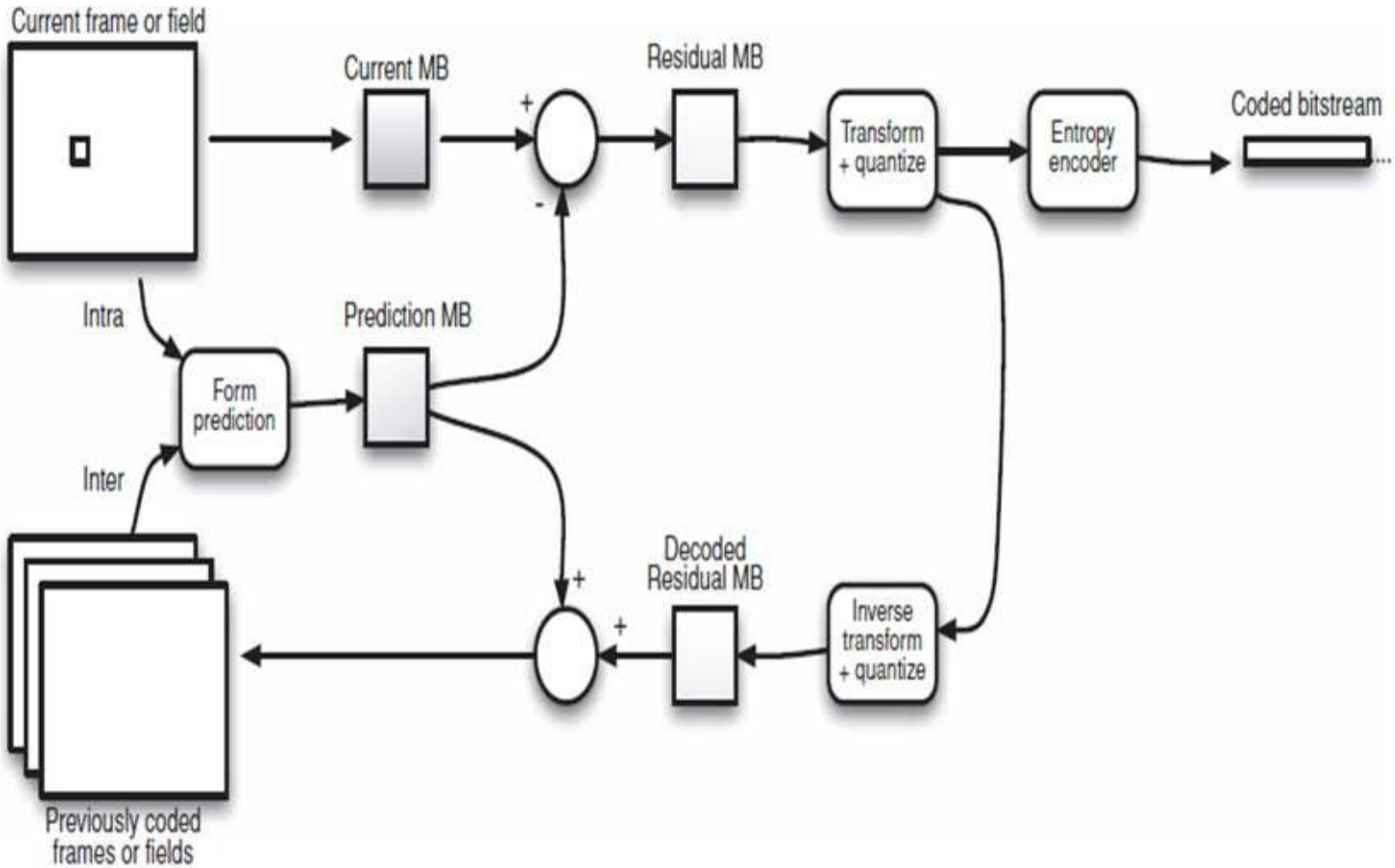


Figure : Video Encoder

High Efficiency Video Coding (HEVC)

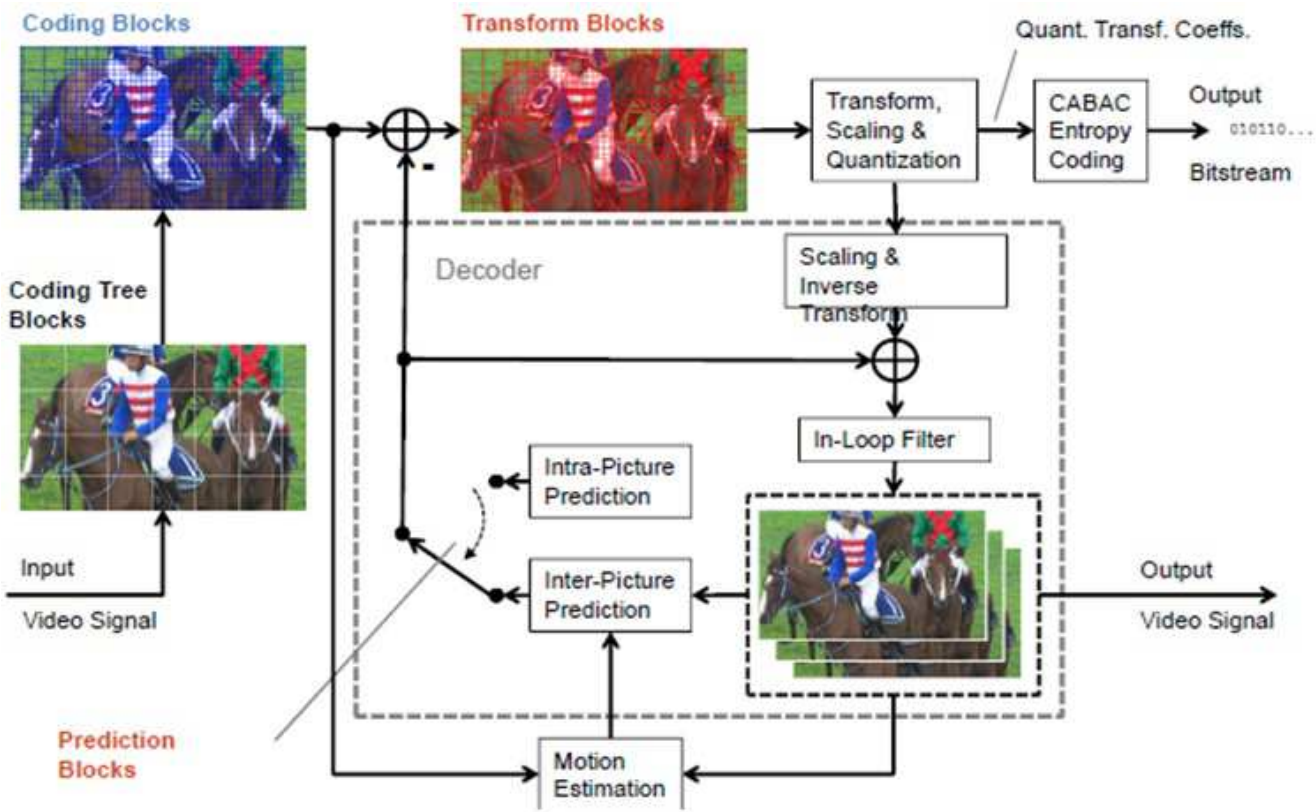


Figure : HEVC Encoder

New video coding standard by Joint Collaborative Team on Video Coding (JCTVC)

▸ HEVC features ▸ QuadTree Decomposition ▸ Intra Prediction ▸ Scanning Patterns

Introduction to HEVC

JCTVC

Joint venture of ITU-T Video Coding Experts Group (VCEG) and ISO/IEC Moving Picture Experts Group (MPEG)

Problem Definition

HEVC:

Use fixed Quantization Matrices (QM) that rely block size alone

Drawback : QM is computed independent of frame characteristics

- Directional bias on the energy distribution of intra prediction error is not considered
- Sparsity of the significance map is not exploited effectively

Adaptive Quantization(AQ)

Why prediction mode dependent Scaling

- Texture details of each frames decides the best prediction mode
- Scanning patterns depends on Prediction mode and block size

Proposed Method

Prediction mode dependent scaling of QM for the effective exploration of directional bias in residual energy distribution

- Adaptive scaling of QM ensure strong quantization for
  1. Highly sparse coefficient levels in a Coefficient Group (CG)
  2. Coefficient levels in the high frequency region of a CG
- Hence, CG flag is zero for the corresponding CG that eliminates further coding inside the CG

Adaptive Quantization contd..

Quantization Patterns

AQ uses three quantization patterns

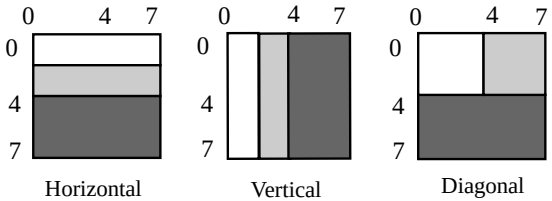
$\Rightarrow$ Diagonal (D) $\Rightarrow$ Horizontal (H) $\Rightarrow$ Vertical (V)

- Quantization pattern of TU : depends on intra prediction mode and TU size
- For larger TU size, D is preferred over V and H

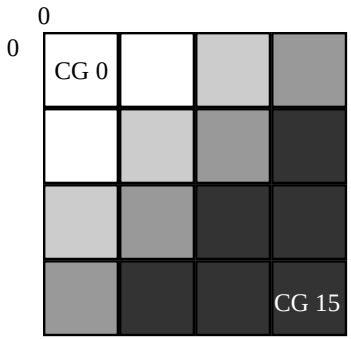
Table : Lookup table for Adaptive Quantization

TU Size	Intra Prediction Mode						
	0	1	2 - 5	6 - 14	15 - 21	22 - 30	31 - 34
8 x 8	D	D	D	V	D	H	D
16 x 16	D	D	D	D	D	D	D
32 x 32	D	D	D	D	D	D	D

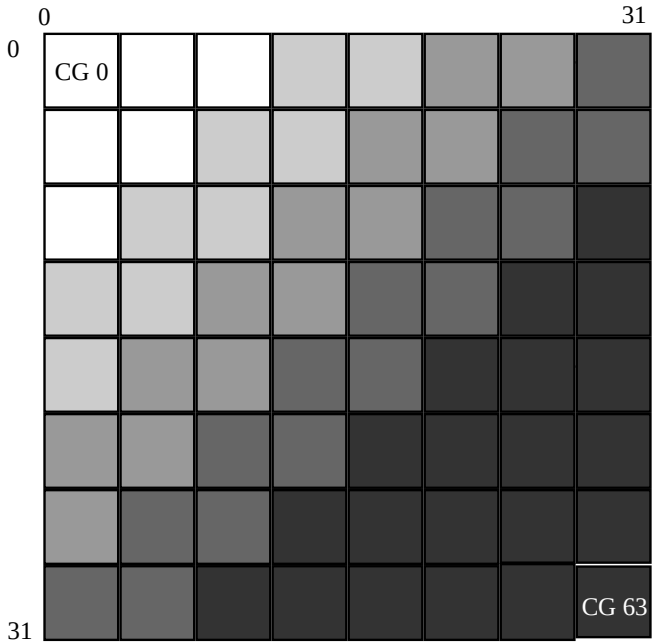
Adaptive Quantization contd...



(a) 8 x 8



(b) 16 x 16



(c) 32 x 32

Figure : Adaptive Quantization (a) 8 x 8 (b) 16 x 16 (c) 32 x 32

Low frequency regions: Finely quantized High frequency regions : Coarsely quantized

Number of stages, $S = log_2 N$

Scaling Factors for AQ

$$S_L = e^{-a*level} \quad (1)$$

$$S_{CH} = e^{-1.5*a*level} \quad (2)$$

$$\mathbf{f}'_{L,QP\%6} = \mathbf{f}_{QP\%6} * S_L \quad (3)$$

$$\mathbf{f}'_{CH,QP\%6} = \mathbf{f}_{QP\%6} * S_{CH} \quad (4)$$

$$\mathbf{g}'_{L,QP\%6} = 2^{20}/\mathbf{g}_{QP\%6} * S_L \quad (5)$$

$$\mathbf{g}'_{CH,QP\%6} = 2^{20}/\mathbf{g}_{QP\%6} * S_{CH} \quad (6)$$

- Distribution of the DCT coefficients follow Laplacian distribution [13] - [14]
- Exponential scaling factor is selected for each level in the quantization stage
- Used in the design of scaling factors S_L and S_{CH}
- a is constant which is taken as 0.1

Table : Scaling Factors for Adaptive Quantization

Scaling stage	8 x8		16 x 16		32 x 32	
	S_L	S_{CH}	S_L	S_{CH}	S_L	S_{CH}
1	1	1	1	1	1	1
2	0.90	0.86	0.90	0.86	0.90	0.86
3	0.81	0.74	0.81	0.74	0.81	0.74
4	-	-	0.74	0.64	0.74	0.64
5	-	-	-	-	0.67	0.55

Simulation Results

Simulation Settings and Configurations [15] - [16]

- Reference Software : HEVC reference software (HM 12.0)
- Test sequences : Sequences from class A to class F
- Configuration : All Intra Main 10 and All Intra Main
- QP value : 22, 27, 32 and 37

Simulation Results : Bit Rate Savings(QP=22)

Class	Sequence	Intra Main Bit Rate Saving %		Intra Main 10 Bit Rate Saving %	
		AQ	N level	AQ	N level
A (2560 x 1600)	Traffic	-1.99	-1.94	-2.05	1.99
	PeopleOnStreet	-1.83	-1.79	-1.89	-1.82
B (1920 x 1080)	Kimono	-7.50	-7.43	-7.60	-7.51
	Cactus	-6.10	-6.01	-6.30	-6.19
C (832 x 480)	BasketballDrill	-1.81	-1.76	-1.84	-1.78
	BQMall	-1.30	-1.28	-1.37	-1.33
D (416 x 240)	BlowingBubbles	-1.35	-1.34	-1.50	-1.47
	BQSquare	-2.29	-2.25	-2.30	-2.25
E (1280 x 720)	Johnny	-2.00	-1.91	-2.20	-2.11
	KristenAndSara	-2.48	-2.39	-2.69	-2.58
F : (832 x 480)	BaskeballDrillText	-1.80	-1.76	-1.84	-1.78
Avg.		-2.77	-2.71	-2.87	2.80

Simulation Results - Adaptive Quantization

EXPERIMENTAL RESULTS IN BD

Class	Sequence	Intra Main		Intra Main 10	
		Rate %	PSNR(dB)	Rate %	PSNR(dB)
A	Traffic	-0.129	0.001	-0.122	0.006
	PeopleOnStreet	-0.176	0.009	-1.039	0.061
B	Kimono	-0.100	-0.001	-0.768	0.024
	Cactus	-1.110	0.036	-1.381	0.044
C	BasketballDrill	-0.511	0.023	-0.520	0.024
	BQMall	0.167	- 0.010	0.243	-0.014
D	BlowingBubbles	-0.149	0.011	-0.185	0.011
	BQSquare	-0.265	0.020	-0.253	0.019
E	Johnny	-0.290	0.010	-0.480	0.018
	KristenAndSara	-0.858	0.397	-0.069	0.003
F	BaskeballDrillText	-0.434	0.22	-0.446	0.223
Avg		**-0.351**	**0.065**	**-0.456**	**0.038**

Rate Distortion plot

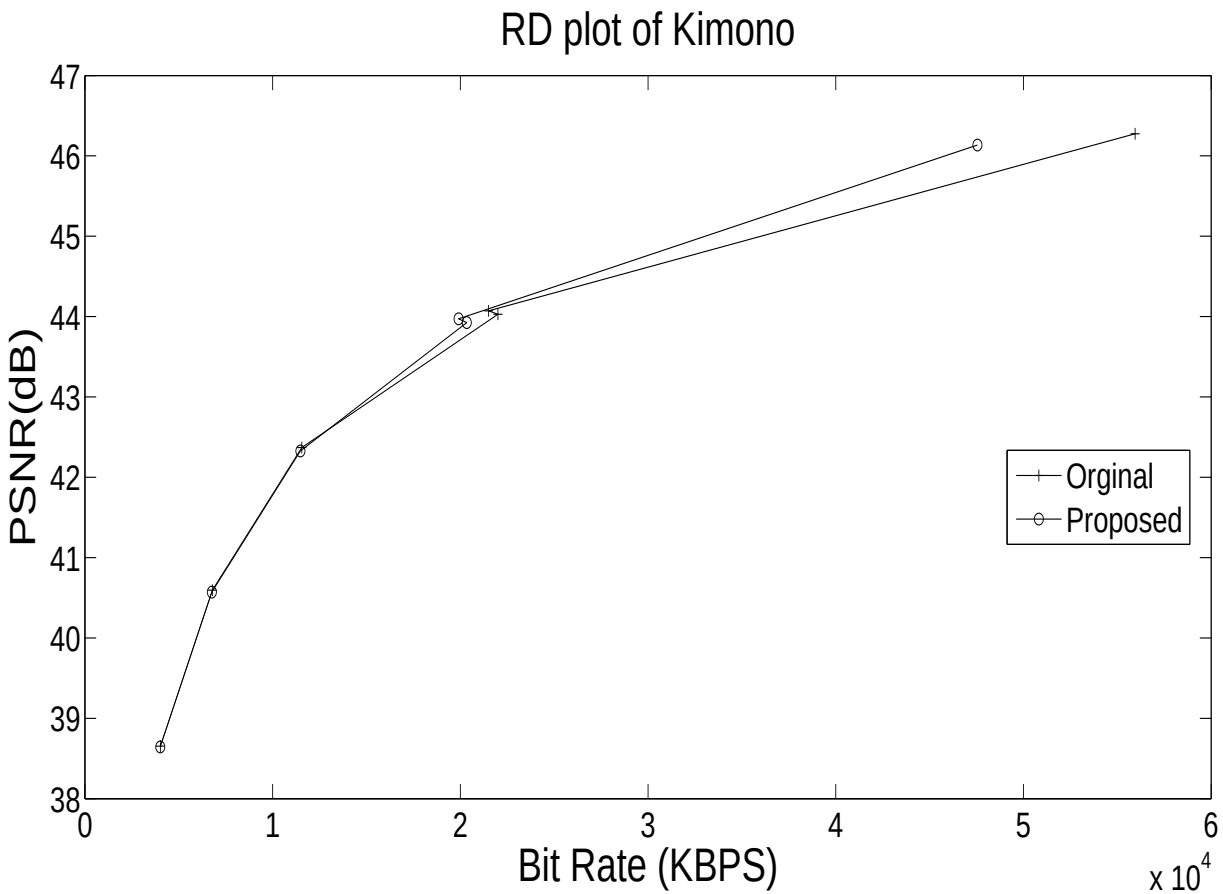


Figure : RD plots of Original and Proposed Adaptive Quantisation

Conclusions and Future Work

Conclusion

By adaptively choosing the quantizer weights based on the prediction modes of the CU,

- Bit rate reductions of 2.77% and 2.87% were obtained in Intra Main and Intra Main 10 configurations without any perceptual quality loss

Future Work

Investigate the effectiveness of an adaptive quantizer that adjusts its level of quantization in accordance with video peculiarities

References I

[1] G. J. Sullivan, J.-R. Ohm, W.-J. Han, and T. Wiegand, "Overview of the High Efficiency Video Coding (HEVC) standard," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 22, no. 12, pp. 1648-1667, Dec. 2012.

[2] M.T. Pourazad, C. Doutre, M. Azimi, and P. Nasiopoulos, "HEVC: The new gold standard for video compression: How does HEVC compare with H. 264/AVC?," *IEEE Consum. Electron. Mag.*, vol. 1, No. 3, pp. 36-46, Jul. 2012.

[3] T. Wiegand, G. J. Sullivan, G. Bjontegaard, and A. Luthra "Overview of the H.264/AVC video coding standard," *IEEE Trans. Circuits Syst. Video Technol.* vol. 13, no. 7, pp. 560-576, Jul. 2003.

[4] A.B. Watson, "Visual optimization of DCT quantization matrices for individual images," in *Proc. of AIAA Computing in Aerospace*, vol. 9, San Diego, Sep. 1993, pp. 286-291.

[5] R. Gweon and Y.-L. Lee, "N-level quantization in HEVC," in *IEEE Int. Symp. Broadband Multimedia Syst. Broadcast.*, Seoul, Jun. 27-29, 2012, pp. 1-5.

[6] B. Bross, W. Han, J.R. Ohm, G.J Sullivan, and T. Wiegand, *High Efficiency Video Coding (HEVC) text specification draft 8*, document JCTVC - J1003 of JCT-VC, Stockholm, Sweden, Jul. 2012.

[7] H.M. Hang, W.H. Peng, and C.H. Chan, "Towards the next video standard: High Efficiency Video Coding," in *Proc. APSIPA Annual Summit and Conf.*, Dec 2010, pp. 609-618.

[8] B. Bross, P. Helle, S. Oudin, T. Nguyen, D. Marpe, H. Schwarz, and T. Wiegand, "Quadtree structures and improved techniques for motion representation and entropy coding in HEVC", in *IEEE Int. Conf. Consum. Electron.*, Berlin, Sep. 3-5, 2012, pp. 26-30.

[9] J. Lainema and K. Ugur, "Angular intra prediction in High Efficiency Video Coding (HEVC)," in *IEEE Workshop Multimedia Signal Process.*, Hangzhou, China, Oct. 17-19, 2011, pp. 1-5.

[10] F. Li, G. Shi, F. Wu, "An efficient VLSI architecture for 4 X 4 intra prediction in the High Efficiency Video Coding (HEVC) standard," in *IEEE Int. Conf. on Image Process.*, Brussels, Sep. 11-14, 2011, pp. 373 - 376.

References II

[11] M. Budagavi, A. Fuldseth, G. Bjontegaard, V. Sze, and M. Sadafale, "Core Transform Design in the High Efficiency Video Coding (HEVC) Standard," *IEEE J. Sel. Topics Signal Process.* vol. 7, no. 6, pp. 1029-1041, Dec. 2013.

[12] J. Sole, R. Joshi, N. Nguyen, T. Ji, M. Karczewicz, G. Clare, F. Henry, and A. Duenas, "Transform coefficient coding in HEVC," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 22, no. 12, pp. 1765-1777, Dec. 2012.

[13] R. Reininger and J. Gibson, "Distributions of the two-dimensional DCT coefficients for images," *IEEE Trans. Commun.*, vol. 31, no. 6, pp. 835-839, Jun. 1983.

[14] E. Y. Lam and J. W. Goodman, "A mathematical analysis of the DCT coefficient distributions for images," *IEEE Trans. Image Process.* vol. 9, no. 10, pp. 1661-1666, Oct. 2000.

[15] HEVC Reference Software [Online]. Available: https: //hevc.hhi.fraunhofer.de/trac/hevc/browser/tags/HM-12.0/

[16] F. Bossen, *Common HM Test Conditions and Software Reference Configurations*, JCT-VC document L1100, Jan. 2013.

[17] G. Bjontegard, *Calculation of Average PSNR Differences between RD Curves*, document VCEG-M33, ITU-T Q6/16, Austin, TX, Apr. 2001.

Thank You

HEVC Block Diagram

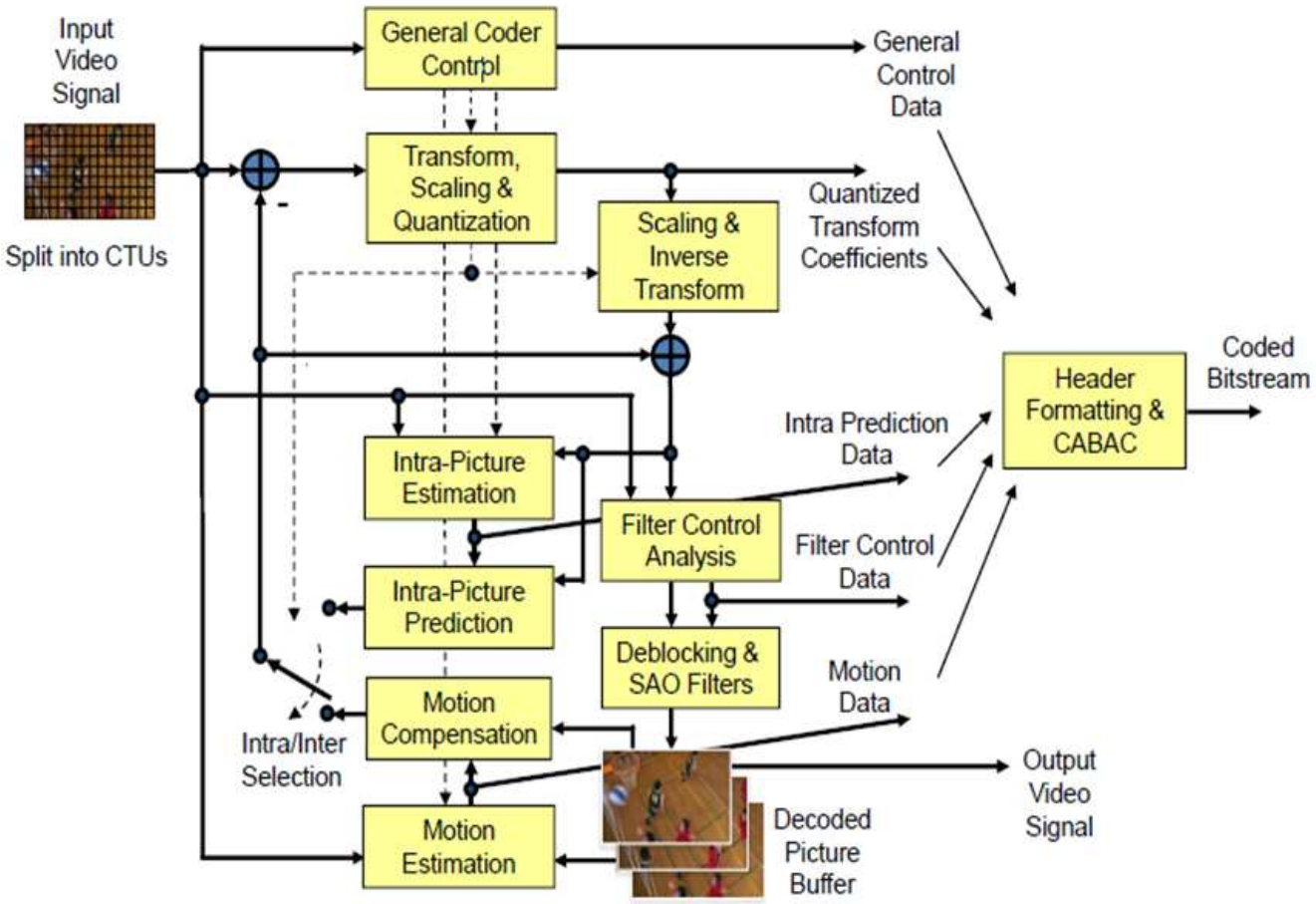


Figure : HEVC Video Encoder [1]

HEVC : Salient Features

Main Profile Specifications	
Coding Tree Block	64x64, 32x32, 16x16
Coding Unit	64x64 to 8x8 in Quadtree structure
Prediction Unit	Symmetric + Asymmetric
Transform Unit	DCT Kernals DST Kernals
Intra Prediction	upto 35 modes
Interpolation Filter	8 tap DCT-IF
Motion Coding	AMVP and Merging
Entropy Coding	CABAC only
In-loop Filters	De-blocking Filter and SAO
Multiple Slices	Dependent Slice
Parallelization	WPP Tiles

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QuadTree Decomposition [1] , [8]

HEVC : Introduces the new Quadtree structure concept that consists

⇒ **Coding Unit (CU)** ⇒**Prediction Unit (PU)** ⇒**Transform Unit (TU)**

AIM: Flexible Block Partition that suits to image peculiarities

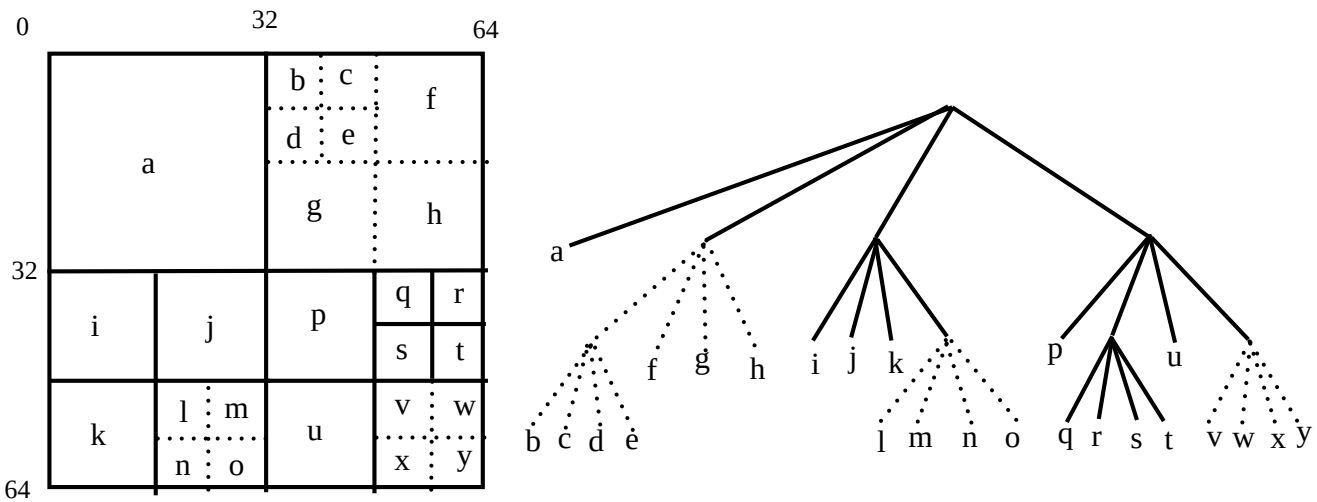

Figure : Subdivision of a CTB into CBs and TBs. Solid lines indicate CB boundaries and dotted lines indicate TB boundaries. Left: the CTB with its partitioning, right: the corresponding quadtree [1]

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Intra Prediction in HEVC

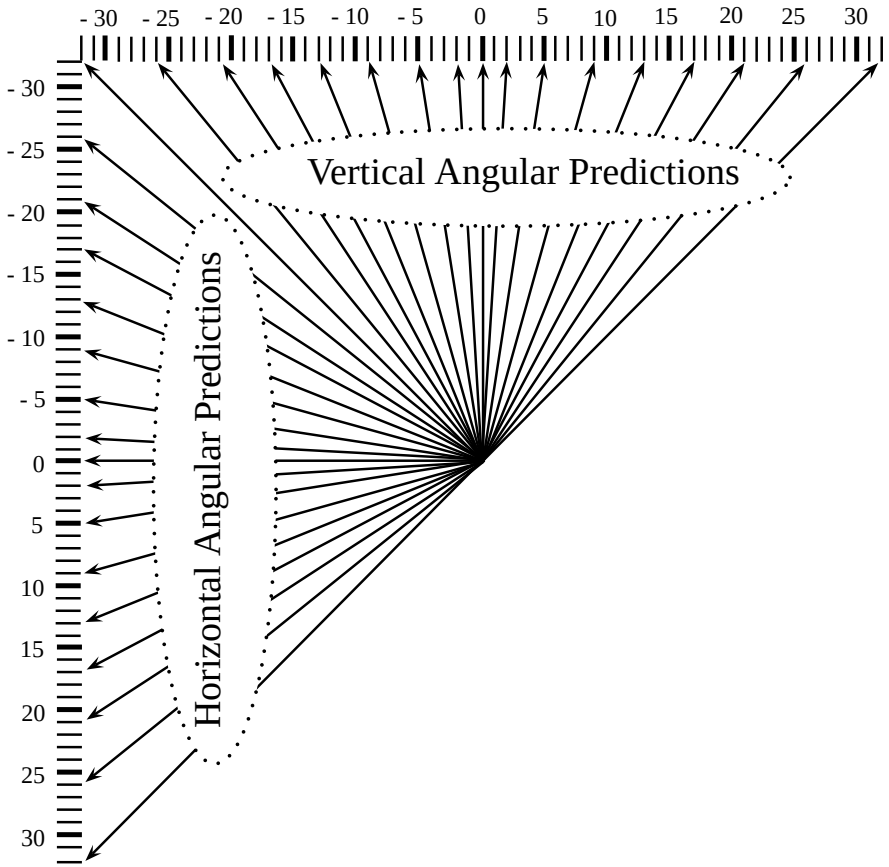

Figure : Intra prediction Angles [9]

HEVC Scanning Patterns

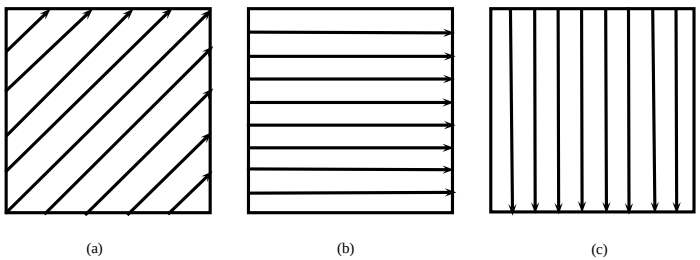

Figure : Three coefficient scanning methods in HEVC: (a) diagonal up-right scan (b) horizontal scan and (c) vertical scan [1]

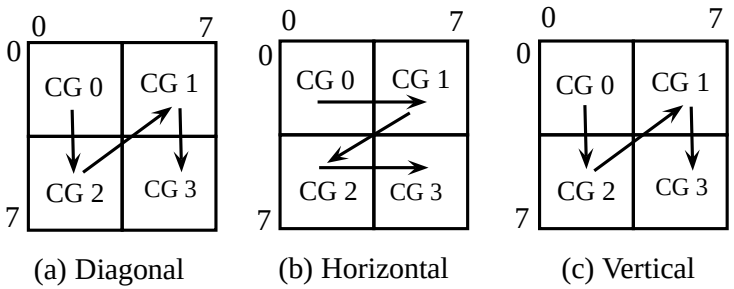

Figure : Coefficient scanning methods in 8 x 8 TB (a) diagonal (b) horizontal (c) vertical

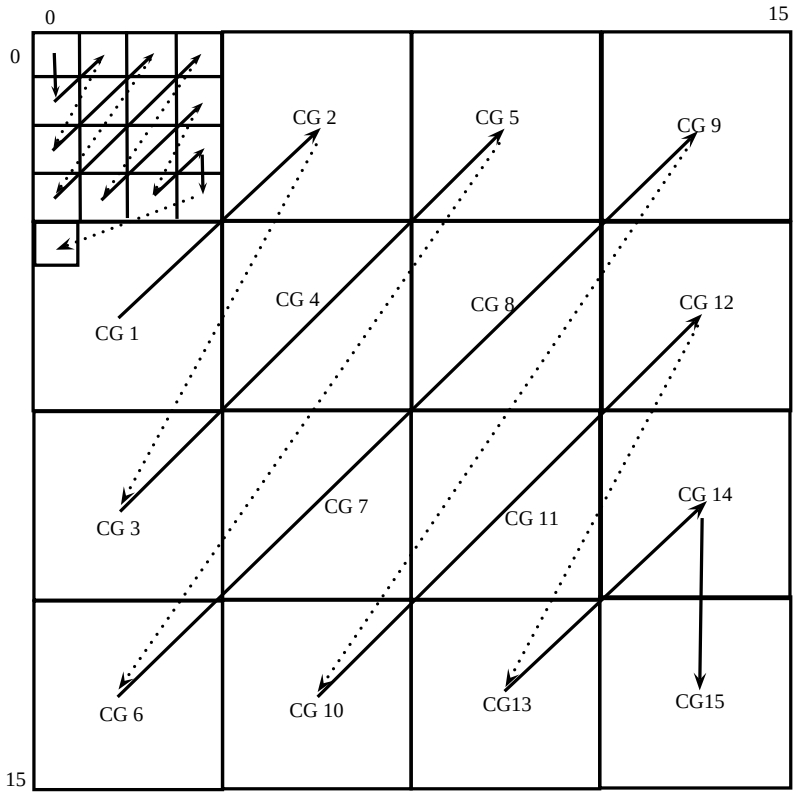

Figure : Scanning Pattern - 16 x 16 block