7th Apr, 2014

Intra Coding in HEVC

Lainema, Jani, and Kemal Ugur. "**Angular intra prediction in high efficiency video coding (HEVC).**" *Multimedia Signal Processing (MMSP), 2011 IEEE 13th International Workshop on*. IEEE, 2011.

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General Introduction of HEVC (High Efficiency Video Coding)

What is HEVC?

- Video compression standard and successor to H. 264/AVC
- Jointly developed by ‘ISO/IEC Moving Pictures Expert Group (MPEG)’ & ‘ITU-T Video Coding Expert Group (VCEG)’
- MPEG & VCEG established ‘Joint Collaborative Team on Video Coding (JCT-VC)’ to develop HEVC
- Also known as ISO/IEC 23008-2 (MPEG-H Part-2) and ITU-T H.265

Prominent Features

- Double compression rate for same video quality*
- Substantially better video quality for same bit rate*
- Support for 8K UHD resolution

*Compared to H.264/AVC

The Standard Draft

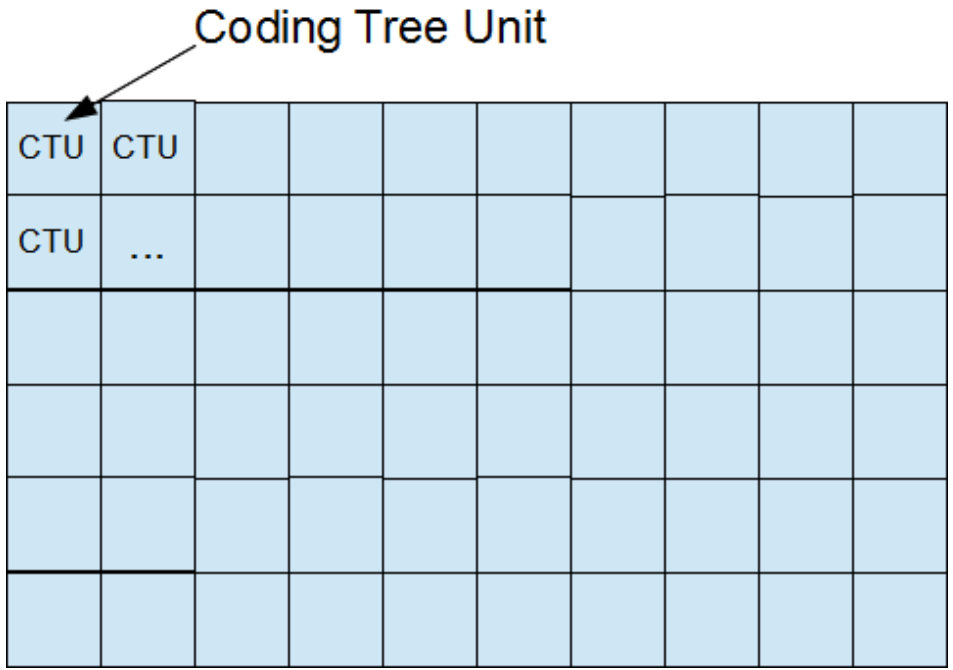
- 1st Version of Standard draft published Early 2013
  - Download URL : http://www.itu.int/rec/T-REC-H.265-201304-I/en
- Extensions still under development (Early 2014)
  - Scalable Coding Extension
  - 3D Video Extensions
  - Screen Content Extension

http://www.itu.int/en/ITU-T/studygroups/2013-2016/16/Pages/video/jctvc.aspx

HEVC – What are CTU, CU, CTB, CB, PB, and TB?

Reference : http://codesequoia.wordpress.com/2012/10/28/hevc-ctu-cu-ctb-cb-pb-and-tb/

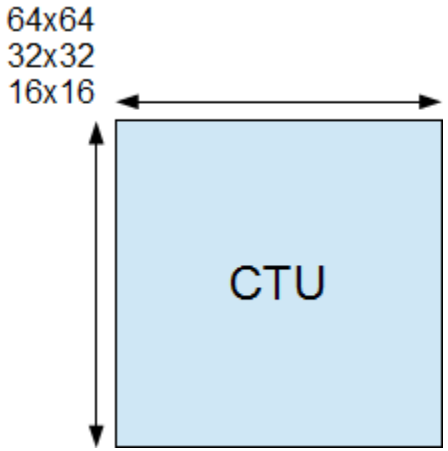
HEVC divides picture into CTUs*



CTU is an acronym for ***Coding Tree Unit***

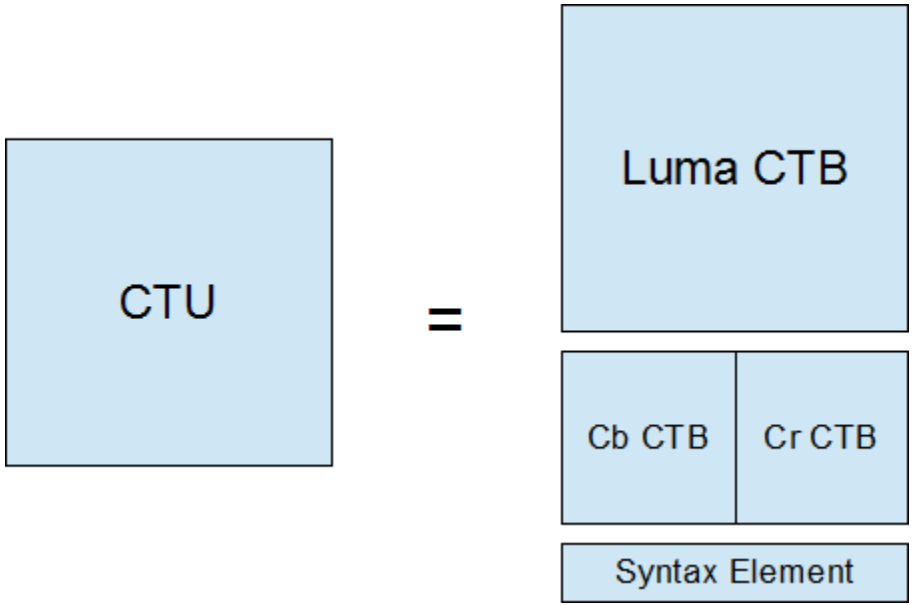
CTU (Coding *Tree* Unit) - Things to Remember

- Dimensions of CTU is fixed for the entire video sequence



xxxUnit Vs. xxxBlock

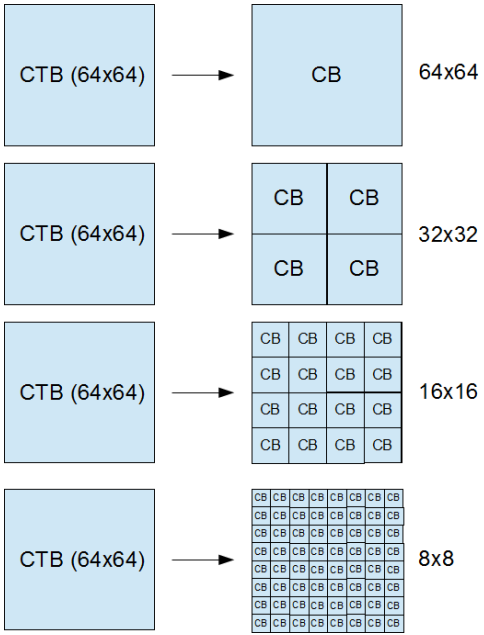
xxxUnit ⇒ Luma block, Chroma block, Syntax elements together



Coding Tree Unit (CTU)	Coding Tree Block CTB)
Coding Unit (CU)	Coding Block (CB)
Prediction Unit (PU)	Prediction Block (PB)
Transform Unit (TU)	Transform Block (TB)

CTB is split to form CB (Coding Block)

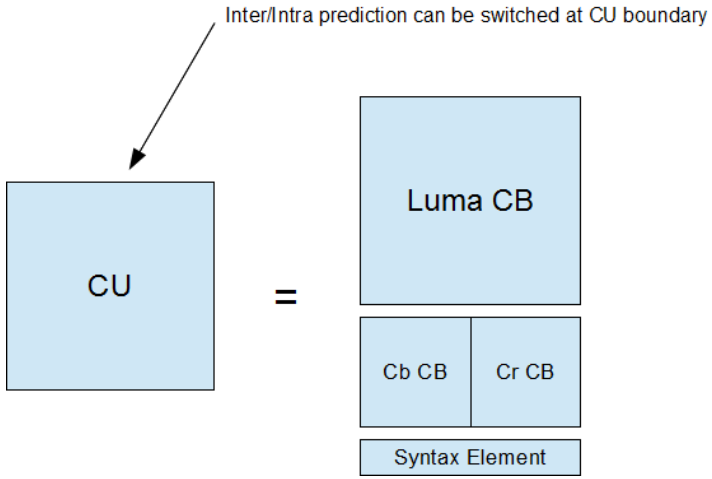
CTB too big to decide
whether to perform Inter or Intra prediction
(and select their prediction directions)



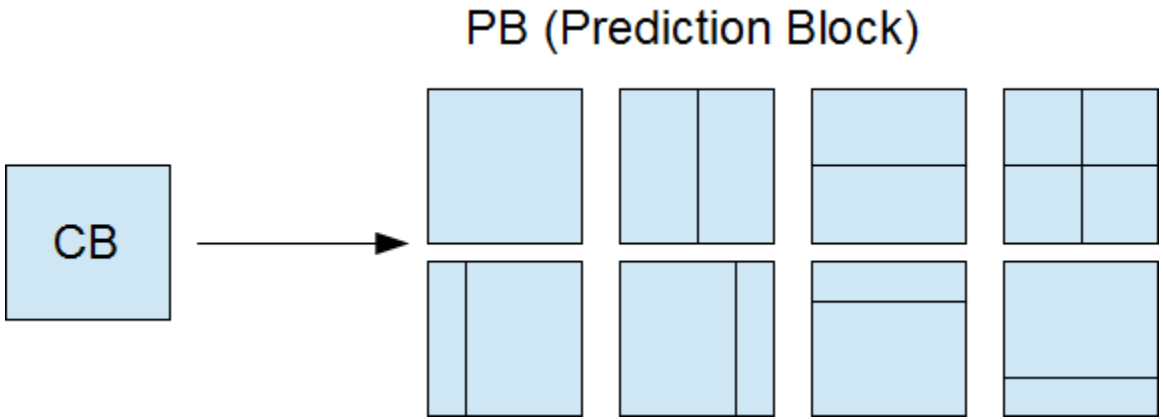
*Inter prediction only for P & B-frames

CU & CB

- Size of CU is good enough to switch between Intra- & Inter-prediction (P & B-frames only)
- Too large to store motion vectors (inter prediction) or intra prediction mode.



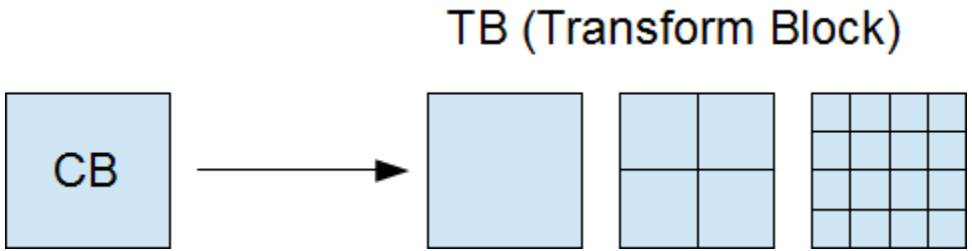
Prediction Block (PB)



*Non square division of CB only for inter-prediction.
**Prediction direction is decided on per CU basis

Transform Block (TB)

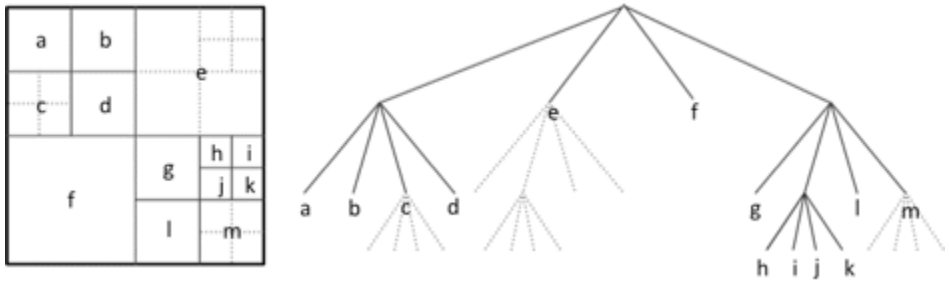
- Once prediction is made, the residue* need to be transformed with DCT-like transform
- CB may be too big, thus option to subdivide



*Difference between predicted block and actual block

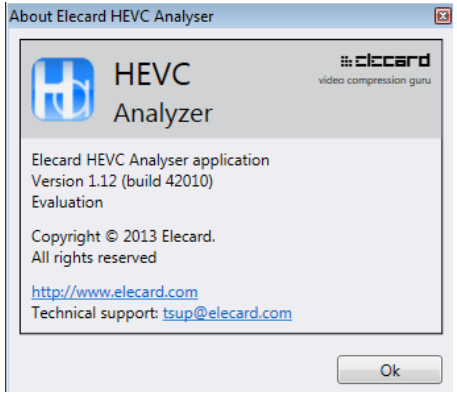
Quad-tree based block partitioning

- CTB ⇒ Bold lines
- CB ⇒ Solid lines
- TB ⇒ Dashed lines



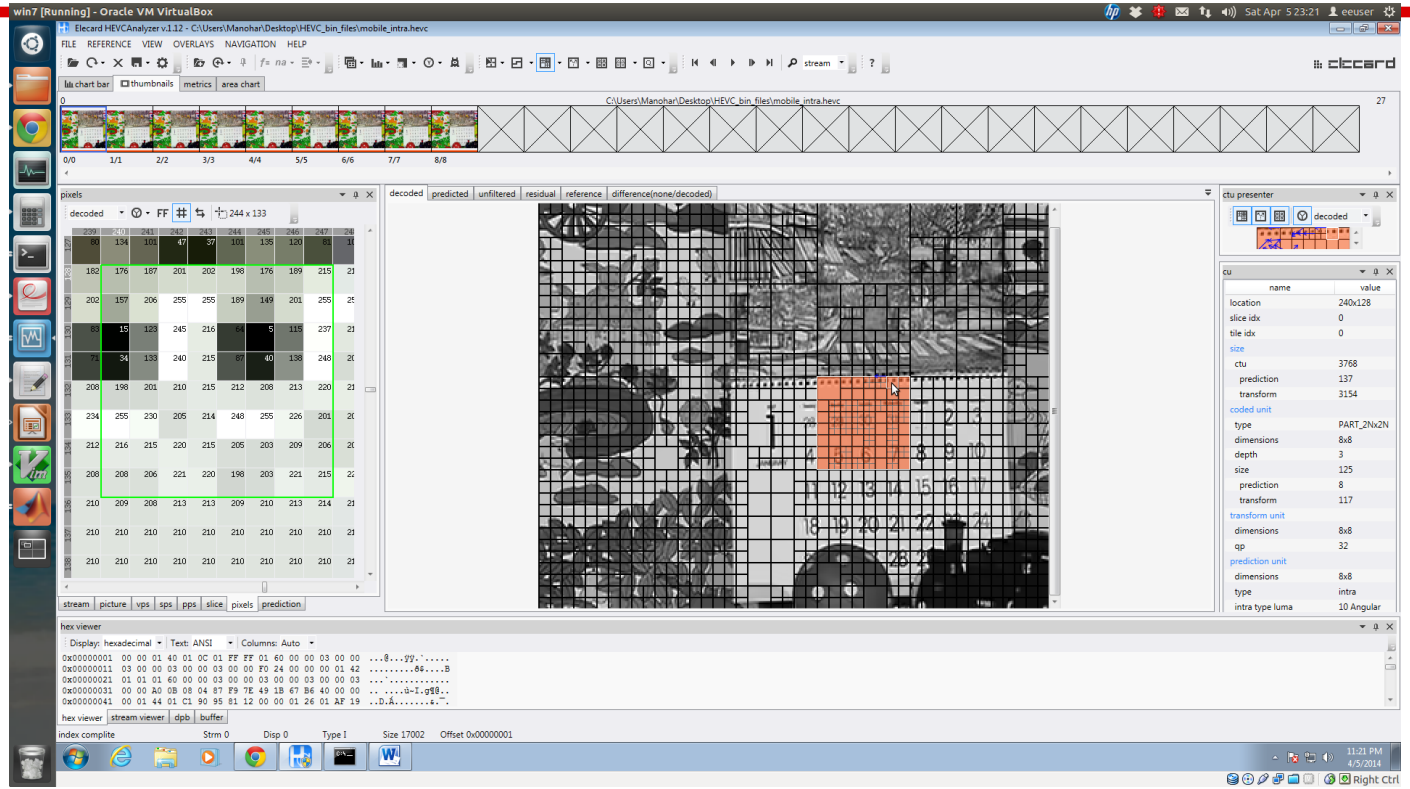
Reference : http://www.hhi.fraunhofer.de/fields-of-competence/image-processing/research-groups/image-video-coding/hevc-high-efficiency-video-coding/generic-quadtree-based-approach-for-block-partitioning.html

Elecard HEVC Analyzer Demo

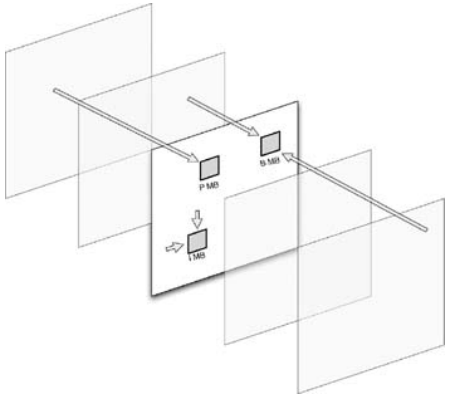


http://www.elecard.com/en/index.html

Elecard HEVC Analyzer Demo

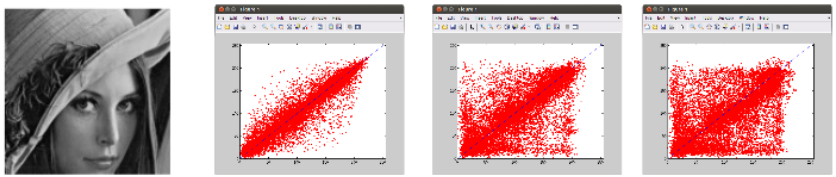


Intra Prediction



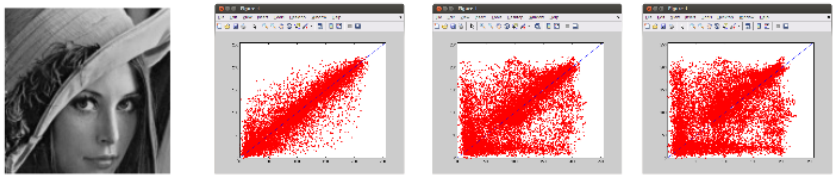
General Motivation for Intra-prediction

- Neighbouring Pixel intensities are highly correlated
- Function of distance between the pixels



(a) Image (b) $(k,l) = (1,0)$ (c) $(k,l) = (5,0)$ (d) $(k,l) = (10,0)$

Figure 5: Scatter plots $(x_{i,j}, x_{i+k,j+l})$



(a) Image (b) $(k,l) = (0,1)$ (c) $(k,l) = (0,5)$ (d) $(k,l) = (0,10)$

Figure 6: Scatter plots $(x_{i,j}, x_{i+k,j+l})$

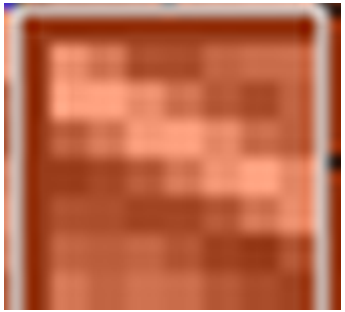
Horizontal & Vertical Correlation

Why difference coding result in better compression ?

1. Predict the unknown pixel intensities
    a. from it's neighbours (this is justified due to correlation amongst the neighbours)
2. Code the difference

Motivation for having directional prediction

In presence of a dominant edge in a block,

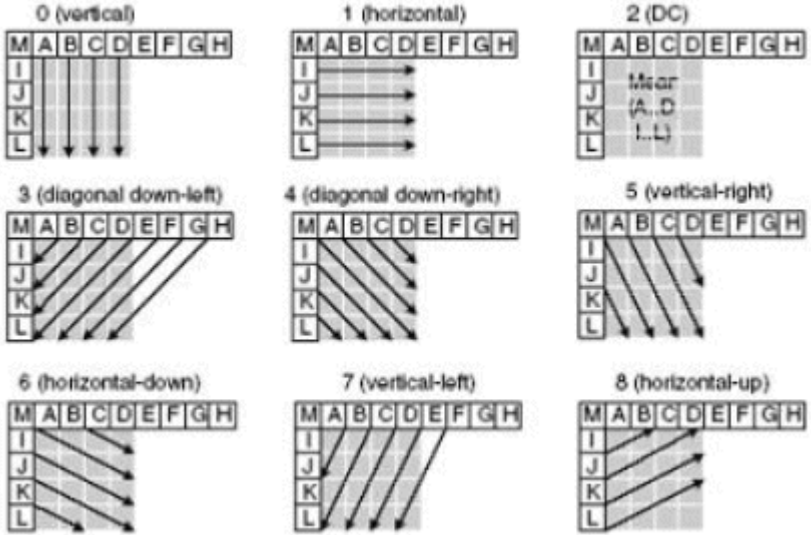


130	69	76	87	107	127	147	170
203	192	122	70	77	89	109	130
141	207	203	184	113	71	78	92
54	75	150	206	202	175	105	72
86	43	56	84	159	206	202	167
156	132	80	44	57	92	167	205
154	175	154	126	74	46	59	101
91	130	157	172	151	120	68	47

Highest correlation would be along the direction of the edge

Intra-Prediction Modes in H.264

8 Angular Modes, 1 DC mode

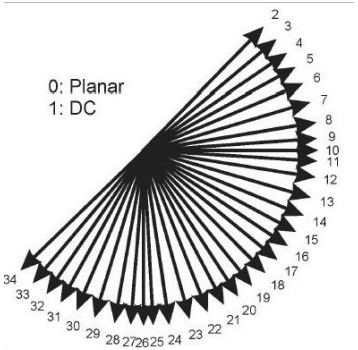


Not flexible enough

H.264 Macroblocks, 8 angular prediction modes

*With bigger CTB sizes in HEVC, having more prediction directions is imperative

Intra Prediction in HEVC
&
It’s Efficient Computation



HEVC Intra-prediction

Introduces :

- 33 Angular modes
- 1 Planar mode
    - (was added later in 2012)
- 1 DC mode

with 1/32 pixel accuracy

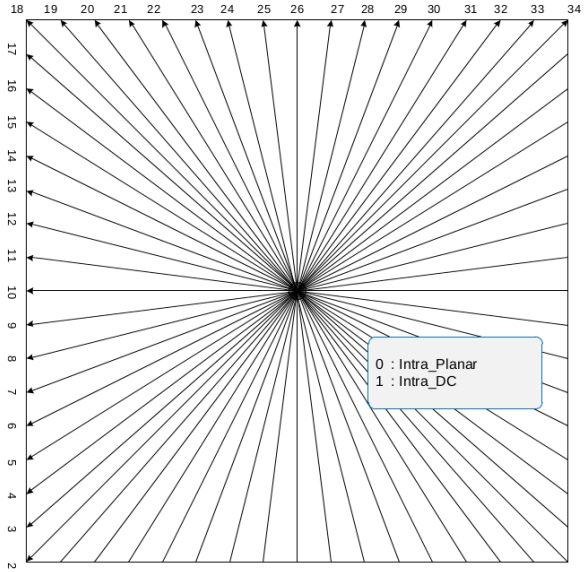


*Figure above represents 1 pixel

Problem :

How to efficiently compute the predicted values?

Computing Predicted Samples

Predicted Sample : P_{xy}

Reference Sample : R_{xy}

"Predicted sample is obtained by backward projecting its location to the reference row using selected prediction mode"

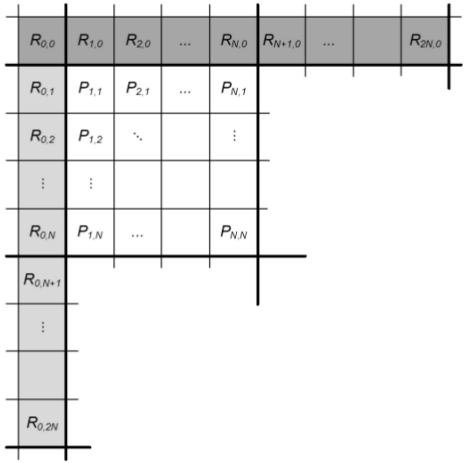


Fig. 1. Reference samples $R_{x,y}$ used in prediction to obtain predicted samples $P_{x,y}$ for a block of size $N \times N$ samples.

Note: For efficiency purpose, HEVC uses only the reference row (for all vertical angular modes). Also, HEVC uses only reference column (for all horizontal modes)

Efficient Computation

$$P_{x,y} = ((32 - w_y)\cdot R_i + w_y \cdot R_{i+1} + 16) >> 5$$

$$c_y = (y \cdot d) >> 5$$
$$w_y = (y \cdot d) \,\&\, 31$$
$$i = x + c_y$$

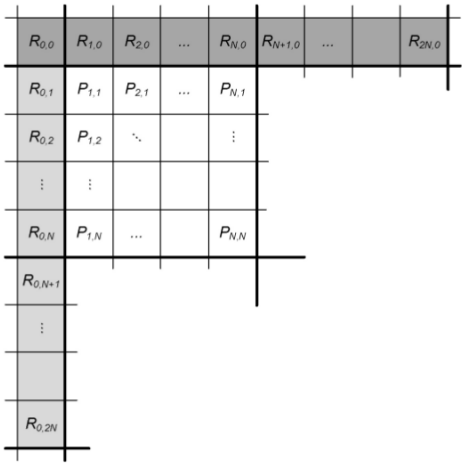
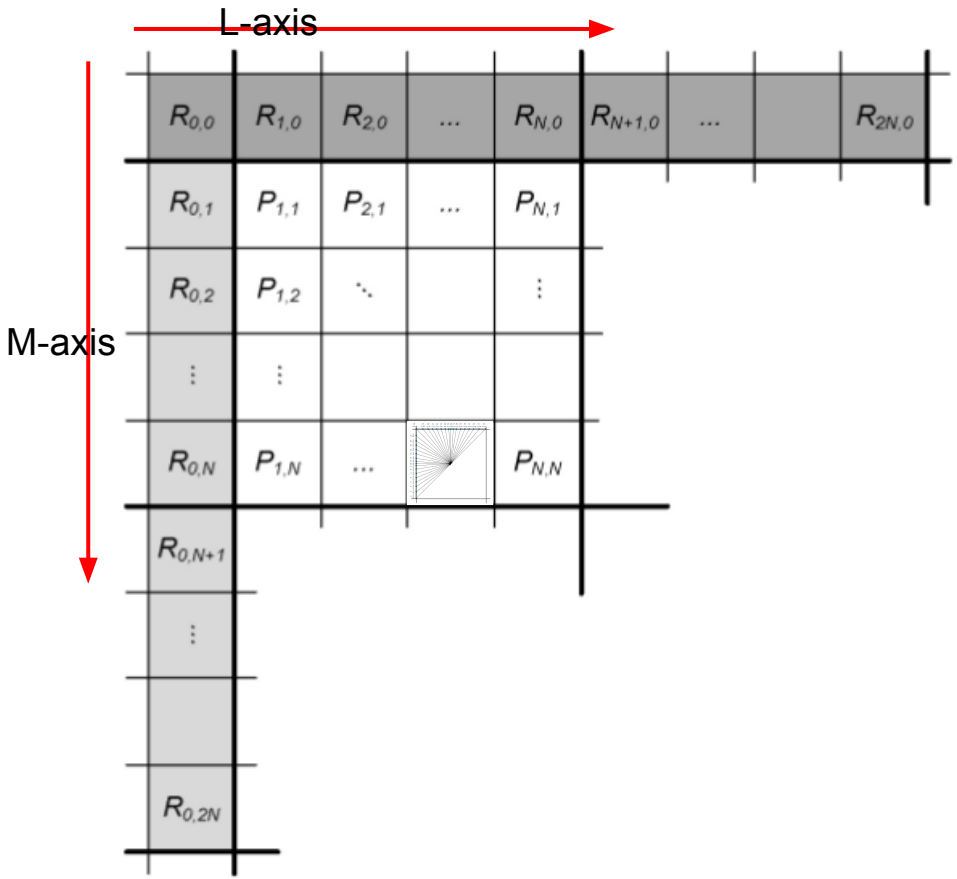


Fig. 1. Reference samples $R_{x,y}$ used in prediction to obtain predicted samples $P_{x,y}$ for a block of size $N \times N$ samples.

*These equations valid only for all vertical predictions (mode 19-34)
Note-1 : '>> 5' left shift by 5 is divide by 32 operation
Note-2 : '&31' is for modulo division operation



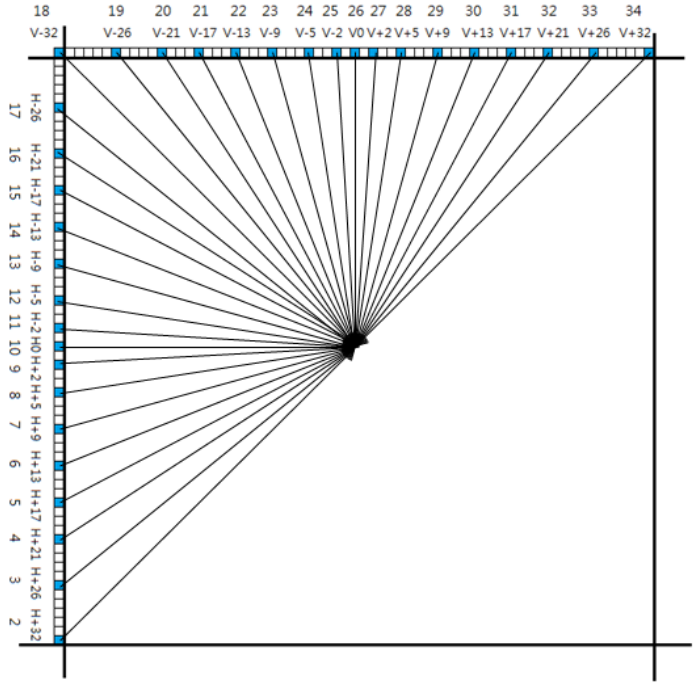
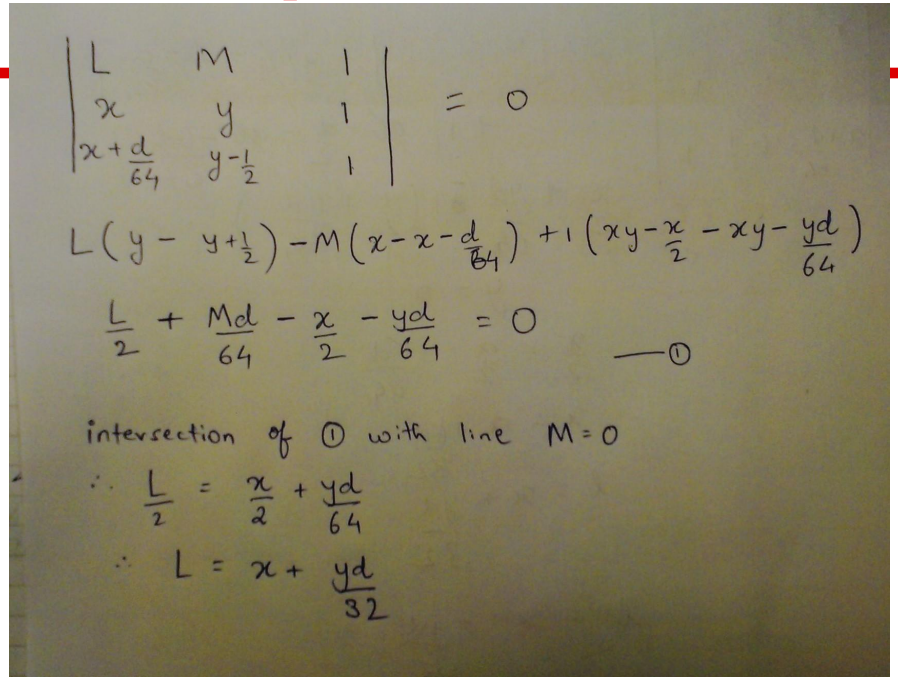


Fig. 1. Reference samples $R_{x,y}$ used in prediction to obtain predicted samples $P_{x,y}$ for a block of size $N \times N$ samples.

Deriving the equations



$$P_{xy} = (32\text{-}w_y)/32 \,.\, R_{floor(L)} + w_y \,.\, R_{floor(L+1)}$$

Why the weighted average?

-1- ‘L’ thus obtained may not be an integer. However, the available intensity values are only for integer values of ‘L’.

-2- Thus, a solution could be to have a weighted average of ‘floor(L)’ and floor(L+1).

-3- Weights may be taken as the distance of L from floor(L) and floor(L+1) respectively.

-4- (3) can be realized with a modulo division operation. This justifies the equations show in HEVC standard document for intra-prediction.

Dealing with values outside reference rows

In this case, row is extended by projecting left reference column.

For performance reasons copying rightmost value*

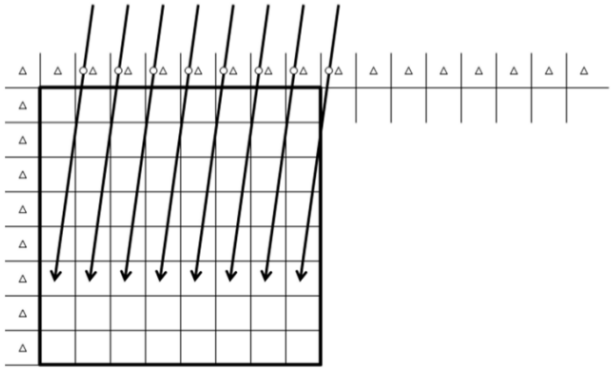


Figure 3. An example of angular prediction when operating on the sixth row of an 8x8 block with vertical prediction that utilizes a positive displacement value. Triangles indicate the reference pixels and circles indicate the projected fractional pixels at 1/32 pixel accuracy.

*Negligible effect for compression performance JCTVC-C046. [12]

Experimental Results

Experiment

Use H.264 modes (9) in HEVC Intra-main profile

vs

Use 33 Angular & 1 DC mode in HEVC Intra-main profile

Subjective measure - demo

HE (High Efficiency Mode)
- Uses CABAC
- Uses ALF (Adaptive loop filters)
- Bit depth is 10bits

LC (Low Complexity mode)
- Uses CAVLC
- no ALF
- Bit depth of 8bits

*All frames were intra coded

Resolution	Sequence	Configuration	
		HE	LC
2560x1600	Traffic	-4.1	-5.2
	PeopleOnStreet	-4.5	-5.5
	Nebuta	-1.6	-1.5
	SteamLocomotive	-1.5	-2.0
1080p	Kimono	-2.4	-2.7
	ParkScene	-1.0	-1.6
	Cactus	-5.9	-6.9
	BasketballDrive	-7.6	-9.0
	BQTerrace	-5.9	-7.3
832x480	BasketballDrill	-8.6	-9.6
	BQMall	-4.0	-5.6
	PartyScene	-1.4	-1.8
	RaceHorses	-3.3	-3.6
416x240	BasketballPass	-4.5	-5.5
	BQSquare	-3.1	-3.4
	BlowingBubbles	-2.3	-2.8
	RaceHorses	-3.6	-4.0
720p	Vidyo1	-8.7	-10.5
	Vidyo3	-5.6	-7.5
	Vidyo4	-5.8	-7.2
Min/Max	Smallest gain	-1.0	-1.5
	Largest gain	-8.7	-10.5
Averages	4Kx2K	-2.9	-3.6
	1080p	-4.6	-5.5
	832x480	-4.3	-5.1
	416x240	-3.4	-3.9
	720p	-6.7	-8.4
	Average (all)	-4.3	-5.2

Improvement in coding efficiency in percentage (%).
Calculated using Bjontegaard-delta measure (BD-bit rate)

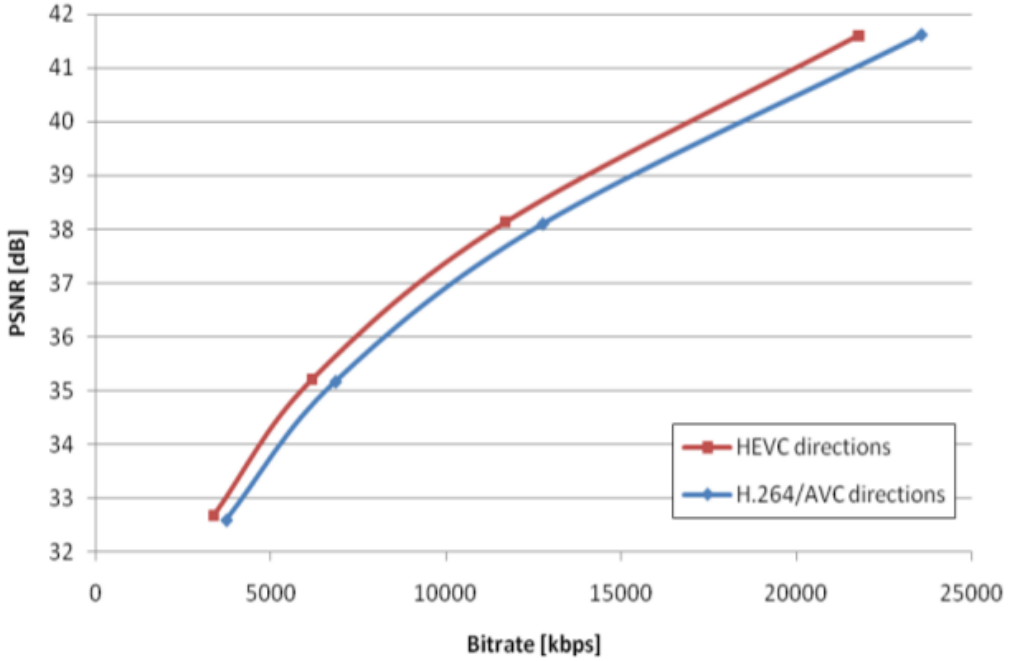


Fig. 4. Rate-distortion performance of the proposed method for the sequence Basketball Drill in low complexity configuration

1. For a fixed rate HEVC gives lesser distortion
2. For a fixed distortion HEVC gives smaller rate

References

Lainema, Jani, and Kemal Ugur. "Angular intra prediction in high efficiency video coding (HEVC)." *Multimedia Signal Processing (MMSP), 2011 IEEE 13th International Workshop on*. IEEE, 2011.

Lainema, Jani, et al. "Intra coding of the HEVC standard." *Circuits and Systems for Video Technology, IEEE Transactions on* 22.12 (2012): 1792-1801.

Section 8.4 of HEVC standard draft. http://www.itu.int/rec/T-REC-H.265-201304-I/en