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Fast HEVC Intra Mode Decision Based on Edge Detection and SATD Costs Classification

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Outline

- Introduction
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- Background
- Literature review
- Proposed method
- Experimental results
- Conclusion

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Introduction

- New demands for video coding standards
  - Demand for high quality video (4K × 2K and 8K × 4K)
  - Video delivery on mobile devices
  - High resolution 3D or multiview video

- HEVC can reduce the bit rate by half relative to the previous H.264/MPEG-4 standard

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Problem Statement

- HEVC encoding could require up to 10x more computational complexity than H.264 with 2x-3x for decoding [1]
  - Need for new algorithms to reduce its complexity without sacrificing the coding performance
- Our focus is on HEVC intra coding complexity reduction
  - All-intra profile to replace the current intra coding techniques

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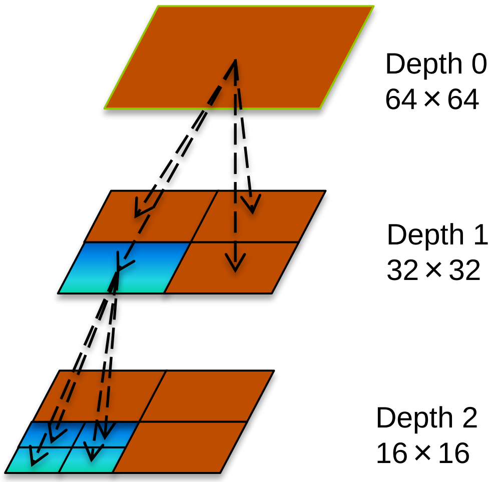
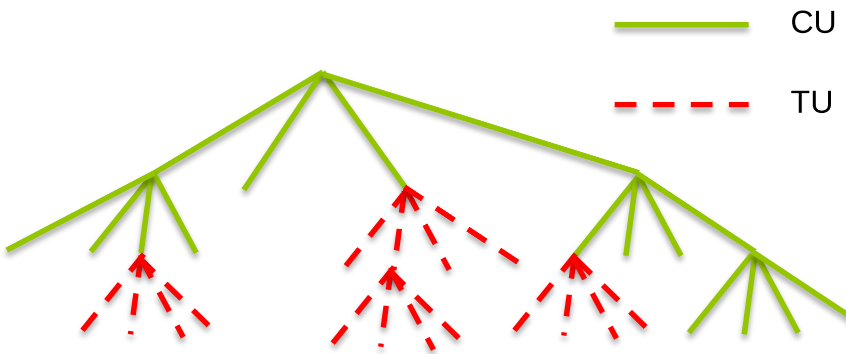
[1] M. Goldman, "AVC and HEVC: The Future of Encoding", PBS Technology Conference, 2012

Background

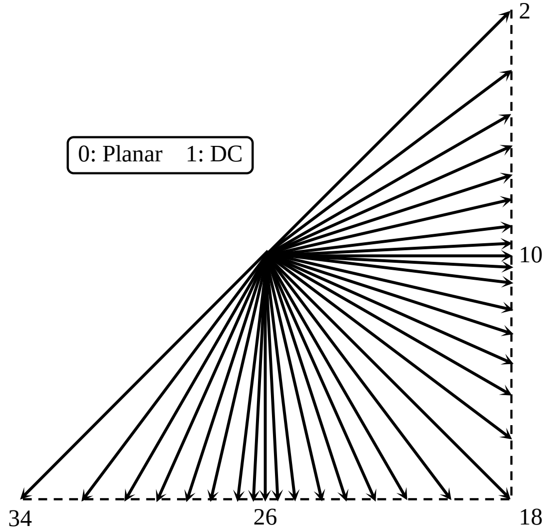
- Coding unit splitting
- Segmentation units
  - Coding tree units (CTUs)
  - Coding units (CUs)
  - Transform units (TUs)
  - Prediction units (PUs)

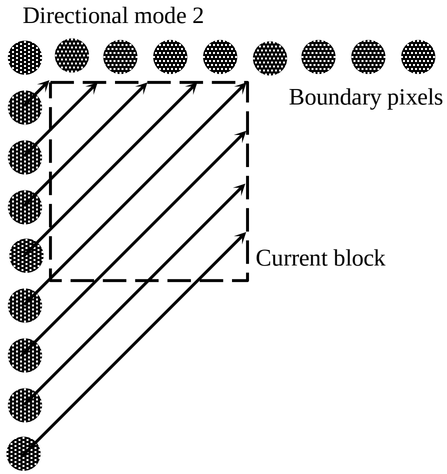




Background

- Intra mode decision
- HEVC intra modes
  - 33 directional modes
  - DC to predict the homogeneous regions
  - Planar to produce smooth sample surfaces





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Background

- Intra mode decision processes (HM)
  - Rough mode decision (RMD)
    - SATD: Sum of absolute transformed differences

$$J_{RMD} = D_{SATD} + \lambda_{RMD} \times B_{RMD}$$

  - Rate distortion optimization (RDO)
    - SSE: Sum of squared errors

$$J_{RDO} = D_{SSE} + \lambda_{RDO} \times B_{RDO}$$

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Literature Review

- Edge detection
- Neighboring blocks' modes
- RDO cost estimation

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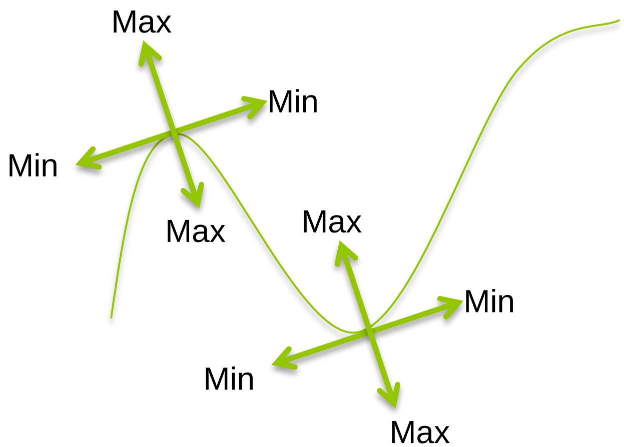
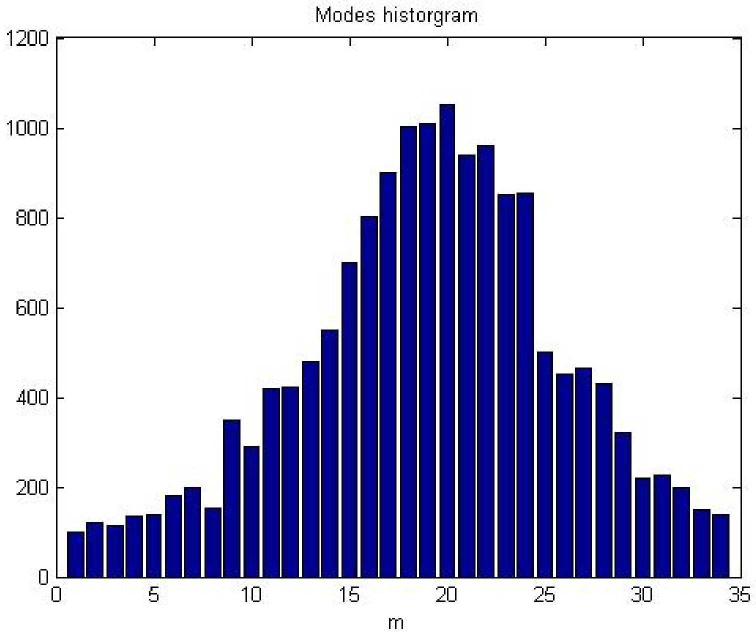
Literature Review

- Mode decision
  - Edge detection [2, 3, 4]



Gradient and edge direction



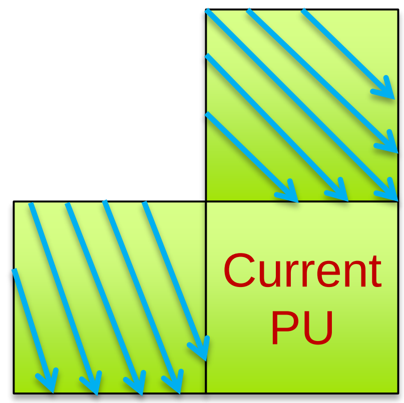
[2] G. Chen, L. Sun, Z. Liu and T. Ikenaga, "Fast Mode and Depth Decision HEVC Intra Prediction Based on Edge Detection and Partitioning Reconfiguration", ISPACS 2013

[3] T. L. da Silva, L. V. Agostini, L. A. da Silva Cruz, "Fast HEVC Intra Prediction Mode Decision based on Edge Direction Information", European Signal Processing Conference, Aug. 2012

[4] W. Jiang, H. Ma, Y. Chen, "Gradient based Fast Mode Decision Algorithm for Intra Prediction in HEVC", CECNet 2012

Literature Review

- Mode decision
  - neighboring blocks [5]



[5] Y. Wang, X. Fan, L. Zhao, S. Ma, D. Zhao and W. Gao, “A Fast Intra Coding Algorithm for HEVC”, IEEE International Conference on Image Processing, Oct. 2014

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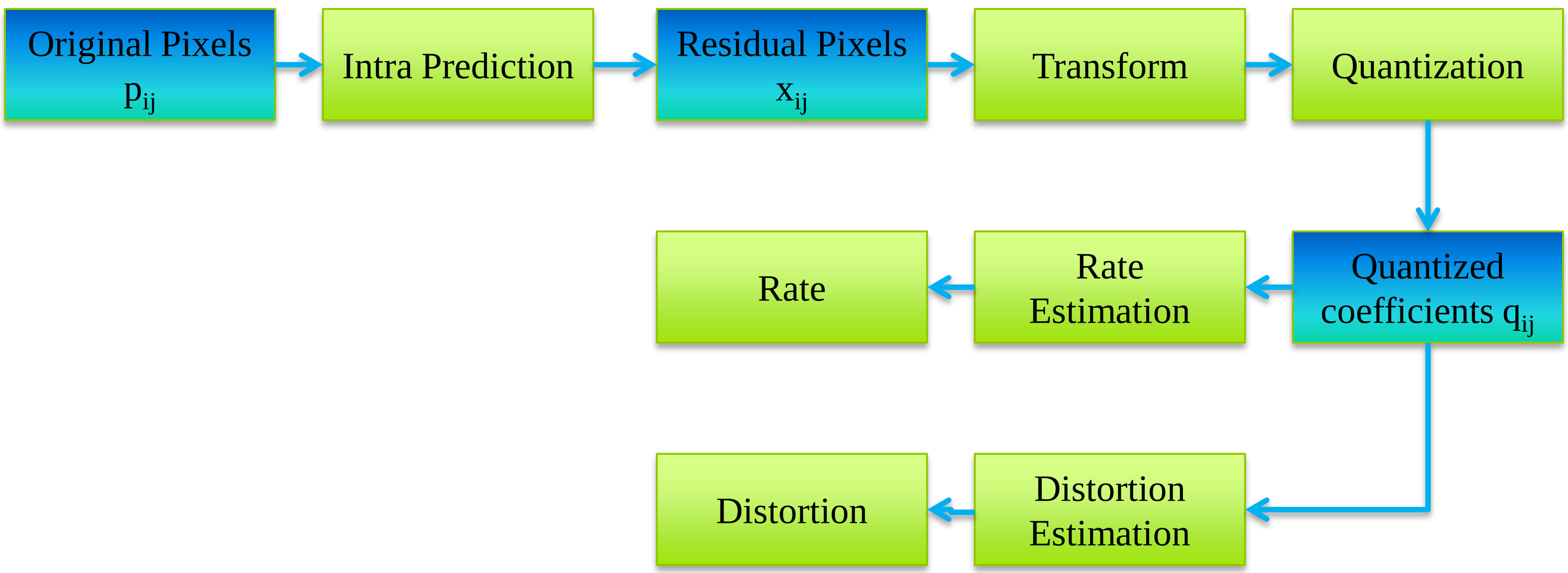
Literature Review

- Mode decision
  - RDO cost estimation [6]



[6] Z. Sheng, D. Zhou, H. Sun and S. Goto, “Low-Complexity Rate-Distortion Optimization Algorithms for HEVC Intra Prediction”, MMM Part I, LNCS 8325, Springer 2014

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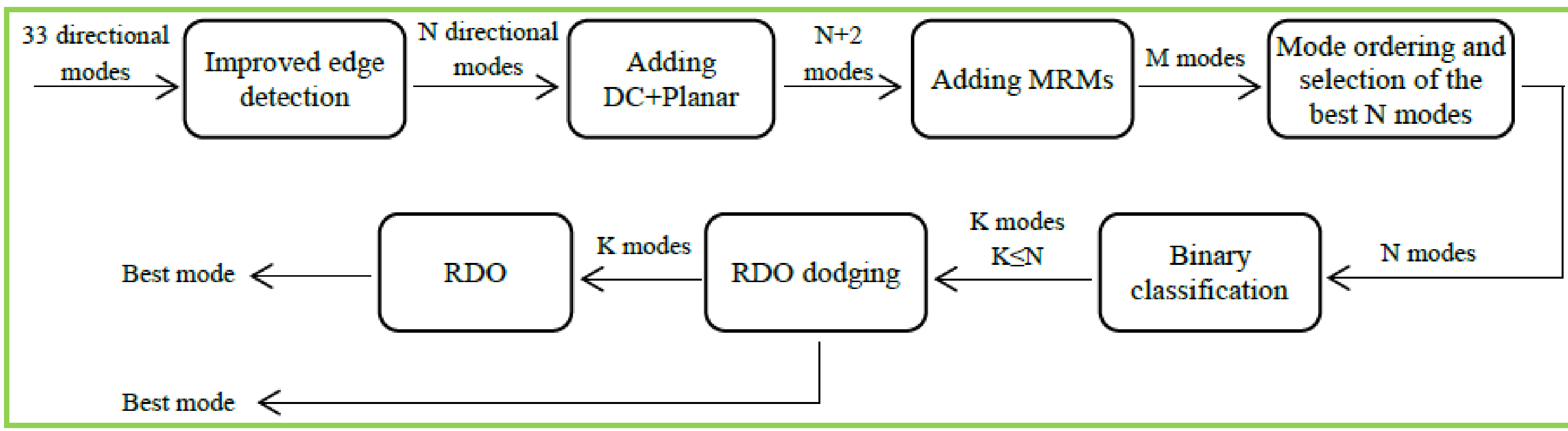
Proposed Method

- Intra mode decision based on
  - Improved edge detection
  - Most relevant modes (MRMs) of the neighboring blocks
  - Selecting promising candidates based on SATD



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Proposed Method

- Edge detection operator

$$\vec{G} = G_x\vec{j} + G_y\vec{i}$$

$$G_x = p_{i-1,j+1} + 2 \times p_{i,j+1} + p_{i+1,j+1} - p_{i-1,j-1} - 2 \times p_{i,j-1} - p_{i+1,j-1}$$

$$G_y = p_{i+1,j-1} + 2 \times p_{i+1,j} + p_{i+1,j+1} - p_{i-1,j-1} - 2 \times p_{i-1,j} - p_{i-1,j+1}$$

$$|\vec{G}| = \sqrt{G_x^2 + G_y^2} \longrightarrow |G_x| + |G_y| \qquad Ang(\vec{G}) = atan\left(\frac{G_y}{G_x}\right) \longrightarrow G_y/G_x$$

-1	0	1
-2	0	2
-1	0	1

(a) G_x

-1	-2	-1
0	0	0
1	2	1

(b) G_y

Sobel masks

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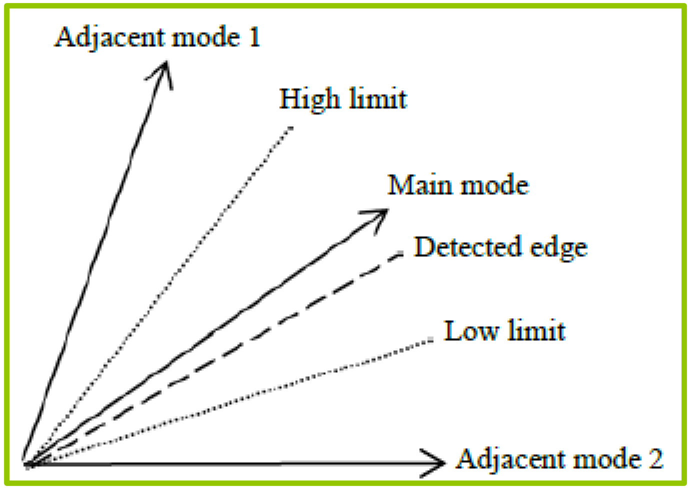
Proposed Method

- Three assigned modes for each edge



Detected edge and three related modes

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Proposed Method

- High and low limits of G_y/G_x for angular modes

Mode	lowLimit	highlimit	Mode	lowLimit	highLimit
2	-1.15928	-1	18	0.86261	1.15928
3	-1.53711	-1.15928	19	0.65057	0.86261
4	-1.98666	-1.53711	20	0.50336	0.65057
5	-2.59240	-1.98666	21	0.38574	0.50336
6	-3.61354	-2.59240	22	0.27674	0.38574
7	-5.76314	-3.61354	23	0.17352	0.27674
8	-11.61240	-5.76314	24	0.08611	0.17352
9	-40.73548	-11.61240	25	0.02455	0.08611
10	-∞	-40.73548	26	-0.02455	0.02455
10	40.73548	∞	27	-0.08611	-0.02455
11	11.61240	40.73548	28	-0.17352	-0.08611
12	5.76314	11.61240	29	-0.27674	-0.17352
13	3.61354	5.76314	30	-0.38574	-0.27674
14	2.59240	3.61354	31	-0.50336	-0.38574
15	1.98666	2.59240	32	-0.65057	-0.50336
16	1.53711	1.98666	33	-0.86261	-0.65057
17	1.15928	1.53711	34	-1	-0.86261

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Proposed Method

- Weights of main and adjacent modes

$$mainModeWeight = |G_x| + |G_y|$$

$$modeWeightFactor = (highLimit - \frac{G_y}{G_x})/(highLimit - lowLimit)$$

$$adjacentMode1Weight = (1 - modeWeightFactor) \times (|G_x| + |G_y|)$$

$$adjacentMode2Weight = modeWeightFactor \times (|G_x| + |G_y|)$$

  – Special mode (10)

$$modeWeightFactor = 0.5 \times (1 + 40.73548/\left|\frac{G_y}{G_x}\right|)$$

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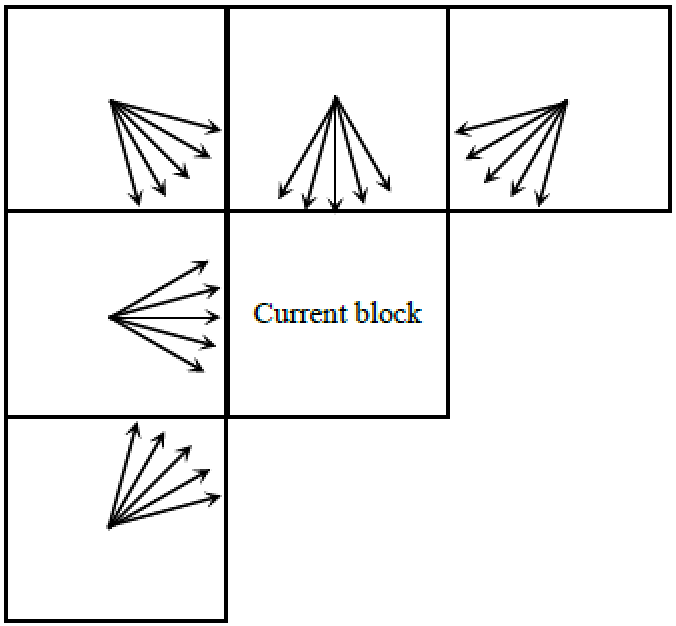
Proposed Method

- Adding DC, planar and most relevant modes (MRMs)
- MRM: A neighboring mode that based on its direction is a promising mode for the current block
  - 2n+1 modes



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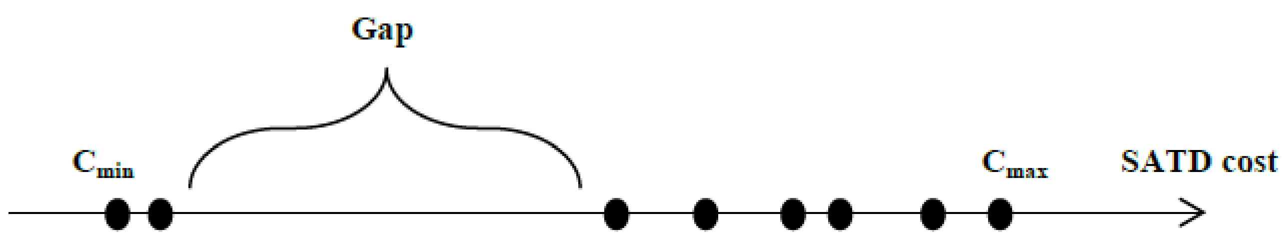
Proposed Method

- Mode ordering, binary classification
- RDO dodging
  - If the mode with lowest cost is one of MRMs select it as a final mode



$$Gap = \alpha \times (C_{max} - C_{min})$$

$$\alpha \leq 1$$

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Experimental Results

- Implementation setup
  - HEVC test model HM 15.0 (All-Intra profile)
  - Implementation platform: Intel® i7-3770 CPU-3.40, 12 GB of RAM, running Windows 7
  - 100 first frames of the recommended sequences [7]
  - Quantization parameters: 22, 27, 32, 37
  - Parameters of the algorithm: $N = 8$ and $\alpha = 1/4$ for block sizes 4×4 and 8×8 and $N = 3$ and $\alpha = 2/3$ for block sizes 16×16, 32×32 and 64×64, n=3

[7] F. Bossen, "Common Test Conditions and Software Reference Configurations", JCTVC-L1100, 12th Meeting, Geneva, Jan. 2013

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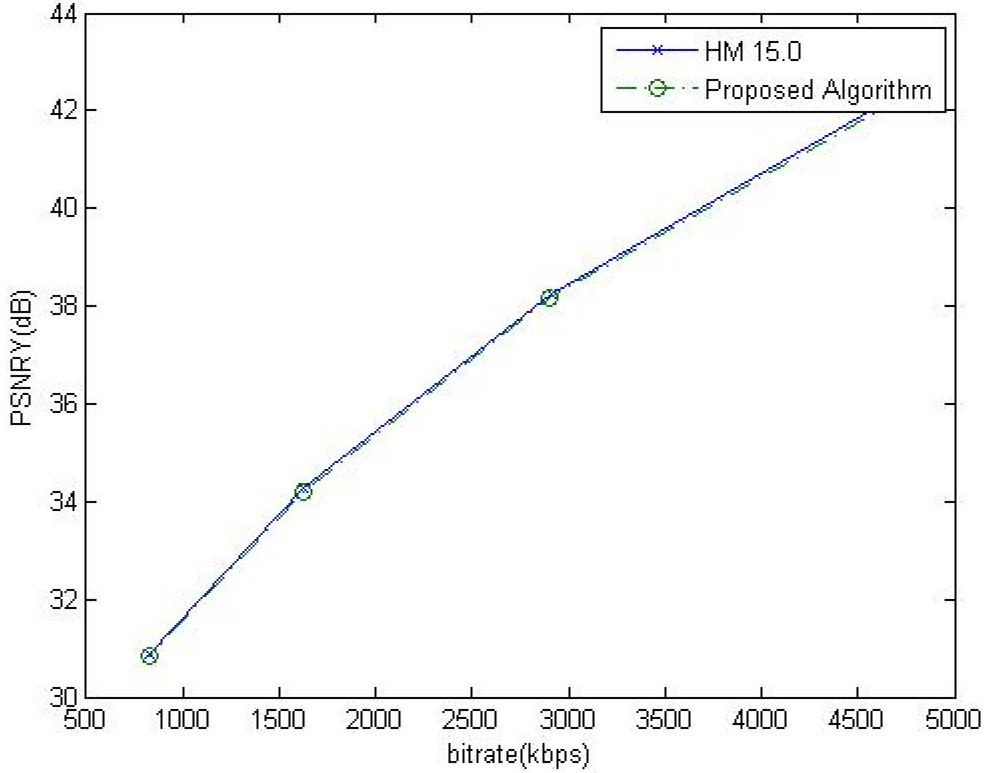
Experimental Results (Versus HM 15.0)

Class	Video Sequences	ΔT (%)	BD-Rate (%)	BD-$PSNR_Y$ (dB)
A 2560x1600	Traffic	-35.4	0.95	-0.051
	PeopleOnStreet	-34.1	1	-0.057
	NebutaFestival	-34.1	0.53	-0.039
	SteamLocomotiveTrain	-37.8	0.48	-0.025
B 1920x1080	Cactus	-36.1	1.34	-0.05
	Kimono	-39.2	0.79	-0.028
	ParkScene	-37.5	0.87	-0.039
	BasketballDrive	-38.4	2.17	-0.059
	BQTerrace	-35.2	0.79	-0.048
C 832x480	BQMall	-34.3	1.15	-0.068
	PartyScene	-32.8	1.18	-0.092
	RaceHorsesC	-34.7	0.72	-0.047
	BasketballDrill	-33.1	0.8	-0.039
D 416x240	RaceHorses	-34.1	0.99	-0.065
	BasketballPass	-36	1.45	-0.085
	BlowingBubbles	-33.7	1.01	-0.06
	BQSquare	-32.7	1.38	-0.123
E 1280x720	Vidyo1	-36.8	1.31	-0.066
	Vidyo3	-37.4	1.23	-0.069
	Vidyo4	-37.7	1.33	-0.061
Average		***-35.6***	***1.07***	***-0.059***
Jiang's algorithm		-20	0.74	-0.040
da Silva's algorithm		-18.9	1.3	-0.062

Experimental Results



RD curve of the proposed method and HM 15.0 for the RaceHorses sequence

Originality of the Work

- Using an improved edge detector
  - Considering three adjacent modes for each detected edge
- Using all five possible neighboring blocks and select only the relevant modes from them
- Using low-complex SATD in a novel way
  - Select the promising modes based on a Gap
- Simple to implement

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Conclusion

- Goal
  - Optimize HEVC intra coding processes for complexity reduction for the same quality

- Procedure
  - Obtain the best intra mode based on edge detection and binary classification
    - We have achieved 35% time reduction using the proposed approach with about 1% BD-rate increment

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