vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Coding Unit Splitting Early Termination for Fast HEVC Intra Coding Based on Global and Directional Gradients

Mohammadreza Jamali
Stéphane Coulombe

École de technologie supérieure,
Université du Québec, Montréal

September 22, 2016

ÉTS
Le génie pour l'industrie
Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Outline

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

ÉTS

Le génie pour l'industrie

Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

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

ÉTS
Le génie pour l'industrie
Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Introduction

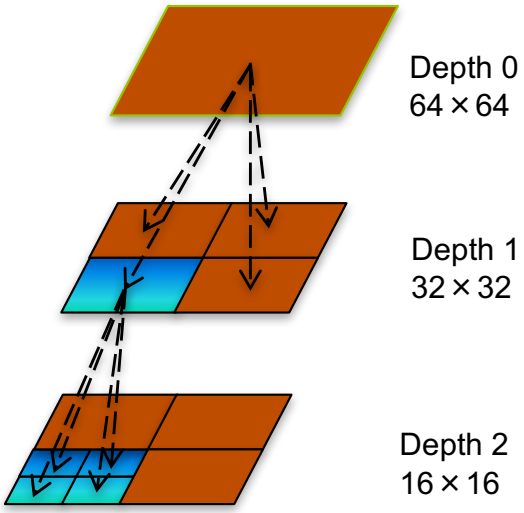
- HEVC encoding could require up to 10x more computational complexity than H.264 with 2x-3x for decoding [1]
  - Need for new algorithms to reduce its complexity without sacrificing the coding performance
- Our focus is on HEVC intra coding complexity reduction
  - 3.2x more complex for intra coding
  - All-intra profile to replace the current intra coding techniques

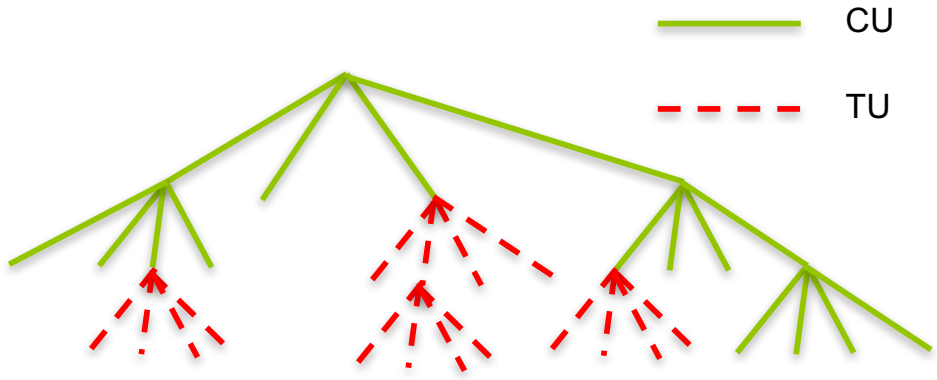
ÉTS
Le génie pour l'industrie
Département de génie logiciel et des TI

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

Background

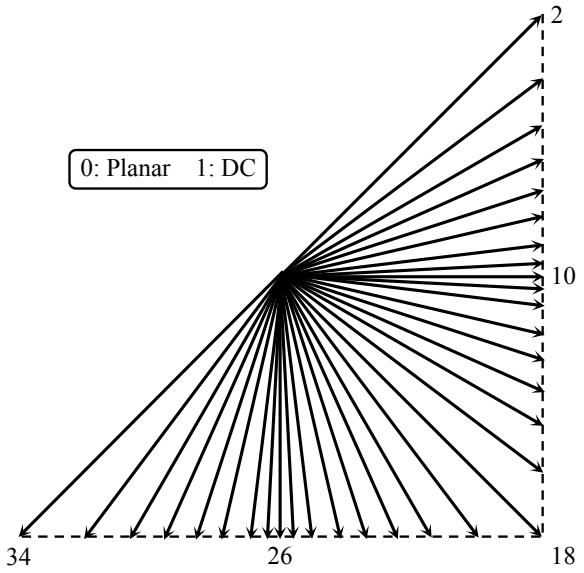
- Coding unit splitting
- Segmentation units
  - Coding tree units (CTUs)
  - Coding units (CUs)
  - Transform units (TUs)
  - Prediction units (PUs)

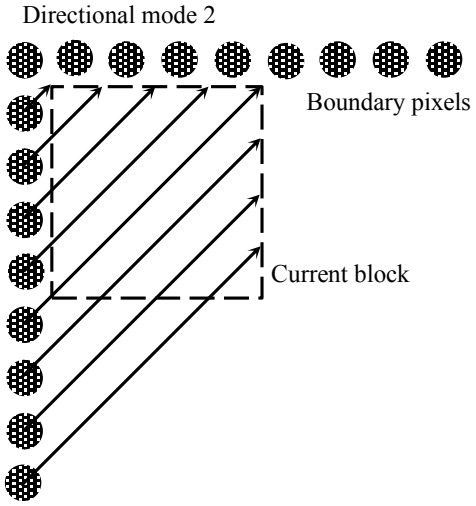




Background

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





vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Background

- Intra mode decision processes (HM)
  - Rough mode decision (RMD)
    - SATD: Sum of absolute transformed differences
      - Eight candidates among 35 modes

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

  - Rate distortion optimization (RDO)
    - SSE: Sum of squared errors
      - Best mode among eight candidates

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

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Literature Review

- Fast HEVC intra coding
  - Fast mode decision
    - Decrease the number of modes to be checked by RDO
  - CU splitting early termination
    - RDO is performed only for some selected CU levels

ÉTS
Le génie pour l'industrie
Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Literature Review

- Depth information of the neighboring CUs [2]
- A bottom-up approach to find an optimum depth [3]

[2] X. Shang, G. Wang, T. Fan and Y. Li, “Fast CU Size Decision and PU Mode Decision Algorithm in HEVC Intra Coding”, in Proc. of the IEEE International Conference on Image Processing (ICIP), 2015

[3] W. Shi, X. Jiang, T. Song and T. Shimamoto, “Edge Detector Based Fast Level Decision Algorithm for Intra Prediction of HEVC”, Journal of Signal Processing, vol. 19, no. 2, 2015

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Literature Review

- Coefficient of variation (CV) [4]
- Thresholds on the RDO cost of the current level, Depth information of the previous frame[5]

[4] A. Oztekin, E. Ercelebi, "An Early Split and Skip Algorithm for Fast Intra CU Selection in HEVC", Journal of Real-Time Image Processing, Springer, 2015

[5] L. Shen, Z. Liu, X. Zhang, W. Zhao and Z. Zhang, "An Effective CU Size Decision Method for HEVC Encoders", IEEE Transactions on Multimedia, vol. 15, no. 2, 2013

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Problem Statement

- Using neighbouring CUs
  - domino effect
- Utilizing variance or RDO cost thresholds
  - limited time reduction

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Proposed Method

- Fast intra coding based on
  - Global and directional gradients
- CU classification
  - Split class
    - No intra mode to effectively predict the CU
  - Non-split class
    - Smooth blocks predicted by DC or planar modes
    - Non-smooth blocks predicted accurately by a directional mode

ÉTS Le génie pour l'industrie

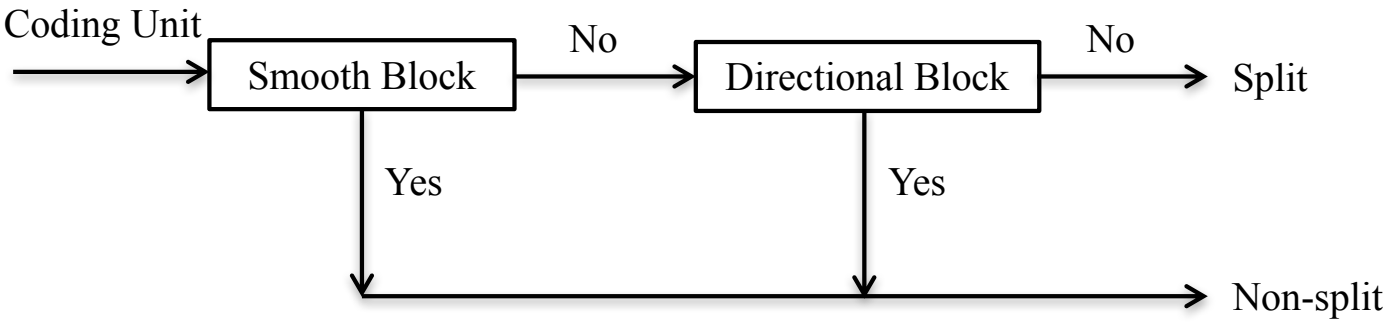
Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Proposed Method



ÉTS
Le génie pour l'industrie
Département de génie logiciel et des TI

Proposed Method

- CU classification

$$C=\{C_S, C_N\}$$

$$\boldsymbol{F} = \{f_1, f_2, f_3 \ldots\}$$

$$MI(F;C) = \int_C \int_F p(F,C) \log \frac{p(F,C)}{p(F)p(C)} dFdC$$

Proposed Method

- Splitting early termination by global gradient

$$MGA = \frac{1}{n}\sum_{i}\sum_{j}\left|G_X(i,j)\right| + \left|G_Y(i,j)\right|$$

- To compute the gradient components G_X and G_Y at each pixel, the *Sobel* operator is applied with 3×3 convolution masks

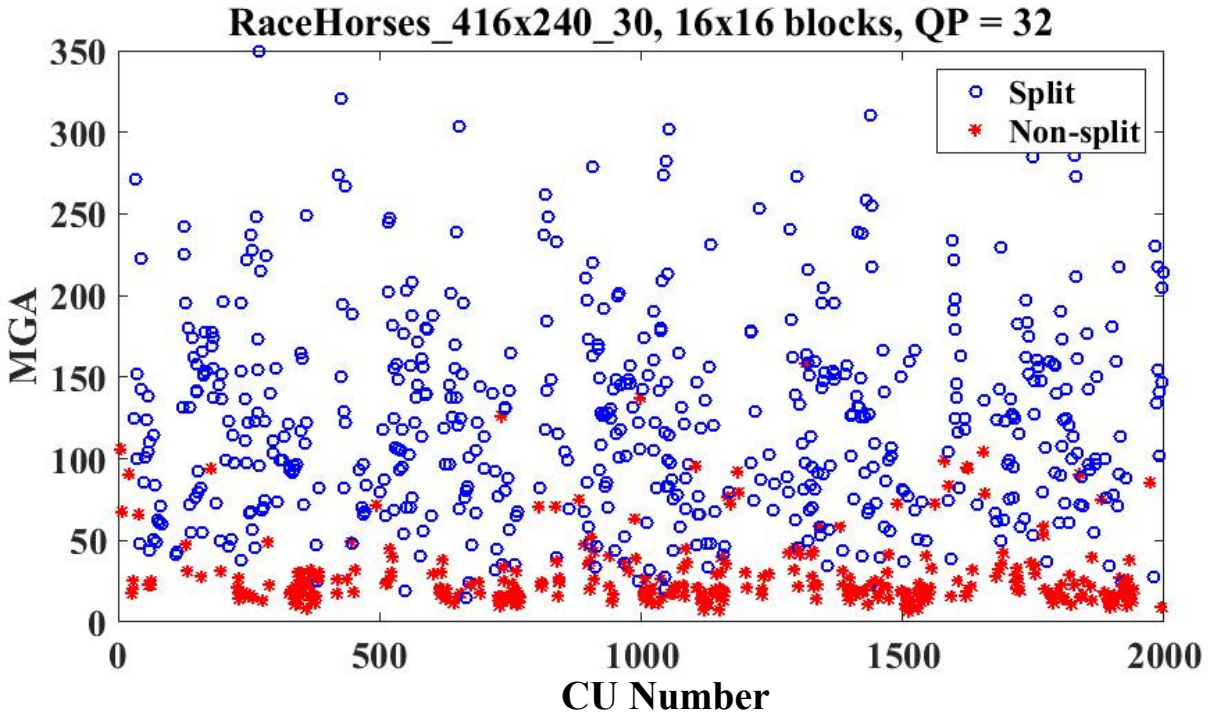
vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Proposed Method

- Discrimination ability of *MGA*
  - The CUs with larger *MGA* tend to split while those with smaller *MGA* are predicted at the current level



ÉTS
Le génie pour l'industrie
Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Proposed Method

- First feature is QP dependent
  - The effect of QP to discriminate *split* and *non-split* regions performed well when assumed linear, *alpha* is a coefficient assigned for each block size

$$f_1 = \frac{MGA}{\alpha} - QP$$

- The CU is of the *non-split* class if $f_1 < Th_1$

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

Proposed Method

- Splitting early termination by directional gradient

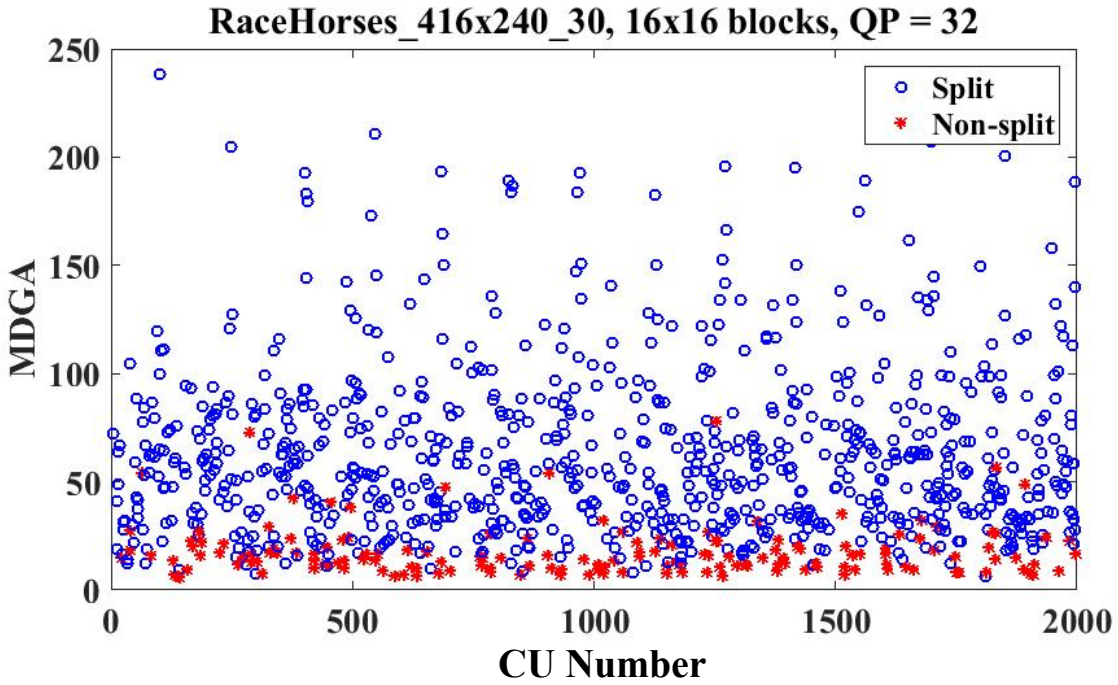
$$MDGA = \frac{1}{n}\sum_{i}\sum_{j}\left(\left|G_X(i,j)\right| + \left|G_Y(i,j)\right|\right) \times \cos\theta(i,j)$$

- G_X and G_Y are gradient components and θ is the angle between the gradient at each pixel and the best angular mode of the current CU
- The best angular mode is achieved based on the classification of SATD costs [6]

[6] M. Jamali, S. Coulombe and F. Caron, "Fast HEVC Intra Mode Decision Based on Edge Detection and SATD Costs Classification", in Proc. of the IEEE Data Compression Conference, 2015.

Proposed Method

- Discrimination ability of *MDGA*
  - CUs with large *MGA* but small *MDGA* along the best angular mode can be predicted at the current level effectively



vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Proposed Method

- Second feature is QP dependent, *beta* is a coefficient assigned for each block size

$$f_2 = \frac{MDGA}{\beta} - QP$$

- The CU is of the *non-split* class if $f_2 < Th_2$

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Experimental Results

- Implementation setup
  - HEVC test model HM 15.0 (*All-Intra* profile)
  - Implementation platform: Intel® i7-4790 CPU-3.60, 32 GB of RAM, running Windows 7
  - 100 first frames of the recommended sequences [7]
  - Quantization parameters: 22, 27, 32, 37
  - Parameters of the algorithm:
    - $\alpha = 1, 0.9, 0.4$ and 0.3 for block sizes 8×8, 16×16, 32×32 and 64×64
    - $\beta = 0.8, 0.7, 0.2$ and 0.1 for block sizes 8×8, 16×16, 32×32 and 64×64

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

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Experimental Results

- Experimental results compared to HM 15.0

		Proposed Method			Shi et al. [3]			Oztekin et al. [4]		
Class	Video Sequences	ΔT(%)	BD-RATE(%)	BD-PSNR(dB)	ΔT(%)	BD-RATE(%)	BD-PSNR(dB)	ΔT(%)	BD-RATE(%)	BD-PSNR(dB)
A 2560x1600	Traffic	-52.5	1.30	-0.061	-	-	-	-46.17	5.0	-0.09
	PeopleOnStreet	-47.8	1.29	-0.063	-36.0	1.58	-0.058	-37.56	5.0	-0.06
B 1920x1080	Cactus	-50.8	1.49	-0.049	-	-	-	-	-	-
	Kimono	-59.1	0.85	-0.028	-40.5	0.18	-0.018	-60.13	3.5	-0.04
	ParkScene	-49.7	0.67	-0.026	-41.7	0.39	-0.73	-50.63	3.7	-0.08
	BasketballDrive	-62.2	2.35	-0.059	-	-	-	-	-	-
	BQTerrace	-50.1	0.87	-0.041	-37.4	1.89	-0.054	-	-	-
C 832x480	BQMall	-49.6	1.75	-0.091	-40.5	1.11	-0.072	-27.52	6.7	-0.12
	PartyScene	-39.2	1.14	-0.076	-	-	-	-28.67	5.6	-0.14
	RaceHorsesC	-47.2	0.76	-0.043	-	-	-	-	-	-
	BasketballDrill	-48.4	1.39	-0.063	-37.5	1.81	-0.061	-	-	-

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Experimental Results

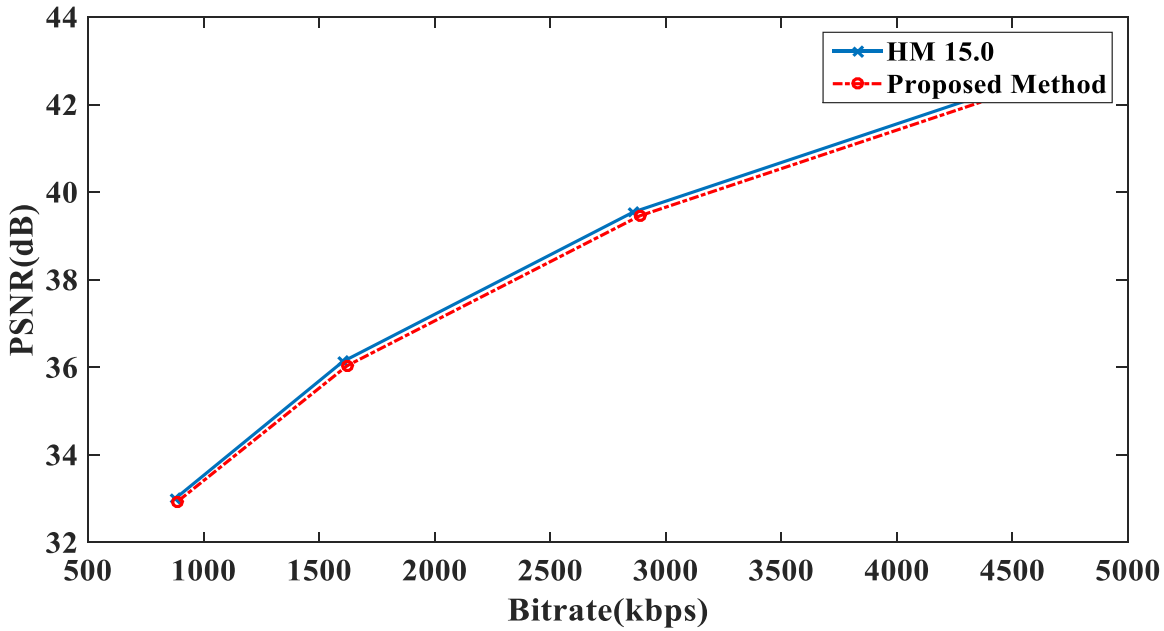
- Experimental results compared to HM 15.0

		Proposed Method			Shi et al. [3]			Oztekin et al. [4]		
Class	Video Sequences	ΔT(%)	BD-RATE(%)	BD-PSNR(dB)	ΔT(%)	BD-RATE(%)	BD-PSNR(dB)	ΔT(%)	BD-RATE(%)	BD-PSNR(dB)
D 416x240	RaceHorses	-41.7	1.15	-0.065	-27.0	1.31	-0.051	-29.47	4.5	-0.11
	BasketballPass	-54.1	2.07	-0.110	-	-	-	-	-	-
	BlowingBubbles	-40.5	1.00	-0.052	-25.6	1.61	-0.077	-29.37	3.6	-0.09
	BQSquare	-39.2	1.41	-0.103	-	-	-	-	-	-
E 1280x720	Vidyo1	-63.8	2.07	-0.091	-46.5	3.08	-0.114	-	-	-
	Vidyo3	-63.8	2.94	-0.141	-	-	-	-	-	-
	Vidyo4	-64.3	2.19	-0.088	-48.3	2.84	-0.101	-	-	-
Average		**-51.9**	**1.50**	**-0.070**	**-37.1**	**1.46**	**-0.063**	**-38.7**	**4.7**	**-0.10**

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

Experimental Results



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

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

Conclusion

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

- Procedure
  - CU classification to *split* and *non-split* based on global and directional gradients
    - We have achieved 52% time reduction using the proposed approach with about 1.5% BD-rate increment

ÉTS
Le génie pour l'industrie
Département de génie logiciel et des TI

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

ÉTS Le génie pour l'industrie

Département de génie logiciel et des TI

This research is funded by

The Natural Science And Engineering Research Council of Canada and

Vantrix Corporation

under the

Collaborative Research and Development Program

NSERC-CRD 428942-11

vantrix

Chaire de recherche industrielle Vantrix en optimisation vidéo

NSERC CRSNG

ÉTS
Le génie pour l'industrie
Département de génie logiciel et des TI