JCT3V-G0114
AHG 10: Complexity Assessment on Illumination Compensation (IC)

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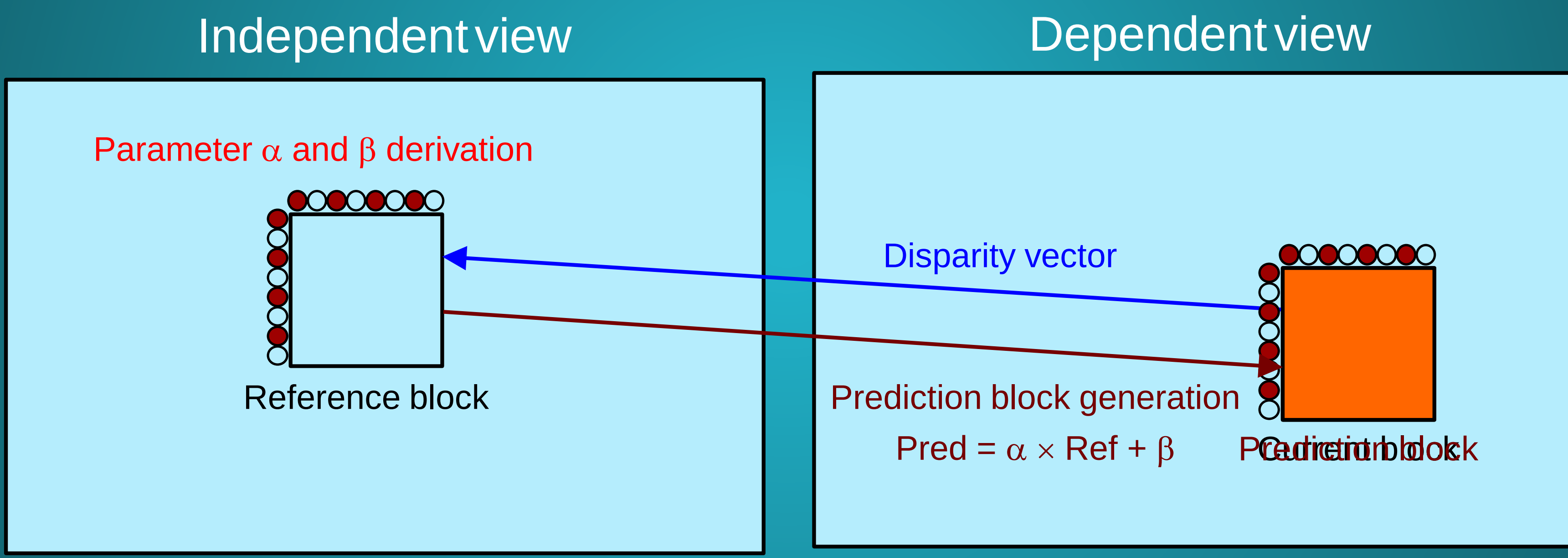
Abstract

- Complexity assessment on IC
  - Number of operations
  - Data storage requirement
  - Data transfer rate
- Complexity at 64×64 block with various PU sizes
- Coding performance when IC is OFF at HTM-9.0r1
  - Video PSNR vs. video bitrate: 0.6% coding loss.
  - Video PSNR vs. total bitrate: 0.6% coding loss.
  - Synth PSNR vs. total bitrate: 0.4% coding loss.

Outline

- Abstract
- Introduction to IC
- Complexity assessment at PU level
  - Number of operations
  - Data storage requirement
  - Data transfer rate
- Overall complexity of IC at 64$\times$64 block level
- Coding performance without IC
- Conclusion

Introduction to IC

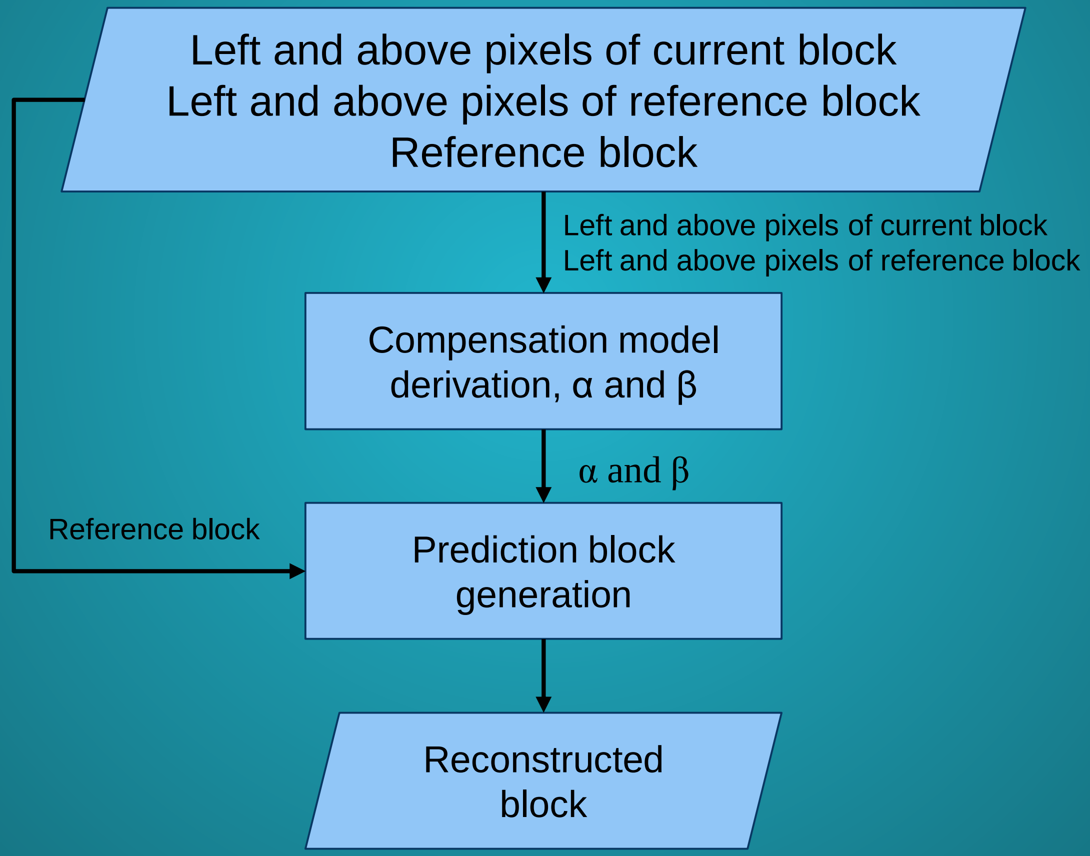


● Pixels used for deriving parameter α and β

Disparity vectors could be derived from neighboring block based disparity vector (NBDV) or Depth-oriented NBDV (DoNBDV)

Introduction to IC

- Flowchart of IC



Number of operations (1/4)

- Uni-Prediction
  - Compensation model, derivation, α and β

$$\alpha = \frac{\sum_{i=0}^{N-1} Curr(i)Ref(i) - \sum_{i=0}^{N-1} Curr(i) \sum_{i=0}^{N-1} Ref(i)}{\sum_{i=0}^{N-1} Ref(i)Ref(i) - \sum_{i=0}^{N-1} Ref(i) \sum_{i=0}^{N-1} Ref(i)} \qquad \beta = \sum_{i=0}^{N-1} Curr(i) - \alpha \times \sum_{i=0}^{N-1} Ref(i)$$

    - Luma : 4(N-1) additions + 3 subtractions = 4N – 1 additions/subtractions, 2N+3 multiplications, 1 division LUT.
    - Chroma: 4((N/2)-1) additions + 3 subtractions = 2N – 1 additions/subtractions, 2(N/2)+3 multiplications, 1 division LUT.
  - Prediction block generation:

$$Pred[j,i] = \alpha \times Ref[j,i] + \beta, \qquad 0 \le i, j \le N-1$$

    - Luma : N^2 additions, N^2 multiplications.
    - Chroma: $(N/2)^2$ additions, $(N/2)^2$ multiplications.

N: PU size

Curr(i): left and above pixels of current block, i is the index of one-dimension array pixels

Ref(i): left and above pixels of reference block, i is the index of one-dimension array pixels

Number of operations (2/4)

- Bi-Prediction
  - The number of operations included in uni-prediction should be counted twice.
  - Prediction block averaging:

$$PredAverage[x][y] = (PredSamples1[x][y] + PredSamples2[x][y]) >> 1$$

    - Luma : N^2 additions, N^2 shifts.
    - Chroma: $(N/2)^2$ additions, $(N/2)^2$ shifts.

PredSamplesX: Prediction samples by Xth uni-prediction

Number of operations (3/4)

- Algebraic expressions of number of operations
  - Uni-Prediction

N: PU size

Type of operations	Number of operations per PU	
	Luma	Chroma
Add./Sub.	Compensation model derivation: $4(N-1)+3$ Pred. block generation: N^2 Total: N^2+4N-1	Compensation model derivation: $(4(N/2-1)+3)\times 2$ Pred. block generation: $((N/2)^2)\times 2$ Total: $((N/2)^2+4(N/2)-1)\times 2$
Mul.	Compensation model derivation: $2N+3$ Pred. block generation: N^2 Total: N^2+2N+3	Compensation model derivation: $(2(N/2)+3)\times 2$ Pred. block generation: $((N/2)^2)\times 2$ Total: $((N/2)^2+2(N/2)+3)\times 2$
Div. LUT	1	1×2

Numbers colored in orange present two components of chrominance

Number of operations (4/4)

- Algebraic expressions of number of operations
  - Bi-Prediction

N: PU size

Type of operations	Number of operations per PU	
	Luma	Chroma
Add./Sub.	Two uni-predictions: $(N^2+4N-1)\times 2$ Pred. block averaging: N^2 Total: $(N^2+4N-1)\times 2+N^2$	Two uni-prediction: $(((N/2)^2+4(N/2)-1)\times 2)\times 2$ Pred. block averaging: $((N/2)^2)\times 2$ Total: $(((N/2)^2+4(N/2)-1)\times 2)\times 2+((N/2)^2)\times 2$
Shift	Pred. block averaging: N^2	Pred. block averaging: $((N/2)^2)\times 2$
Mul.	Two uni-predictions: $(N^2+2N+3)\times 2$ Total: $(N^2+2N+3)\times 2$	Two uni-predictions: $(((N/2)^2+2(N/2)+3)\times 2)\times 2$ Total: $(((N/2)^2+2(N/2)+3)\times 2)\times 2$
Div. LUT	1×2	$1\times 2\times 2$

Numbers colored in orange present two components of chrominance
Numbers colored in red present bi-prediction

Data storage requirement

- Algebraic expressions of data storage requirement
  - Only Luma component is considered since the storage could be reused.

N: PU size

Data	Data storage requirement	
	Uni-Prediction	Bi-Prediction
Left and above pixels of current block	Left neighboring pixels: (N/2) Above neighboring pixels: (N/2) Total: (N/2)+(N/2)	Left neighboring pixels: (N/2) Above neighboring pixels: (N/2) Total: (N/2)+(N/2)
Left and above pixels of reference block	Left neighboring pixels: (N/2) Above neighboring pixels: (N/2) Total: (N/2)+(N/2)	Left neighboring pixels: ((N/2))×2 Above neighboring pixels: ((N/2))×2 Total: ((N/2)+(N/2))×2
Reference block*	Total: N^2	Total: $(N^2)\times 2$
Total	**N^2+2N**	**$2N^2+3N$**

Numbers colored in red present bi-prediction

*: The storage of reference block could be reused to save the first prediction block due to the fact that the reference is no longer required upon generating the prediction block. Therefore, one N^2 is counted.

Data transfer rate (1/2)

- Algebraic expressions of data transfer rate
  - Uni-Prediction

N: PU size

Data	Data storage requirement	
	Luma	Chroma
Left and above pixels of current block	Left neighboring pixels: (N/2) Above neighboring pixels: (N/2) Total: (N/2)+(N/2)	Left neighboring pixels: $(((N/2)/2))\times 2$ Above neighboring pixels: $(((N/2)/2))\times 2$ Total: $(((N/2)/2))\times 2+(((N/2)/2))\times 2$
Left and above pixels of reference block	Left neighboring pixels: (N/2) Above neighboring pixels: (N/2) Total: (N/2)+(N/2)	Left neighboring pixels: $(((N/2)/2))\times 2$ Above neighboring pixels: $(((N/2)/2))\times 2$ Total: $(((N/2)/2))\times 2+(((N/2)/2))\times 2$
Reference block	Total: N^2	Total: $((N/2)^2)\times 2$
Prediction block	Total: N^2	Total: $((N/2)^2)\times 2$
Total	**$2N^2+2N$**	**$(2(N/2)^2+2(N/2))\times 2$**

Numbers colored in orange present two components of chrominance

Data transfer rate (2/2)

- Algebraic expressions of data transfer rate
  - Bi-Prediction

N: PU size

Data	Data storage requirement	
	Luma	Chroma
Left and above pixels of current block	Left neighboring pixels: (N/2) Above neighboring pixels: (N/2) Total: (N/2)+(N/2)	Left neighboring pixels: (((N/2)/2))×2 Above neighboring pixels: (((N/2)/2))×2 Total: (((N/2)/2))×2+(((N/2)/2))×2
Left and above pixels of reference block	Left neighboring pixels: ((N/2))×2 Above neighboring pixels: ((N/2))×2 Total: ((N/2)+(N/2))×2	Left neighboring pixels: ((((N/2)/2))×2)×2 Above neighboring pixels: ((((N/2)/2))×2)×2 Total: ((((N/2)/2))×2+(((N/2)/2))×2)×2
Reference block	Total: $(N^2)\times 2$	Total: $(((N/2)^2)\times 2)\times 2$
Prediction block	Total: N^2	Total: $((N/2)^2)\times 2$
Total	**$3N^2+3N$**	**$(3(N/2)^2+3(N/2))\times 2$**

Numbers colored in orange present two components of chrominance
Numbers colored in red present bi-prediction

Complexity at 64×64 block level with various PU sizes

	Number of operations					
	Uni-Prediction			Bi-Prediction		
PU_size	Add./Sub.	Mul.	Div. LUT	Add./Sub.	Mul.	Div. LUT
64×64	6,650	6,409	3	19,444	12,818	6
32×32	7,144	6,692	12	20,432	13,384	24
16×16	**8,096**	**7,312**	48	**22,336**	**14,624**	96
8×8	6,080	5,312	**64**	16,256	10,624	**128**

	Data storage requirement (bits)	
PU_size	Uni-Prediction	Bi-Prediction
64×64	**33,792**	**67,072**
32×32	8,704	17,152
16×16	2,304	4,480
8×8	640	1,216

	Data transfer rate (bits per 64×64 block)	
PU_size	Uni-Prediction	Bi-Prediction
64×64	100,352	150,528
32×32	102,400	153,600
16×16	**106,496**	**159,744**
8×8	73,728	110,592

Overall complexity of IC at 64×64 block

Complexity Metric	Worst case	
	Uni-Prediction	Bi-Prediction
Number of operations (Add/Sub)	8,096	22,336
Number of operations (Mul.)	7,312	14,624
Number of operations (Div. LUT)	64	128
Data storage requirement (bits)	33,792	67,072
Data transfer rate (bits per 64×64 block)	106,496	159,744

Coding results without IC

- Anchor: HTM-9.0r1
- Tested: HTM-9.0r1 without IC and IC is turned off via configuration file

	video 0	video 1	video 2	video PSNR / video bitrate	video PSNR / total bitrate	synth PSNR / total bitrate	enc time	dec time	ren time
Balloons	0.0%	2.6%	2.2%	0.9%	0.9%	0.6%	90.8%	100.2%	99.9%
Kendo	0.0%	4.6%	6.0%	2.0%	1.8%	1.5%	91.4%	100.4%	101.0%
Newspaper_CC	0.0%	1.2%	2.5%	0.8%	0.7%	0.6%	92.0%	100.9%	99.5%
GT_Fly	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	98.4%	95.7%	96.9%
Poznan_Hall2	0.0%	1.4%	4.0%	1.2%	1.1%	0.7%	93.3%	95.7%	100.1%
Poznan_Street	0.0%	-0.1%	1.2%	0.2%	0.2%	0.1%	92.2%	97.0%	96.9%
Undo_Dancer	0.0%	-0.2%	-0.1%	0.0%	0.0%	0.0%	94.3%	101.9%	103.0%
Shark	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.3%	101.7%	102.9%
1024x768	0.0%	2.8%	3.6%	1.2%	1.1%	0.9%	91.4%	100.5%	100.1%
1920x1088	0.0%	0.2%	1.0%	0.3%	0.3%	0.2%	95.7%	98.4%	100.0%
average	**0.0%**	**1.2%**	**2.0%**	**0.6%**	**0.6%**	**0.4%**	**94.1%**	**99.2%**	**100.0%**

Conclusion

- Coding results when IC is OFF
  - The coding loss is 0.6%, 0.6%, and 0.4% for video PSNR vs. video bitrate, video PSNR vs. total bitrate, and synth PSNR vs. total bitrate, respectively, at HTM-9.0r1 configuration without IC.
- The intrinsic complexity of IC is presented to be anchor complexity to evaluate IC tools.

Appendix – MC+IC