



SAO software cleanup and non-normative encoder-only bug-fixes

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Presented by Yu-Wen Huang
14th JCT-VC Meeting in Vienna
25 July–2 Aug. 2013

Overall Summary

- Three non-normative encoder-only bug-fixes
 - Pure encoder-only software bug-fixes
 - Negligible BD-rate change
- New SAO software implementation
 - Implemented on top of HM-11.0.
 - Remove legacies in HM (picture quadtree, fine granularity slices, adaptation parameter set)
 - Reduce the number of code lines by half (from 4000 to 2000)
 - Better code quality and readability
 - No run time increase
 - Also implemented on top of RExt, SHVC, and 3D-HEVC reference software packages

Non-normative Encoder-only Bug-fixes

- Merge flag assignment fix
 - Problem: When slice_sao_luma_flag is equal to 0 and slice_sao_chroma_flag is equal to 1, merge flags are not assigned correctly during RDO.
- Rate calculation fix
 - Problem: No matter slice_sao_luma_flag value, SAO type index syntax is always calculated during RDO.
- Boundary condition fix for 0-degree EO
 - Problem: When the CTU is at the bottom boundary of a picture, the bottom sample lines of the CTU are unnecessarily skipped for 0-degree EO statistics collection.

Results of Bug-fixes

- Anchor:
 - HM-11.0
- Test:
 - HM-11.0 with non-normative encoder-only bug-fixes
- Results:
 - Negligible BD-rate change
 - No run time increase

	All Intra Main			All Intra Main10		
	Y	U	V	Y	U	V
Class A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class B	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class D	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Overall	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class F	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	100%			100%		
Dec Time[%]	100%			100%		

	Random Access Main			Random Access Main10		
	Y	U	V	Y	U	V
Class A	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
Class B	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class C	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%
Class D	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%
Class E						
Overall	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class F	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	100%			100%		
Dec Time[%]	101%			100%		

	Low delay B Main			Low delay B Main10		
	Y	U	V	Y	U	V
Class A						
Class B	0.0%	0.0%	-0.4%	0.0%	0.0%	-0.1%
Class C	0.0%	0.0%	-0.1%	0.0%	0.1%	0.1%
Class D	0.0%	0.2%	0.1%	0.0%	0.2%	0.1%
Class E	0.0%	-0.1%	0.0%	0.0%	0.1%	0.1%
Overall	0.0%	0.0%	-0.1%	0.0%	0.1%	0.0%
	0.0%	0.0%	-0.1%	0.0%	0.1%	0.0%
Class F	0.0%	0.4%	-0.3%	0.0%	0.3%	0.1%
Enc Time[%]	100%			100%		
Dec Time[%]	100%			100%		

	Low delay P Main			Low delay P Main10		
	Y	U	V	Y	U	V
Class A						
Class B	0.0%	-0.2%	-0.1%	0.0%	0.2%	-0.1%
Class C	0.0%	-0.4%	0.2%	0.0%	-0.1%	-0.2%
Class D	0.0%	-0.2%	0.0%	0.0%	0.4%	-0.2%
Class E	0.0%	0.2%	0.3%	0.0%	0.0%	0.0%
Overall	0.0%	-0.2%	0.1%	0.0%	0.1%	-0.1%
	0.0%	-0.2%	0.2%	0.0%	0.1%	-0.1%
Class F	0.1%	-0.2%	0.3%	0.0%	-0.1%	0.0%
Enc Time[%]	99%			100%		
Dec Time[%]	98%			100%		

New SAO Software Implementation

- Implemented on top of HM-11.0.
- Include the three non-normative encoder-only bug-fixes
- Remove legacies related to SAO
 - SAO picture quadtree
 - Adaptation parameter set (APS)
 - Fine granularity slice
- Reduce the number of code lines by half
 - From around 4000 to around 2000
- No run time increase

Results of New SAO Implementation

- Anchor:
 - HM-11.0 with non-normative encoder-only bug-fixes
- Test:
 - New SAO software implementation
- Results:
 - BD-rate matches
 - No run time increase

	All Intra Main			All Intra Main10		
	Y	U	V	Y	U	V
Class A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class B	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class D	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Overall	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class F	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	99%			99%		
Dec Time[%]	101%			101%		

	Random Access Main			Random Access Main10		
	Y	U	V	Y	U	V
Class A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class B	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class D	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class E						
Overall	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class F	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	100%			100%		
Dec Time[%]	99%			100%		

	Low delay B Main			Low delay B Main10		
	Y	U	V	Y	U	V
Class A						
Class B	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class D	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Overall	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class F	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	100%			100%		
Dec Time[%]	100%			99%		

	Low delay P Main			Low delay P Main10		
	Y	U	V	Y	U	V
Class A						
Class B	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class D	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Overall	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Class F	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	100%			100%		
Dec Time[%]	101%			99%		

New SAO Implementation for HEVC Ext.

- The corresponding modifications for HEVC extensions are also provided for
 - RExt: HM-10.1+RExt-3.0
 - SHVC: SHM-2.0
 - 3D-HEVC: HTM-DEV-0.3-dev2 (Rev. 538)

Results for HEVC RExt

- Anchor:
 - HM-10.1+Rext-3.0
- Test:
 - New SAO software implementation

	All Intra Main-tier			All Intra High-tier			All Intra Super-High-tier		
	Y	U	V	Y	U	V	Y	U	V
RGB 4:4:4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YCbCr 4:4:4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
YCbCr 4:2:2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Overall	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	98%			99%			99%		
Dec Time[%]	102%			102%			101%		
	Random Access Main-tier			Random Access High-tier					
	Y	U	V	Y	U	V			
RGB 4:4:4	-0.2%	-0.3%	-0.2%	-0.2%	-0.2%	-0.2%			
YCbCr 4:4:4	0.0%	-0.2%	-0.1%	-0.1%	-0.2%	-0.2%			
YCbCr 4:2:2	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%			
Overall	-0.1%	-0.2%	-0.1%	-0.1%	-0.2%	-0.1%			
	-0.1%	-0.3%	-0.1%	-0.1%	-0.2%	-0.1%			
Enc Time[%]	100%			100%					
Dec Time[%]	99%			100%					
	Low delay B Main-tier			Low delay B High-tier					
	Y	U	V	Y	U	V			
RGB 4:4:4	-0.3%	-0.3%	-0.3%	-0.2%	-0.2%	-0.2%			
YCbCr 4:4:4	0.0%	-0.2%	-0.1%	0.0%	-0.2%	-0.1%			
YCbCr 4:2:2	0.0%	-0.2%	-0.1%	0.0%	-0.1%	-0.1%			
Overall	-0.1%	-0.2%	-0.1%	-0.1%	-0.2%	-0.1%			
	-0.1%	0.0%	0.0%	-0.1%	-0.2%	-0.1%			
Enc Time[%]	99%			99%					
Dec Time[%]	97%			100%					

Results for SHVC

- Anchor: SHM-2.0
- Test: New SAO software implementation

	AI HEVC 2x			AI HEVC 1.5x					
	Y	U	V	Y	U	V			
Class A	0.0%	0.0%	0.0%						
Class B	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
Overall (Test vs Ref)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
Overall (Test vs single layer)	12.8%	14.9%	14.6%	10.5%	9.8%	9.3%			
Overall (Ref vs single layer)	12.8%	14.9%	14.6%	10.5%	9.8%	9.3%			
EL only (Test vs Ref)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
Enc Time[%]	100.4%			100.5%					
Dec Time[%]	100.0%			99.9%					
Enc Mem[%]	#NUM!			#NUM!					
BL Match	Not matched			Not matched					
	RA HEVC 2x			RA HEVC 1.5x			RA HEVC SNR		
	Y	U	V	Y	U	V	Y	U	V
Class A	0.0%	0.0%	0.0%				0.0%	0.0%	0.1%
Class B	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Overall (Test vs Ref)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Overall (Test vs single layer)	19.2%	33.3%	32.0%	16.2%	28.9%	29.2%	14.4%	32.1%	34.2%
Overall (Ref vs single layer)	19.2%	33.3%	32.0%	16.2%	28.8%	29.1%	14.4%	32.1%	34.1%
EL only (Test vs Ref)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Enc Time[%]	99.5%			99.6%			99.7%		
Dec Time[%]	98.7%			97.7%			100.4%		
Enc Mem[%]	104.0%			103.5%			102.9%		
BL Match	Not matched			Not matched			Not matched		
	LD-B HEVC 2x			LD-B HEVC 1.5x			LD-B HEVC SNR		
	Y	U	V	Y	U	V	Y	U	V
Class A	0.0%	-0.1%	0.0%				0.0%	-0.1%	0.0%
Class B	0.0%	0.0%	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
Overall (Test vs Ref)	0.0%	0.0%	0.1%	0.0%	0.0%	0.2%	0.0%	-0.1%	0.0%
Overall (Test vs single layer)	28.5%	38.9%	39.9%	24.8%	33.0%	36.1%	24.3%	34.7%	39.4%
Overall (Ref vs single layer)	28.5%	39.0%	39.7%	24.8%	33.0%	35.9%	24.3%	34.7%	39.5%
EL only (Test vs Ref)	0.0%	0.0%	0.1%	0.0%	0.0%	0.2%	0.0%	-0.1%	0.0%
Enc Time[%]	99.8%			100.0%			100.4%		
Dec Time[%]	101.9%			101.9%			100.2%		
Enc Mem[%]	105.5%			104.8%			104.0%		
BL Match	Not matched			Not matched			Not matched		

Results for 3D-HEVC

- Anchor:
 - HTM-DEV-0.3-dev2 (r538)
- Test:
 - New SAO software implementation

3 view test case									
	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%	-0.1%	0.0%	0.0%	0.0%	0.0%	100.0%	93.4%	97.4%
Kendo	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.4%	110.6%	100.4%
Newspaper_CC	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	100.4%	94.6%	101.3%
GT_Fly	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	100.5%	100.8%	101.1%
Poznan_Hall2	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	99.2%	100.4%	98.0%
Poznan_Street	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.7%	97.6%	98.3%
Undo_Dancer	0.0%	0.1%	-0.1%	0.0%	0.0%	0.0%	100.1%	86.9%	103.7%
1024x768	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	100.0%	99.5%	99.7%
1920x1088	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.9%	96.4%	100.3%
average	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.9%	97.8%	100.0%

2 view test case (extracted from 3 view data)					
	video 0	video 1	video PSNR / video bitrate	video PSNR / total bitrate	synth PSNR / total bitrate
Balloons	0.0%	-0.1%	0.0%	0.0%	0.0%
Kendo	0.0%	0.0%	0.0%	0.0%	0.0%
Newspaper_CC	0.0%	0.0%	0.0%	0.0%	0.0%
GT_Fly	0.0%	0.0%	0.0%	0.0%	0.0%
Poznan_Hall2	0.0%	0.1%	0.0%	0.0%	0.0%
Poznan_Street	0.0%	0.0%	0.0%	0.0%	0.0%
Undo_Dancer	0.0%	0.1%	0.0%	0.0%	0.1%
1024x768	0.0%	0.0%	0.0%	0.0%	0.0%
1920x1088	0.0%	0.0%	0.0%	0.0%	0.0%
average	0.0%	0.0%	0.0%	0.0%	0.0%

Conclusions

- Three non-normative encoder-only bug-fixes are proposed
 - Pure encoder-only software bug-fixes
 - Negligible BD-rate change
- New SAO implementation is proposed for HM software
 - No run time increase
 - Reduce the number of code lines by half (4000 => 2000)
 - Better code quality and readability
- Corresponding modifications for RExt, SHVC, and 3D-HEVC are also provided