



# Sample Adaptive Offset with Padding at LCU, Slice, and Image Boundaries

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# Overall Summary

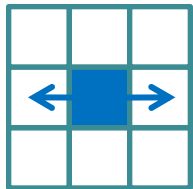
- In HM-3.0, SAO processing of to-be-filtered pixels is skipped at LCU or slice boundaries if the to-be-filtered pixels need to refer pixels outside LCU or slice.
  - May have subjective quality concern in rare special cases
- Proposed to use padding to replace skipping for LCU and slice boundary pixels.
- In comparison with the JCTVC-E700 anchor
  - No changes in BD-rates and run times
  - Improved subjective quality
- Padding is also used in the SAO proposed in JCTVC-F055
  - The main purpose of this contribution is to show padding is superior to skipping, while that of JCTVC-F055 is to remove pixel line buffers.

# Outline

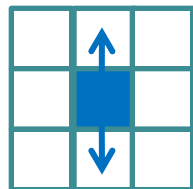
- Current SAO process for LCU and slice boundaries
- Proposed method for boundary pixels
- Subjective quality and BD-rate results
- Conclusions

# Band Offset (BO) & Edge Offset (EO)

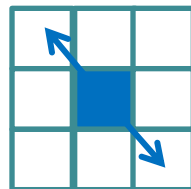
- Band offset (BO)- classify pixels with intensity
  - Pixel classification by the pixel itself
- Edge offset (EO)- classify pixels with neighbors
  - Pixel classification by using a 3x3 window
- If EO is selected, LCU boundary pixels are skipped according to the EO type.



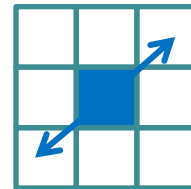
EO\_0



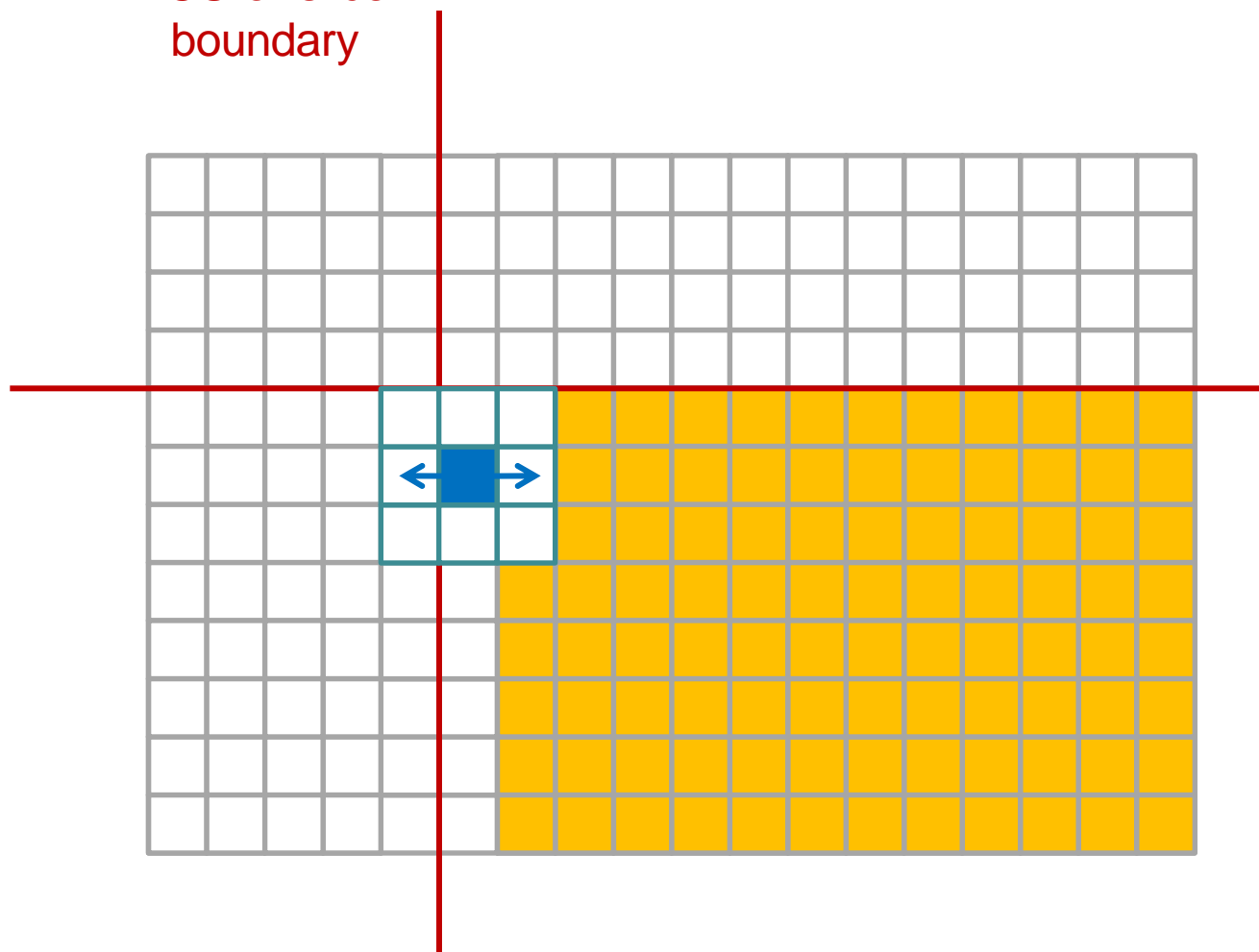
EO\_1



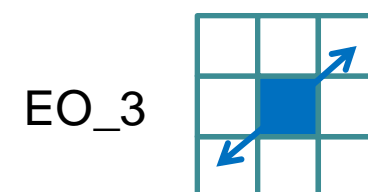
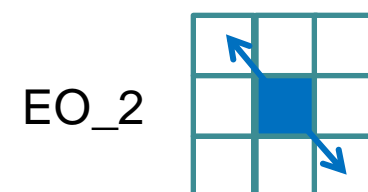
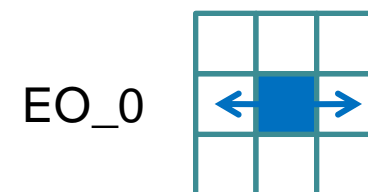
EO\_2

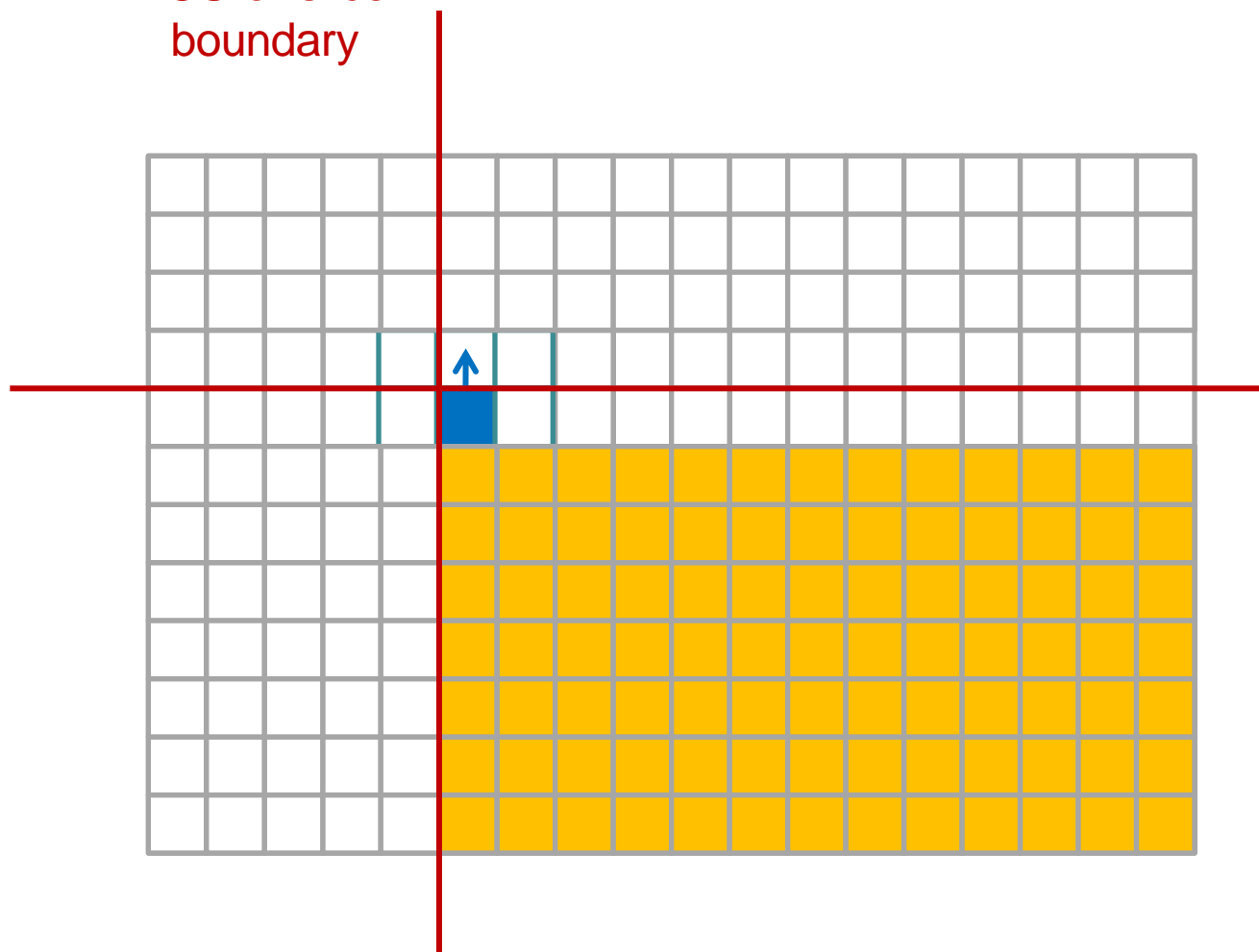


EO\_3

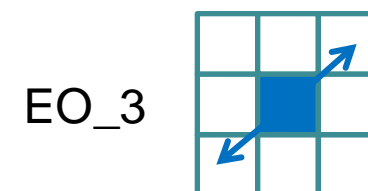
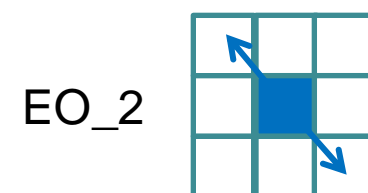
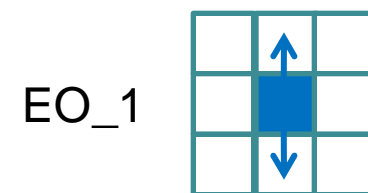
LCU or slice  
boundary

Skip vertical boundary pixels



LCU or slice  
boundary

Skip horizontal boundary pixels



# Visual Quality Improved by Bug Fixes



Visual artifacts caused by pixel skipping with software bugs in HM-3.0



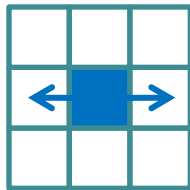
With bug fixes in HM-3.0  
#143, #160, #167, and #168  
(these are committed in HM-3.2)

Visual artifacts are less visible.

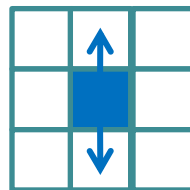
(Kimono, POC=170, QP=32, HE-LD)

# Proposed Method

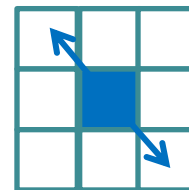
- Replace skipping with padding for LCU and slice boundary pixels
  - The pixels outside LCU/slice are replaced by the current pixel.
  - EO\_0: padding for vertical boundary pixels
  - EO\_1: padding for horizontal boundary pixels
  - EO\_2: padding for both vertical and horizontal boundary pixels
  - EO\_3: padding for both vertical and horizontal boundary pixels



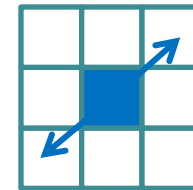
EO\_0



EO\_1



EO\_2



EO\_3



# Simulation Results

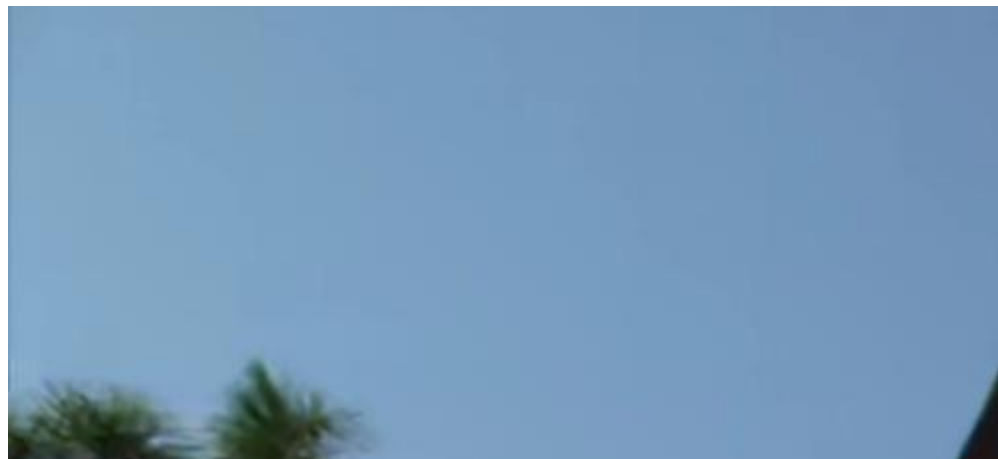
- Anchor
  - HM-3.2
  - JCTVC-E700 conditions
  - Skipping for boundary pixels
- Test
  - Padding for boundary pixels
- Results
  - Average no BD-rate increase
  - Average no enc./dec. time increase

	HE-AI			LC-AI		
	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
All	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
Enc Time	101%			101%		
Dec Time	99%			100%		

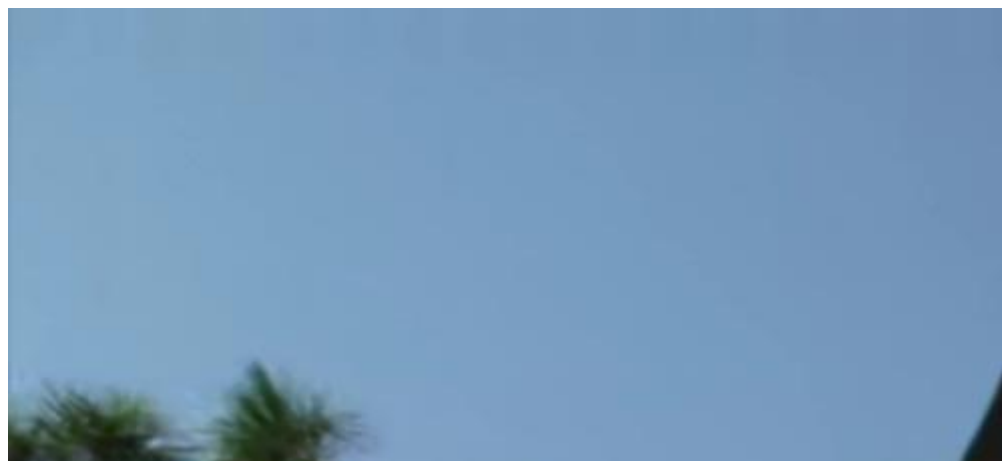
	HE-RA			LC-RA		
	Y	U	V	Y	U	V
Class A	0.0	0.1	0.1	0.0	0.1	-0.1
Class B	0.0	-0.1	0.1	0.0	0.0	0.0
Class C	0.0	0.0	0.0	0.0	0.0	-0.1
Class D	0.0	-0.1	0.1	0.0	0.0	0.0
Class E						
All	<b>0.0</b>	<b>0.0</b>	<b>0.1</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>
Enc Time	101%			100%		
Dec Time	99%			101%		

	HE-LD			LC-LD		
	Y	U	V	Y	U	V
Class A						
Class B	0.0	-0.2	-0.1	0.0	-0.3	0.0
Class C	0.0	-0.1	-0.2	0.0	-0.1	0.0
Class D	0.0	0.1	-0.1	0.0	0.4	0.5
Class E	-0.1	-0.1	0.0	0.1	-0.6	-0.4
All	<b>0.0</b>	<b>-0.1</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.1</b>	<b>0.0</b>
Enc Time	100%			100%		
Dec Time	101%			101%		

# Visual Quality Comparison



HM-3.2 with skipping  
(anchor)



HM-3.2 with padding  
(proposed)

(Kimono, POC=170, QP=32, HE-LD)

# Cross Verification

- We thank Qualcomm for crosschecking our proposal
  - JCTVC-F452
- BD-rates and run times are confirmed
- Visual quality review
  - No visual artifacts around LCU and slice boundaries are found.
- All bitstreams and decoders can be downloaded and requests of the FTP site information can be sent to [chiayang.tsai@mediatek.com](mailto:chiayang.tsai@mediatek.com)

# Conclusions

- Proposed to replace skipping by padding in SAO at LCU, slice, and image boundaries
- Compared with the HM anchor, the proposed method achieved
  - Average no BD-rate increase
  - Average no enc./dec. time increase
  - Improved subjective quality

# Visual Quality (Contrast Enhanced Version)



HM-3.2 with skipping  
(anchor)



HM-3.2 with padding  
(proposed)

(Kimono, POC=170, QP=32, HE-LD)