



JCTVC-E181 Parallel deblocking filter

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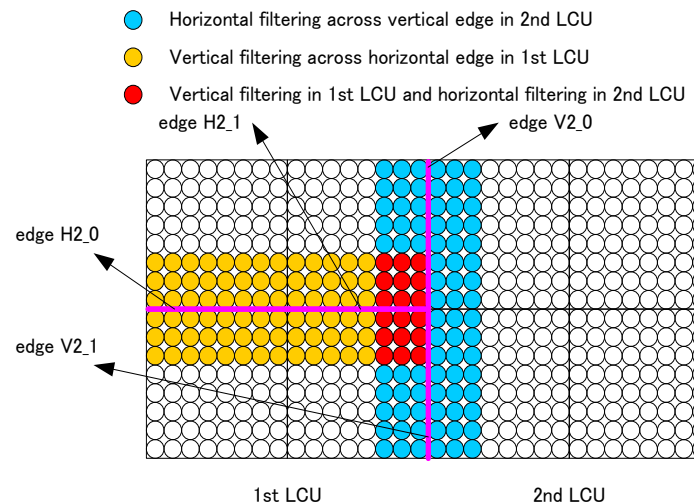
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Outline

- Motivation
- Proposal (based on JCTVC-D263)
- Results
- Conclusion

Motivation

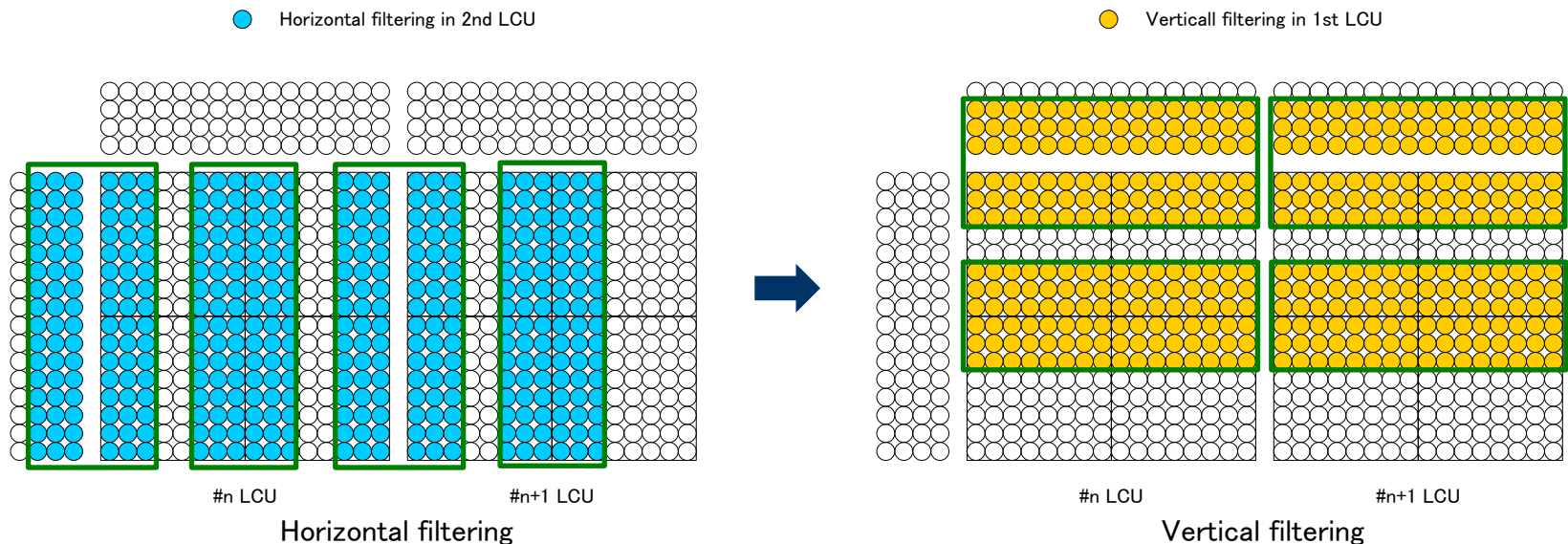
- Deblocking filter in HM-2.0
 - Vertical and horizontal filtering has dependency each other between LCUs
 - Horizontal filtering (see red pixels) in 2nd LCU needs to be performed after vertical filtering in 1st LCU is completed
- ⇒ It is difficult to make deblocking filter parallel



LCU : 16x16

Proposal

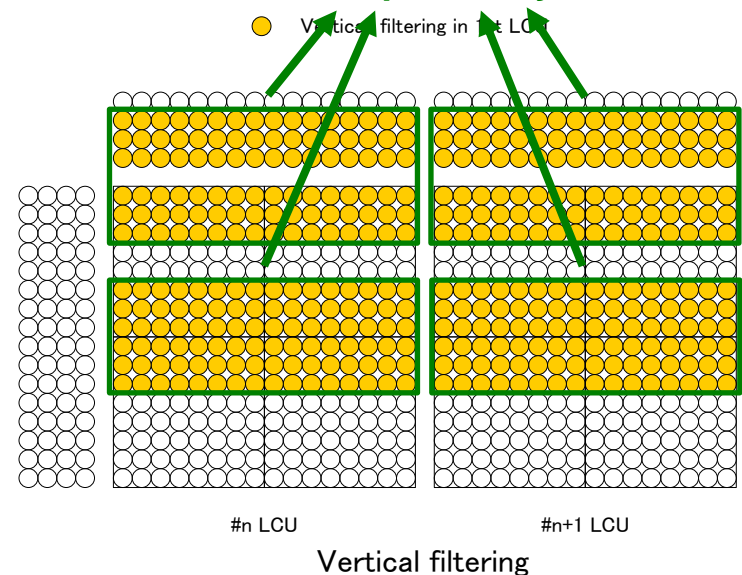
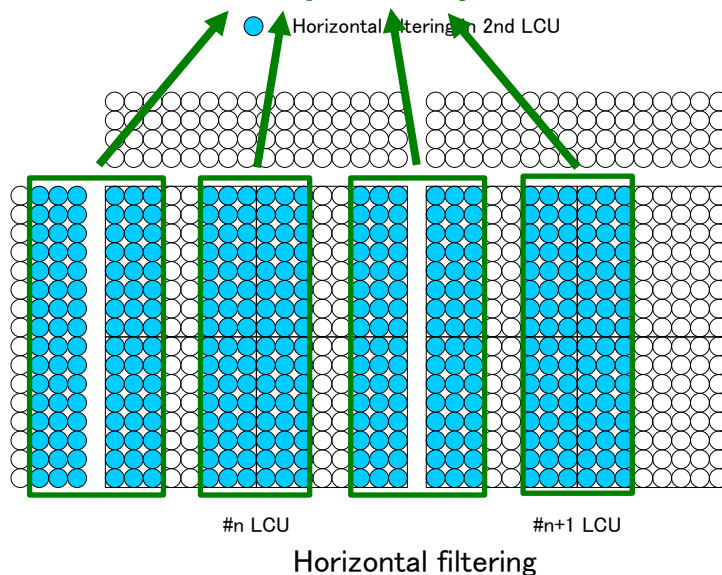
- 1st: Parallelization of filtering (based on JCTVC-D263)
 - Change the order of horizontal and vertical filtering
 1. H filtering is performed across all block edges in processing frame
 2. V filter is performed across all block edges in processing frame



Proposal

- 1st: Parallelization of filtering (based on JCTVC-D263)
 - Change the order of horizontal and vertical filtering
 - H filtering is performed across all block edges in processing frame
 - V filter is performed across all block edges in processing frame
 ⇒ ★ Dependency between H and V filtering is reduced

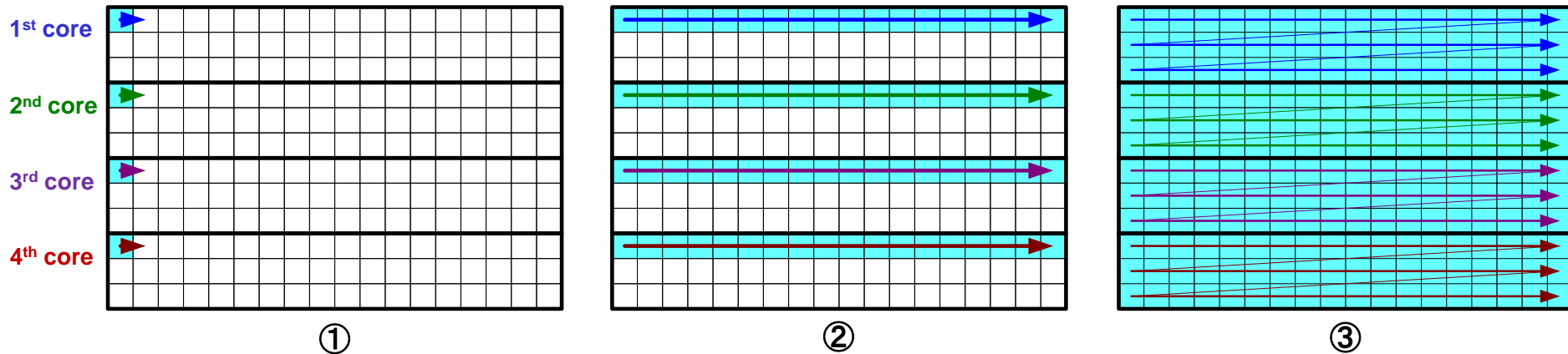
★ The same directional filtering has no dependency in 8x8 adjacent edge
no dependency



Features: Frame-based processing

1st Horizontal filtering

■ LCU performed by horizontal filtering
■ LCU performed by both horizontal and vertical filtering



2nd Vertical filtering

④

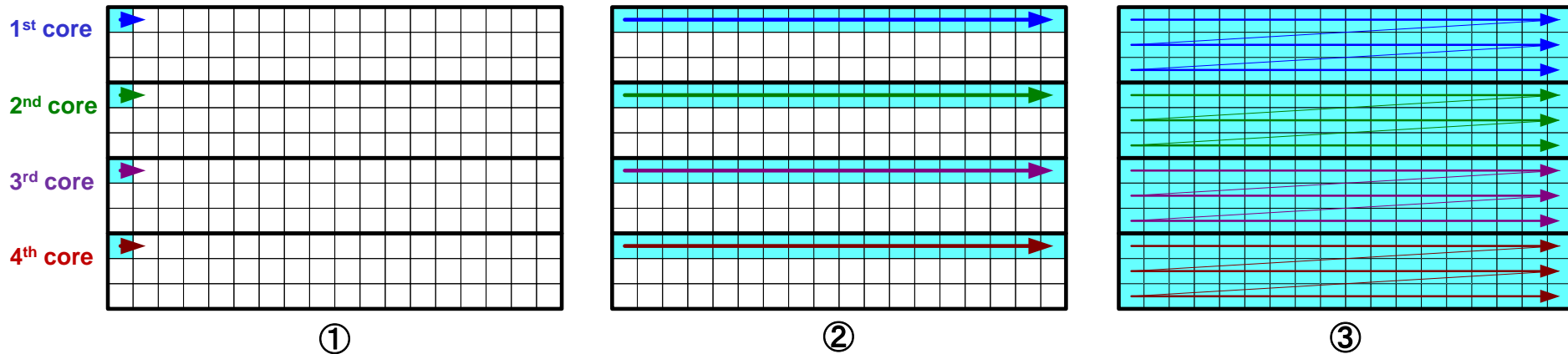
⑤

⑥

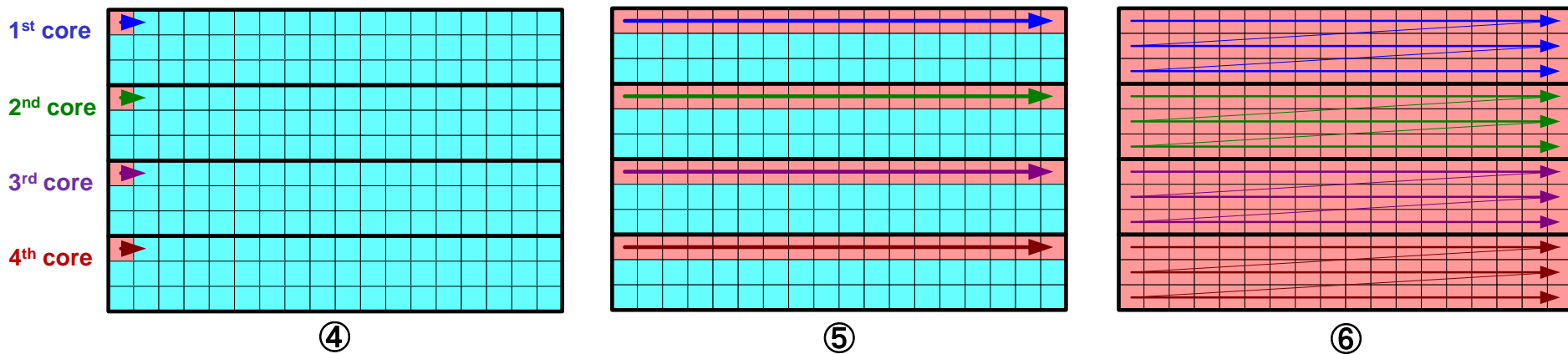
Features: Frame-based processing

1st Horizontal filtering

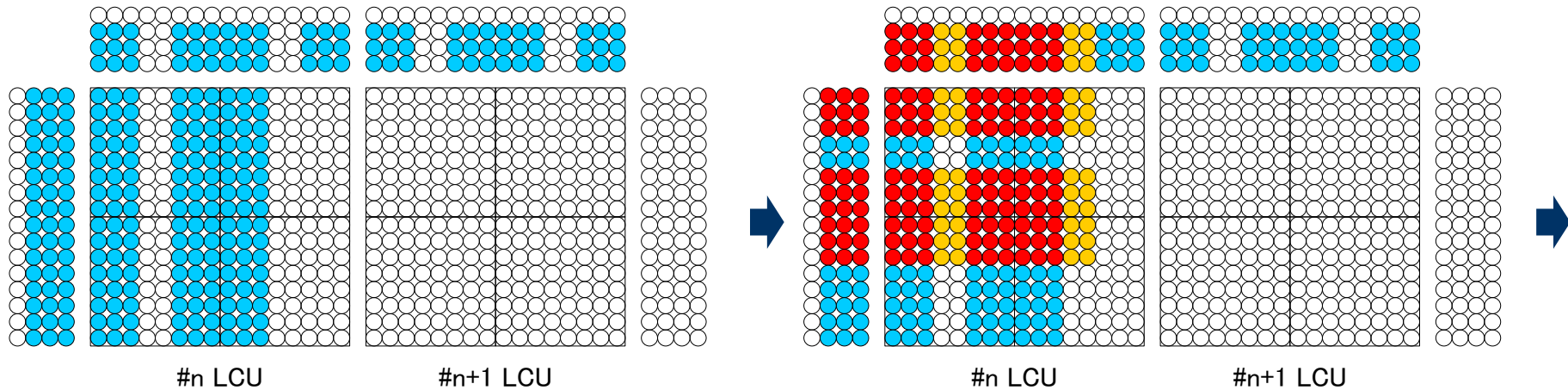
■ LCU performed by horizontal filtering
■ LCU performed by both horizontal and vertical filtering



2nd Vertical filtering

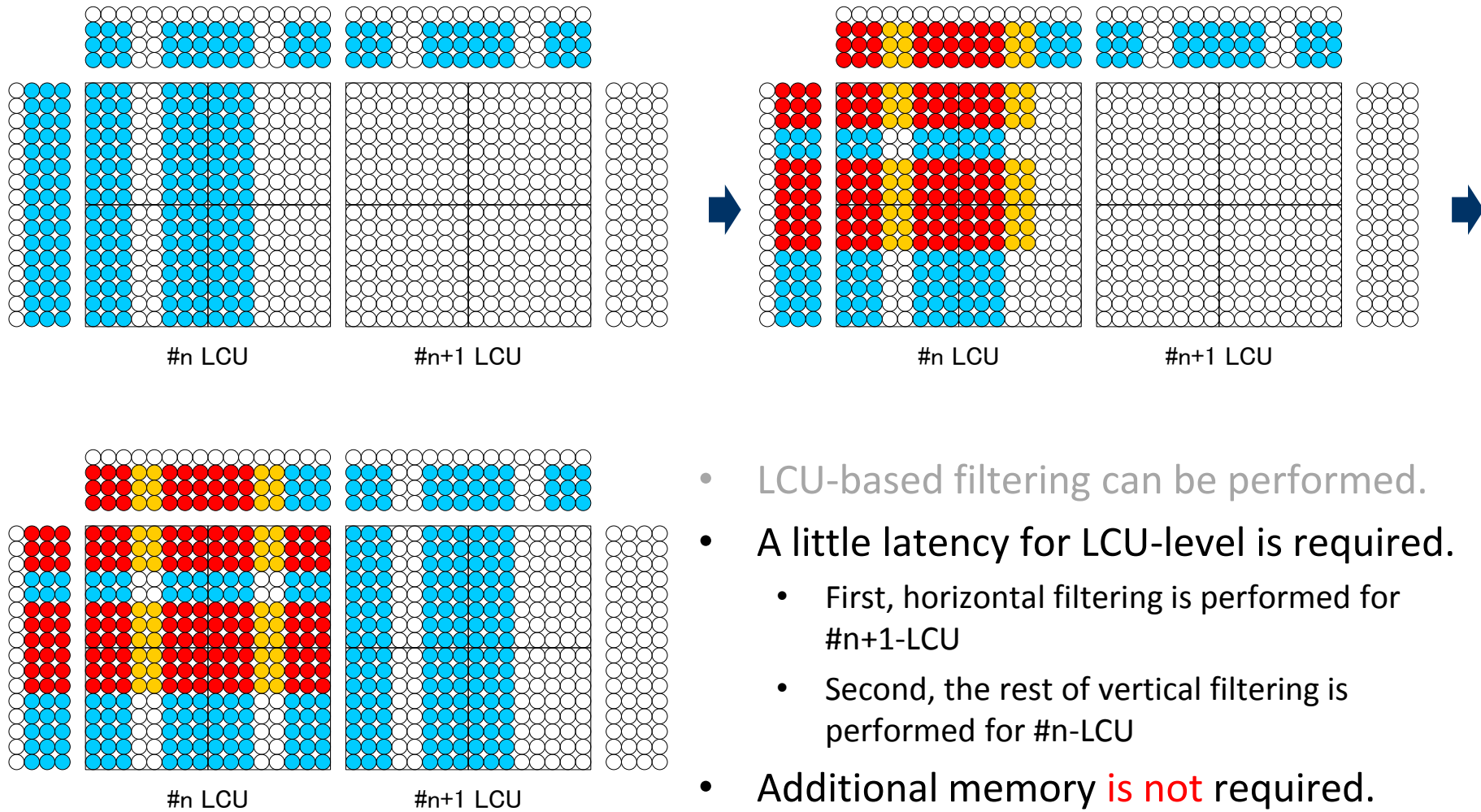


Features: LCU-based processing



- LCU-based filtering can be performed.

Features: LCU-based processing



- LCU-based filtering can be performed.
- A little latency for LCU-level is required.
 - First, horizontal filtering is performed for #n+1-LCU
 - Second, the rest of vertical filtering is performed for #n-LCU
- Additional memory **is not** required.

Proposal

- 2nd: Line-based filtering decision

- HM-2.0

$$|p_{2_2} - 2*p_{1_2} + p_{0_2}| + |q_{2_2} - 2*q_{1_2} + q_{0_2}| + |p_{2_5} - 2*p_{1_5} + p_{0_5}| + |q_{2_5} - 2*q_{1_5} + q_{0_5}| < \beta$$

	p3 ₀	p2 ₀	p1 ₀	p0 ₀	q0 ₀	q1 ₀	q2 ₀	q3 ₀
	p3 ₁	p2 ₁	p1 ₁	p0 ₁	q0 ₁	q1 ₁	q2 ₁	q3 ₁
	p3 ₂	p2 ₂	p1 ₂	p0 ₂	q0 ₂	q1 ₂	q2 ₂	q3 ₂
A	p3 ₃	p2 ₃	p1 ₃	p0 ₃	q0 ₃	q1 ₃	q2 ₃	q3 ₃
	p3 ₄	p2 ₄	p1 ₄	p0 ₄	q0 ₄	q1 ₄	q2 ₄	q3 ₄
	p3 ₅	p2 ₅	p1 ₅	p0 ₅	q0 ₅	q1 ₅	q2 ₅	q3 ₅
	p3 ₆	p2 ₆	p1 ₆	p0 ₆	q0 ₆	q1 ₆	q2 ₆	q3 ₆
	p3 ₇	p2 ₇	p1 ₇	p0 ₇	q0 ₇	q1 ₇	q2 ₇	q3 ₇

1st step: Decision filtering ON/OFF
for block boundary



	p3 ₀	p2 ₀	p1 ₀	p0 ₀	q0 ₀	q1 ₀	q2 ₀	q3 ₀
	p3 ₁	p2 ₁	p1 ₁	p0 ₁	q0 ₁	q1 ₁	q2 ₁	q3 ₁
	p3 ₂	p2 ₂	p1 ₂	p0 ₂	q0 ₂	q1 ₂	q2 ₂	q3 ₂
A	p3 ₃	p2 ₃	p1 ₃	p0 ₃	q0 ₃	q1 ₃	q2 ₃	q3 ₃
	p3 ₄	p2 ₄	p1 ₄	p0 ₄	q0 ₄	q1 ₄	q2 ₄	q3 ₄
	p3 ₅	p2 ₅	p1 ₅	p0 ₅	q0 ₅	q1 ₅	q2 ₅	q3 ₅
	p3 ₆	p2 ₆	p1 ₆	p0 ₆	q0 ₆	q1 ₆	q2 ₆	q3 ₆
	p3 ₇	p2 ₇	p1 ₇	p0 ₇	q0 ₇	q1 ₇	q2 ₇	q3 ₇

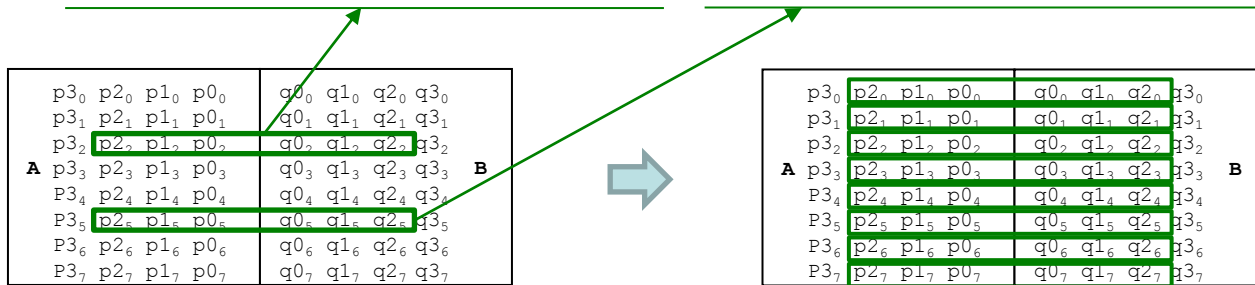
2nd step: Decision strong/weak filter
for each line

Proposal

- 2nd: Line-based filtering decision

- HM-2.0

$$|p2_2 - 2*p1_2 + p0_2| + |q2_2 - 2*q1_2 + q0_2| + |p2_5 - 2*p1_5 + p0_5| + |q2_5 - 2*q1_5 + q0_5| < \beta$$



1st step: Decision filtering ON/OFF
for block boundary

2nd step: Decision strong/weak filter
for each line

- Line-based filtering decision

p3 ₀	p2 ₀	p1 ₀	p0 ₀	q0 ₀	q1 ₀	q2 ₀	q3 ₀
p3 ₁	p2 ₁	p1 ₁	p0 ₁	q0 ₁	q1 ₁	q2 ₁	q3 ₁
p3 ₂	p2 ₂	p1 ₂	p0 ₂	q0 ₂	q1 ₂	q2 ₂	q3 ₂
p3 ₃	p2 ₃	p1 ₃	p0 ₃	q0 ₃	q1 ₃	q2 ₃	q3 ₃
p3 ₄	p2 ₄	p1 ₄	p0 ₄	q0 ₄	q1 ₄	q2 ₄	q3 ₄
p3 ₅	p2 ₅	p1 ₅	p0 ₅	q0 ₅	q1 ₅	q2 ₅	q3 ₅
p3 ₆	p2 ₆	p1 ₆	p0 ₆	q0 ₆	q1 ₆	q2 ₆	q3 ₆
p3 ₇	p2 ₇	p1 ₇	p0 ₇	q0 ₇	q1 ₇	q2 ₇	q3 ₇

$$|p2_i - 2*p1_i + p0_i| + |q2_i - 2*q1_i + q0_i| < (\beta > 1) \quad (i=0..7)$$

Variable "di" is defined as line-based

1st step: Decision ON/OFF and strong/weak filter
for each line

Results: 1st Parallelization of filtering (item2)

	Intra			Intra LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
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	-0.1	-0.1
Class D	0.0	0.0	0.0	0.0	0.0	-0.1
Class E	0.0	0.0	0.0	0.0	-0.1	0.0
All	0.0	0.0	0.0	0.0	0.0	0.0
Enc Time[%]	100%			101%		
Dec Time[%]	101%			100%		

- The difference of both BD-rate and run-time from HM-2.0 is **negligible**

	Random access			Random access LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	0.0	0.1	0.0	0.0	0.0	-0.1
Class B	0.0	0.0	0.1	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	0.0	0.0
Class E						
All	0.0	0.0	0.0	0.0	0.0	0.0
Enc Time[%]	100%			104%		
Dec Time[%]	100%			101%		

	Low delay			Low delay LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A						
Class B	0.0	0.1	0.0	0.0	-0.1	0.0
Class C	0.0	0.1	0.0	0.0	0.1	-0.3
Class D	-0.1	0.0	0.1	0.0	-0.1	0.1
Class E	0.0	-0.4	0.3	0.0	-0.3	0.1
All	0.0	0.0	0.1	0.0	-0.1	0.0
Enc Time[%]	101%			100%		
Dec Time[%]	104%			102%		

Results: 2nd Parallelization of filtering and line-based decision (item3)

	Intra			Intra LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-0.2	0.0	0.0	-0.1	0.0	0.0
Class B	-0.1	0.0	0.0	-0.1	0.0	0.0
Class C	-0.1	0.0	0.0	-0.1	-0.1	-0.1
Class D	0.0	0.0	0.0	-0.1	0.0	-0.1
Class E	-0.2	0.0	0.0	-0.1	-0.1	0.0
All	-0.1	0.0	0.0	-0.1	0.0	0.0
Enc Time[%]	100%			101%		
Dec Time[%]	101%			102%		

	Random access			Random access LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-0.2	-0.1	0.0	-0.2	0.0	0.0
Class B	-0.3	0.0	0.0	-0.2	0.0	0.0
Class C	-0.2	-0.1	-0.1	-0.2	-0.1	0.0
Class D	-0.1	0.0	-0.1	-0.1	-0.1	0.0
Class E						
All	-0.2	0.0	0.0	-0.2	-0.1	0.0
Enc Time[%]	100%			100%		
Dec Time[%]	101%			102%		

	Low delay			Low delay LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A						
Class B	-0.4	-0.1	-0.4	-0.4	-0.2	0.0
Class C	-0.3	0.0	0.0	-0.3	-0.1	-0.3
Class D	-0.2	-0.2	0.0	-0.2	-0.1	0.5
Class E	-0.8	-0.6	0.0	-0.3	-0.3	-0.2
All	-0.4	-0.2	-0.1	-0.3	-0.2	0.0
Enc Time[%]	101%			101%		
Dec Time[%]	103%			102%		

- BD-rate has a **small gain** in all conditions
- Run time increases slightly, but the increase is still small enough

Subjective quality: Line-based decision only

- Decode image is shown as below
 - Line-based decision (not include parallelization of filtering) is improved in 2 points



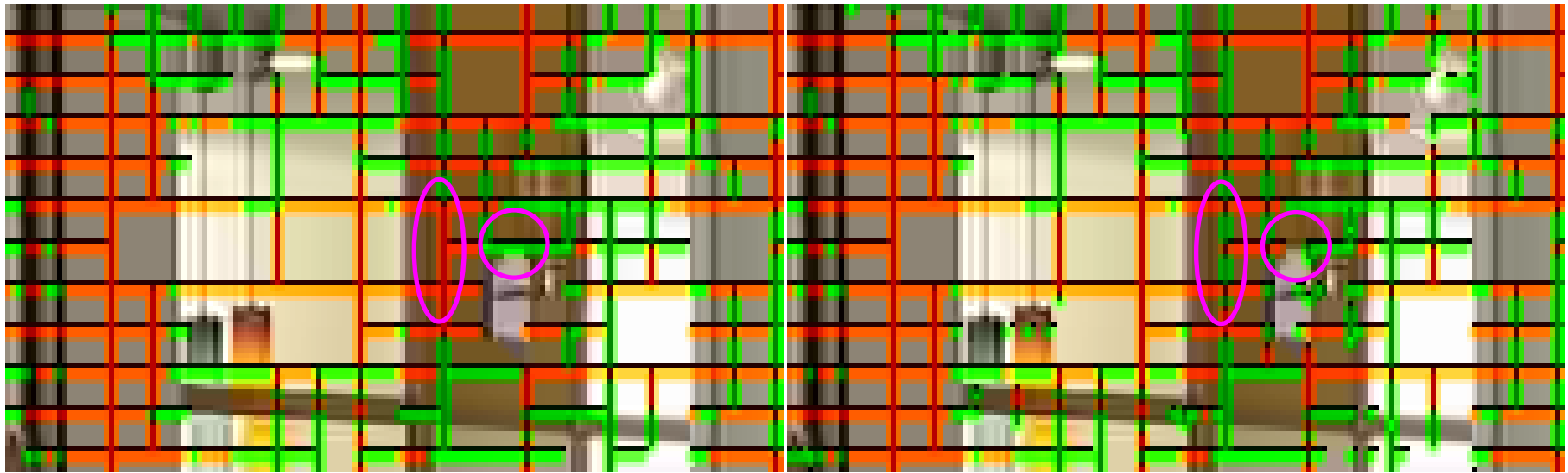
HM-2.0



Line-based decision

Subjective quality : Line-based decision only

- Analysis image is shown as below
 - Left remarkable point shows that weak filter is selected instead of strong filter
 - Right remarkable point shows that no filtering is selected instead of weak filter



HM-2.0

Line-based decision

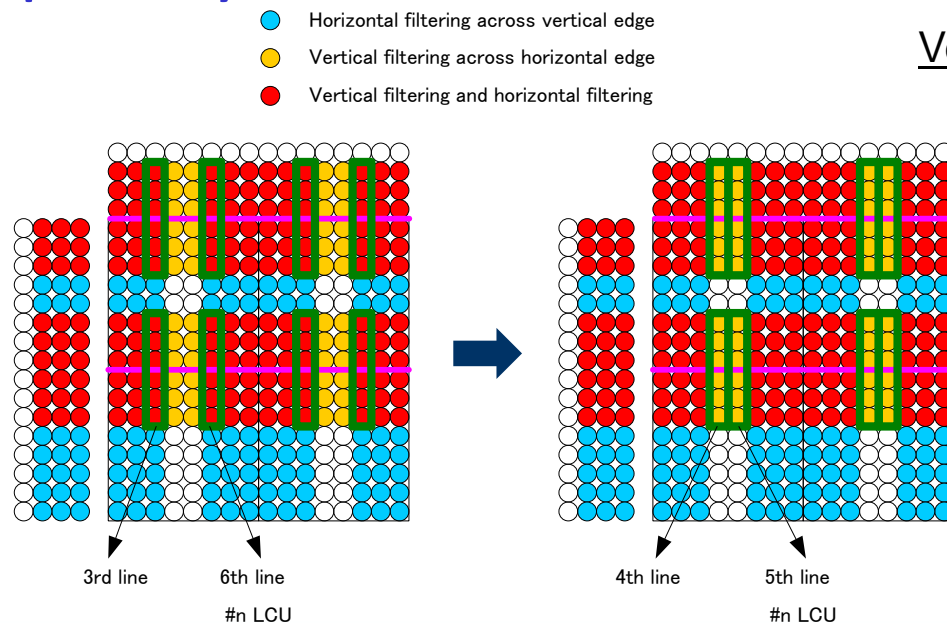
Conclusion

- Sony propose the followings are adopted into HM
 - H/V independent filtering to support high flexibility of parallel processing
 - Line-based filtering decision to support more precise with almost same complexity
- Sony's proposal is cross verified by Panasonic and Qualcomm

Appendix

Proposal

- 3rd: Parallelization of filtering and **filtering decision**
 - Both 3rd and 6th lines are used for the decision in TMuC-2.0
 - ⇒ These lines are filtered by horizontal and vertical filter, so the decision has dependency
 - ⇒ We propose to use both 4th and 5th lines for the judgment to **remove above dependency**



Results: Parallelization of filtering and decision

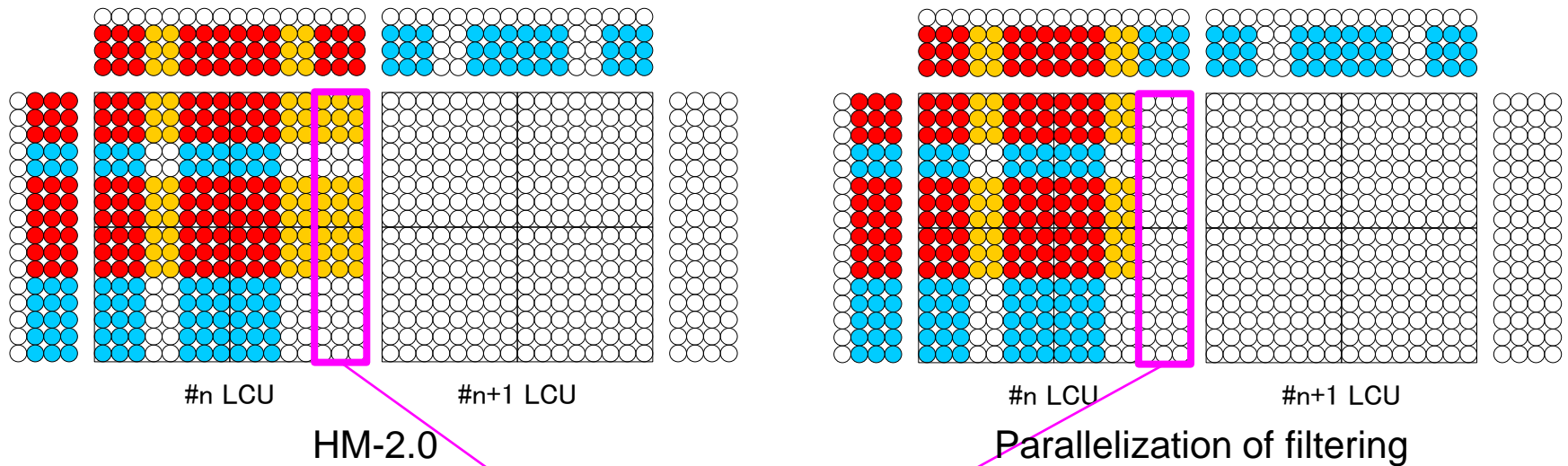
	Intra			Intra LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	0.1	0.0	0.0	0.1	0.0	0.0
Class B	0.1	0.0	0.0	0.1	0.0	0.0
Class C	0.0	0.0	0.0	0.0	-0.1	-0.1
Class D	0.1	0.0	0.0	0.1	0.0	-0.1
Class E	0.1	0.0	0.0	0.1	-0.1	0.0
All	0.1	0.0	0.0	0.1	0.0	0.0
Enc Time[%]	100%			101%		
Dec Time[%]	100%			102%		

	Random access			Random access LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	0.1	0.2	0.2	0.0	0.0	0.0
Class B	0.1	0.1	0.1	0.1	0.0	0.0
Class C	0.0	-0.1	0.0	0.0	0.0	0.0
Class D	0.1	-0.1	-0.1	0.1	-0.1	-0.1
Class E						
All	0.1	0.0	0.0	0.1	0.0	0.0
Enc Time[%]	100%			100%		
Dec Time[%]	100%			100%		

	Low delay			Low delay LoCo		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A						
Class B	0.2	0.3	0.0	0.2	-0.1	0.2
Class C	0.1	0.2	0.0	0.0	-0.1	-0.2
Class D	0.0	0.3	-0.2	0.1	0.2	0.2
Class E	0.4	-0.3	0.5	0.3	0.4	0.5
All	0.1	0.2	0.1	0.1	0.1	0.2
Enc Time[%]	101%			100%		
Dec Time[%]	102%			102%		

- It has slight larger loss in all test conditions, but the loss is still small enough
- Run time increases slightly, but the increase is still small enough

Features: LCU-based processing



Necessary memory in both Sony's and HM-2.0's proposal is the same size