ALF decode complexity analysis and reduction

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Madhukar Budagavi, Vivienne Sze, Minhua Zhou

Texas Instruments

Joint Collaborative Team on Video Coding (JCT-VC)
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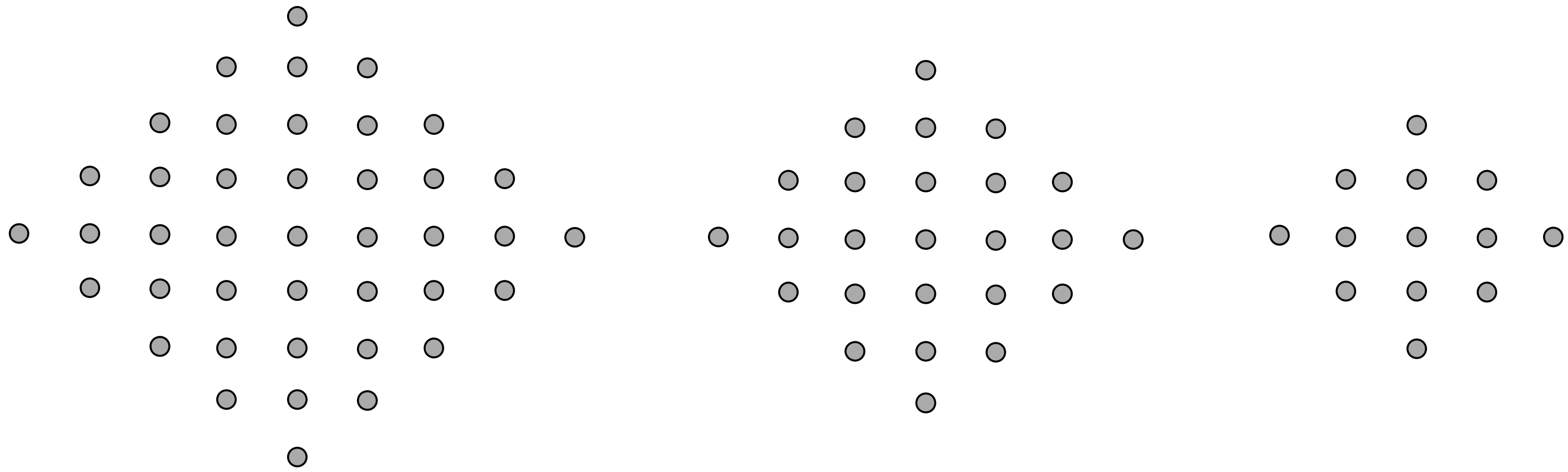
HM 1.0 ALF



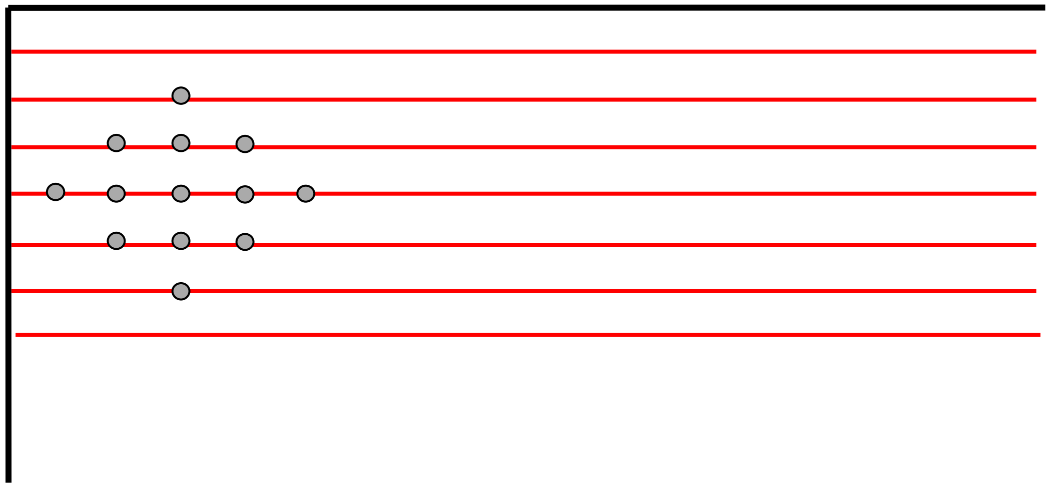
9-Diamond 7-Diamond 5-Diamond

- HM 1.0 ALF uses three diamond shaped filters of sizes 9, 7, 5
  - Worst case number of multiplies: 21
- A maximum of up to 16 filters can be signaled per slice

ALF decode complexity

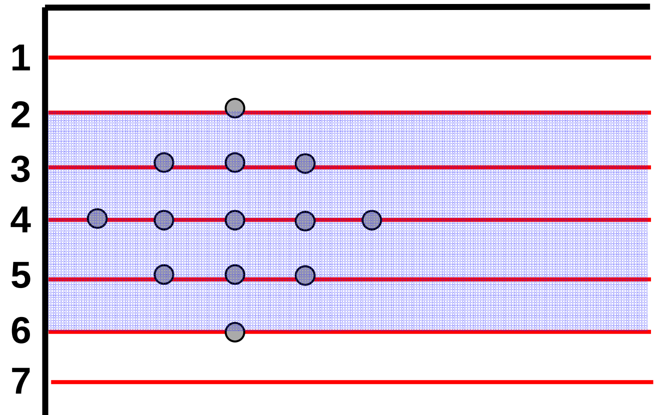
- Complexity considerations
  - Computational complexity
  - Memory bandwidth
  - Memory size (line buffer)
- ALF filtering can be carried out in either frame-based or LCU-based fashion
- Frame-based filtering requires that deblocking filter output be stored in frame buffer
  - Not desirable because of additional external memory bandwidth and memory size requirements
- LCU-based filtering
  - Requires use of line buffers to eliminate additional memory bandwidth/frame buffers
  - Preferred option

Frame based ALF decode (No line buffers)

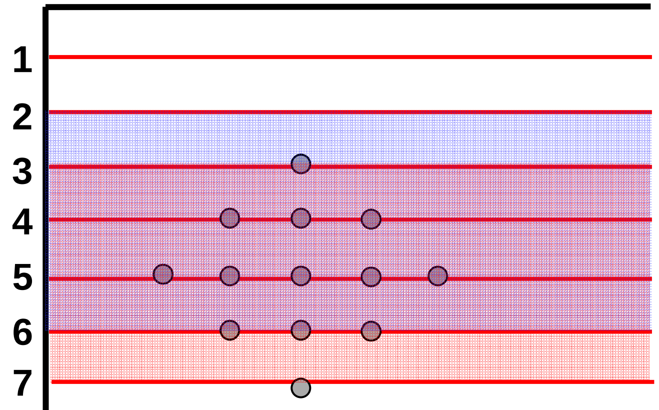


- Each filtering operation requires (N*N/4+1) pixel reads when N is filter size
- For N = 9, number of input pixel reads for each filtering operation = 21
- Memory bandwidth implications
  – Deblock output frame buffer needs to be read 21 times (also written to 1 time)
  – Not practical
- Memory requirements: 1 frame buffer for storing deblock output

Frame based ALF decode (with line buffers)



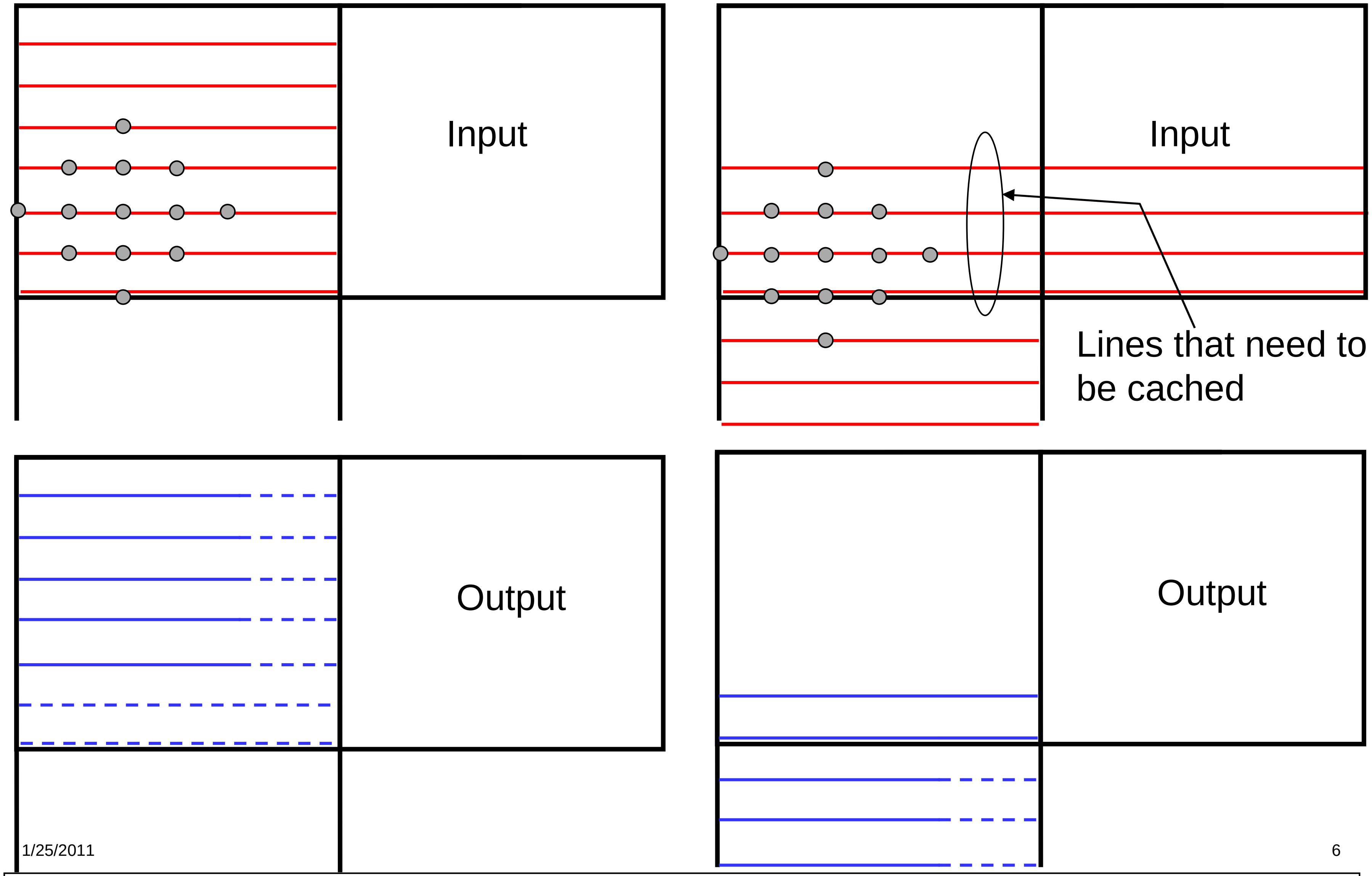
Filtering at (4, x)



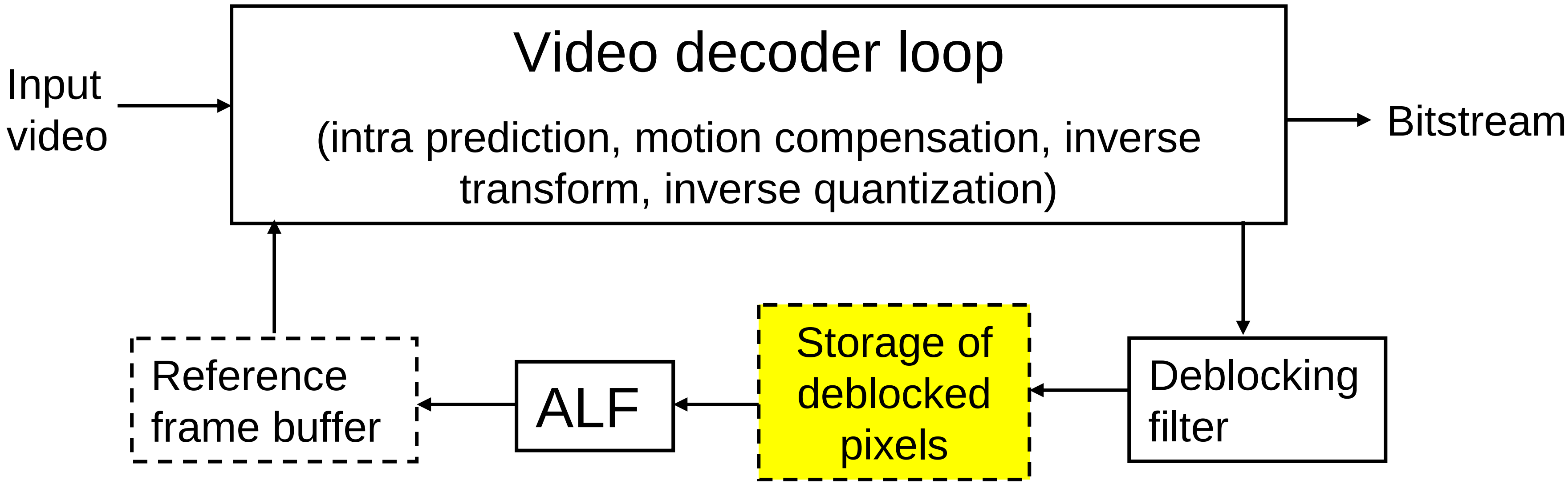
Filtering at (5, x+1)

- Overlapping input data from one line to next need not be fetched when internal line buffers are used
- For N = 9, number of input pixel reads for each filtering operation = 1
- Memory bandwidth implications
  - Deblock output frame buffer needs to be read 1 time (also written to 1 time)
  - Still very expensive
- Memory requirements: ~ 8*picWidth local memory, + 1 frame buffer for storing deblock output

LCU-based ALF decode with line buffers



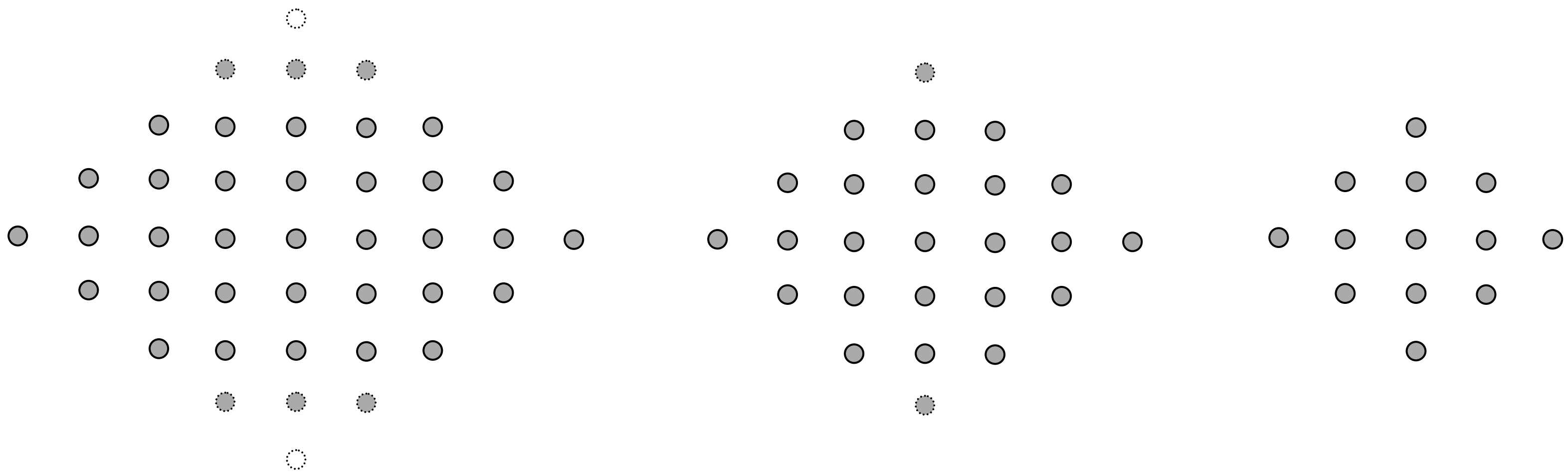
Summary of ALF implementation architecture



LCU-based ALF line buffer requirements

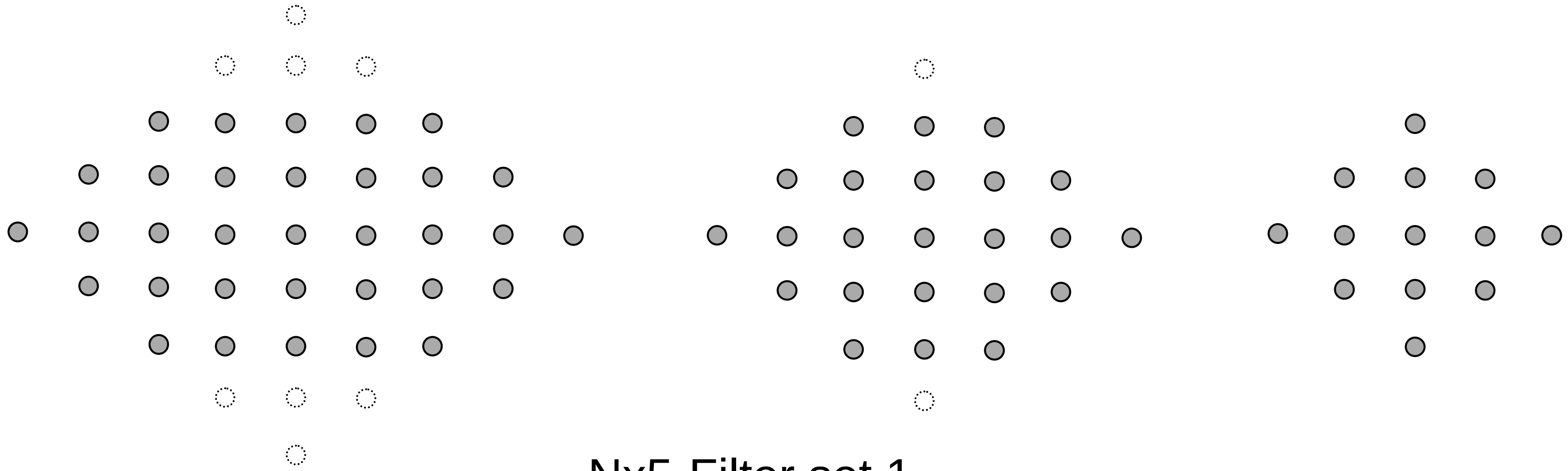
- Assumption
  - 4Kx2K image
  - Maximum ALF filter size = 9
  - IBDI on
  - Memory for storing multiple LCUs not included
- Line buffer size: 4K * 8 lines * 12 bits = 48KBytes
- 48 KB ≈ 140 Kgates
- For comparison purposes:
  - AVC/SVC/MVC video decoder chip uses 414 Kgates and 9 Kbytes of memory (NTU Taiwan, IEEE ISSCC [1])
- ➔ Essential to reduce ALF vertical size for ALF to be a part of HEVC standard that can be cost-effectively implemented

New ALF filters with reduced vertical size (max vertical size = 7)

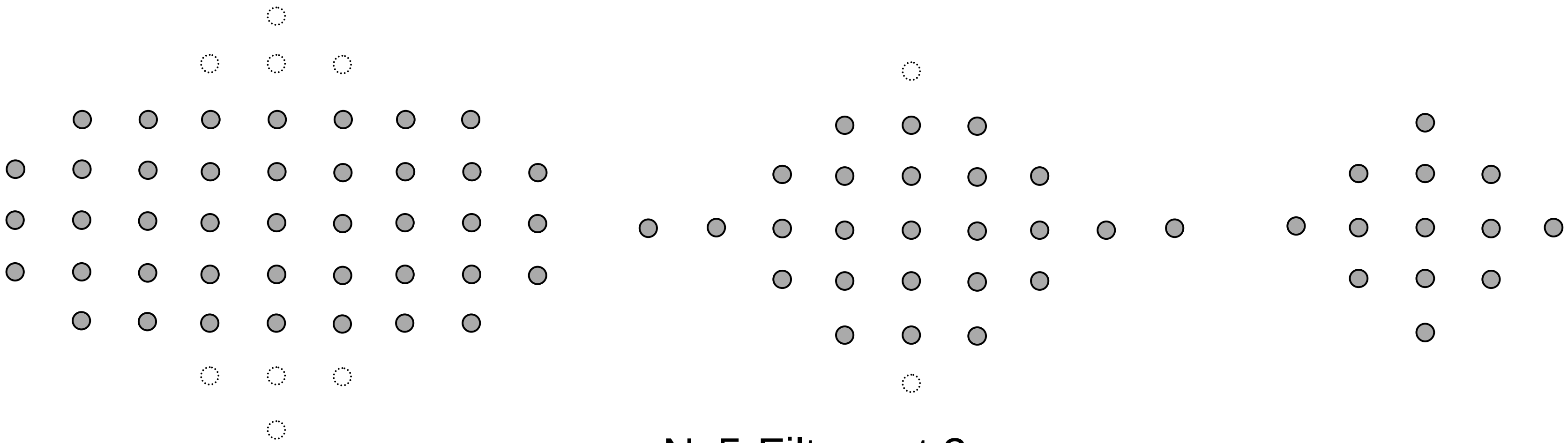


Nx7

New ALF filters with reduced vertical size (max vertical size = 5)



Nx5-Filter set 1



Nx5-Filter set 2

Results

			Intra		Random access		Low delay	
	Line buffer size / Memory bandwidth	Worst case multiplies	BD-Rate	Dec time	BD-Rate	Dec time	BD-Rate	Dec time
No ALF	0	0	3.47	63%	4.43	74%	4.38	73%
HM 1.0 ALF	1X	21						
5x5	0.5X	7	0.7	82%	0.8	101%	1.2	88%
7x7, 5x5	0.75X	13	0.3	94%	0.3	99%	0.9	100%
Nx7	0.75X	19	0.0	101%	0.1	102%	0.3	97%
Nx5-Set 1	0.5X	17	0.2	93%	0.2	95%	0.5	92%
Nx5-Set 2	0.5X	21	0.1	98%	0.1	101%	0.4	102%

Table 1: Summary of BD-Rate, Decoder time, and complexity of ALF filters. Compared to anchor.

Conclusions

- Implementation complexity analysis involves not just analysis of computations but also analysis of memory bandwidth and memory size (area).
- For a given image size, the vertical size of ALF filters determines the size of line buffer/memory bandwidth requirements
  - Reducing vertical size of filter reduces line buffer/memory bandwidth requirements
- Contribution proposes new ALF filter sets with reduced vertical size
- Proposed ALF filter sets capture most of the ALF coding gains
- Nx5-Set2 successfully cross-verified by Toshiba (JCTVC-D188). Thanks to Toshiba.
- Recommend that proposed ALF filter be adopted in HM 2.0 if there are no objections

Results

			Intra		Random access		Low delay	
	Line buffer size / Memory bandwidth	Worst case multiplies	BD-Rate	Dec time	BD-Rate	Dec time	BD-Rate	Dec time
No ALF	0	0		63%		74%		73%
HM 1.0 ALF	1X	21	-3.3		-4.1		-4.1	
5x5	0.5X	7	-2.6	82%	-3.4	101%	-3.0	88%
7x7, 5x5	0.75X	13	-3.1	94%	-3.8	99%	-3.3	100%
Nx7	0.75X	19	-3.3	101%	-4.1	102%	-3.8	97%
Nx5-Set 1	0.5X	17	-3.2	93%	-4.0	95%	-3.7	92%
Nx5-Set 2	0.5X	21	-3.2	98%	-4.0	101%	-3.8	102%

Table 2: Summary of BD-Rate, Decoder time, and complexity of ALF filters. Compared to no ALF.