Perceptually-Driven Video Coding with the Daala Video Codec

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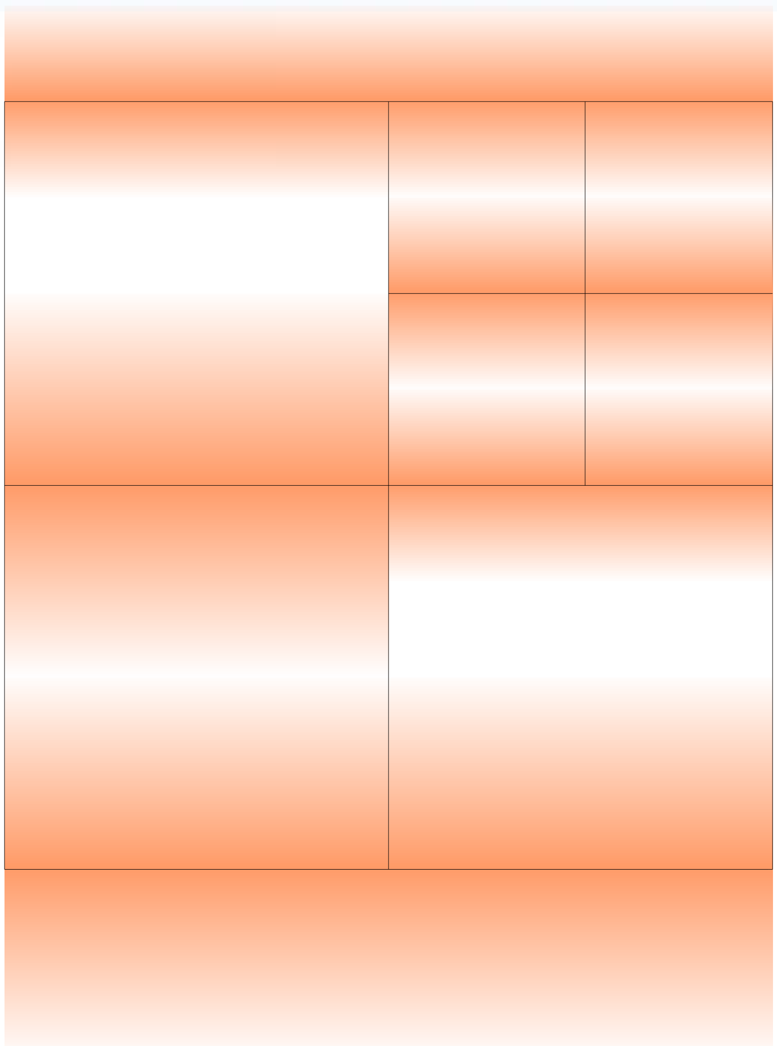
Summary

- Daala is an attempt to completely avoid royalty-bearing technologies
- Used many unconventional tools
- Some worked well, others more challenging
  - We think the challenges are more interesting
- Many lessons learned that can inform AV1 development
  - Only a few presented here, see paper for more

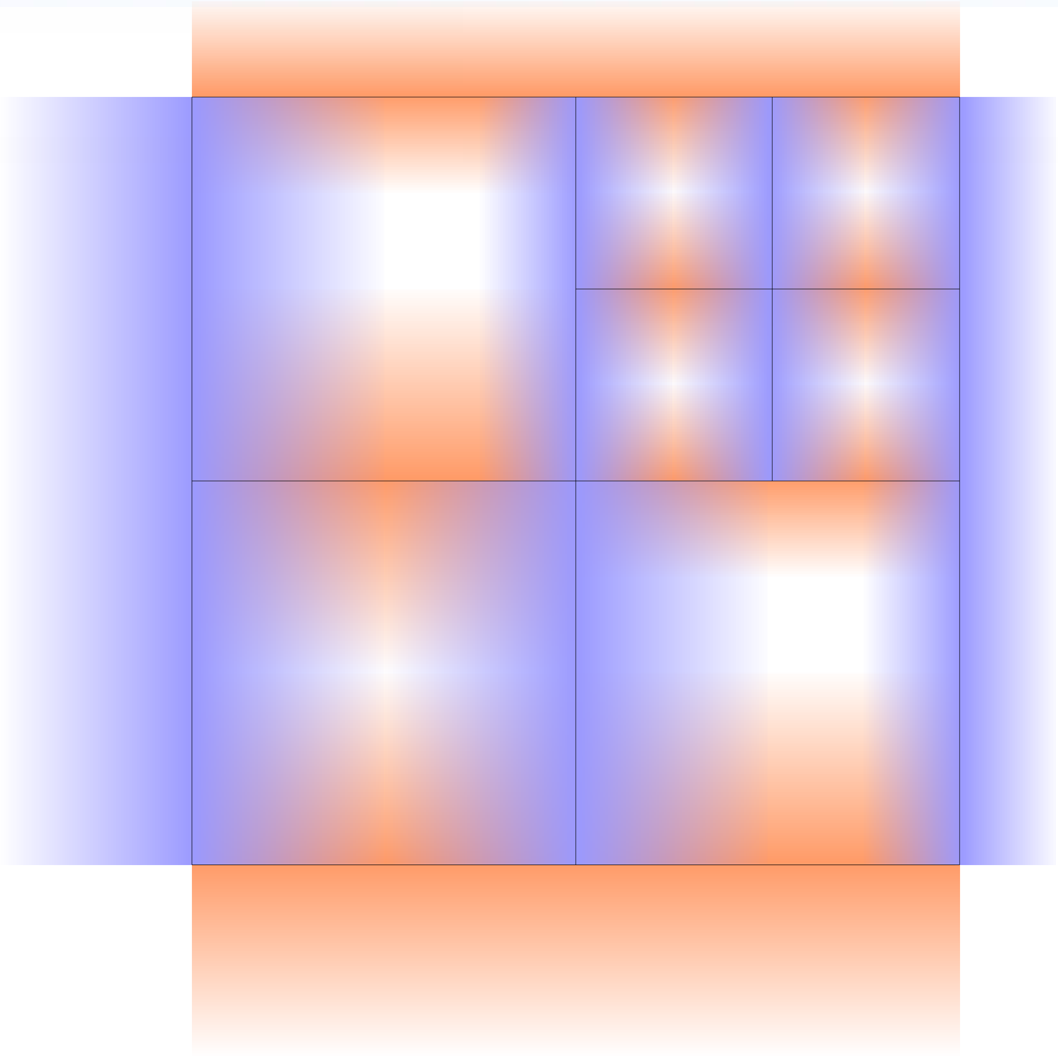
Challenge 1: Lapped Transforms with Variable Block Sizes

Original Lapping Strategy



- Filter size chosen based on size of smallest block on an edge (to prevent overlap)
- Filter order chosen to mimic a loop filter’s
  - Horizontal edges first

Original Lapping Strategy



- Filter size chosen based on size of smallest block on an edge (to prevent overlap)
- Filter order chosen to mimic a loop filter's
  - Then vertical
  - Maximal parallelism, minimum buffering

Problem #1: Basis Weirdness

Problem #2: Block size decision

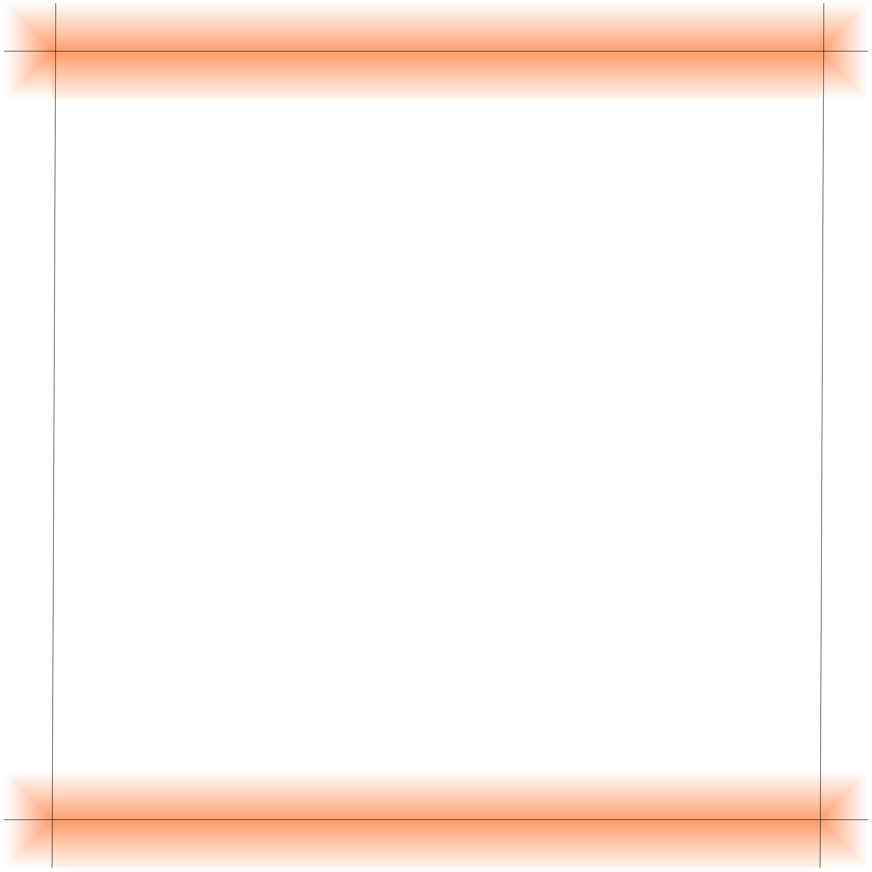
- Have to know neighbors' block sizes to compute lapping size
- Used a heuristic based on the estimated visibility of ringing to pick block sizes up front
  - Worked "okay" for still images (at least not obviously broken)
  - Was not making good decisions for inter frames
- Wanted to try explicit block size RDO (like other encoders)...
  - But lapping dependency makes this infeasible

“Fixed Lapping”: Remove the Dependency

- Always use 8-point lapping (4 pixels on either side of an edge)
  - Except on 4×4 blocks (details in a few slides)
  - Always use 4-point lapping for chroma (because of subsampling)

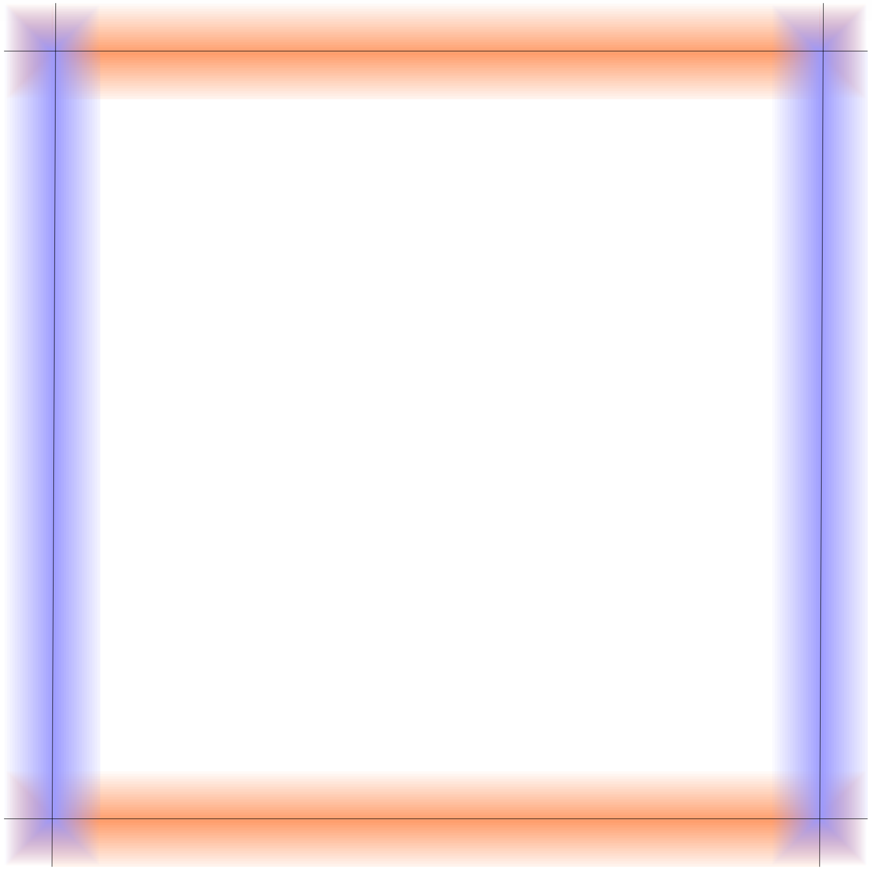
New Filter Order

- Filter top/bottom superblock (64×64) edges first



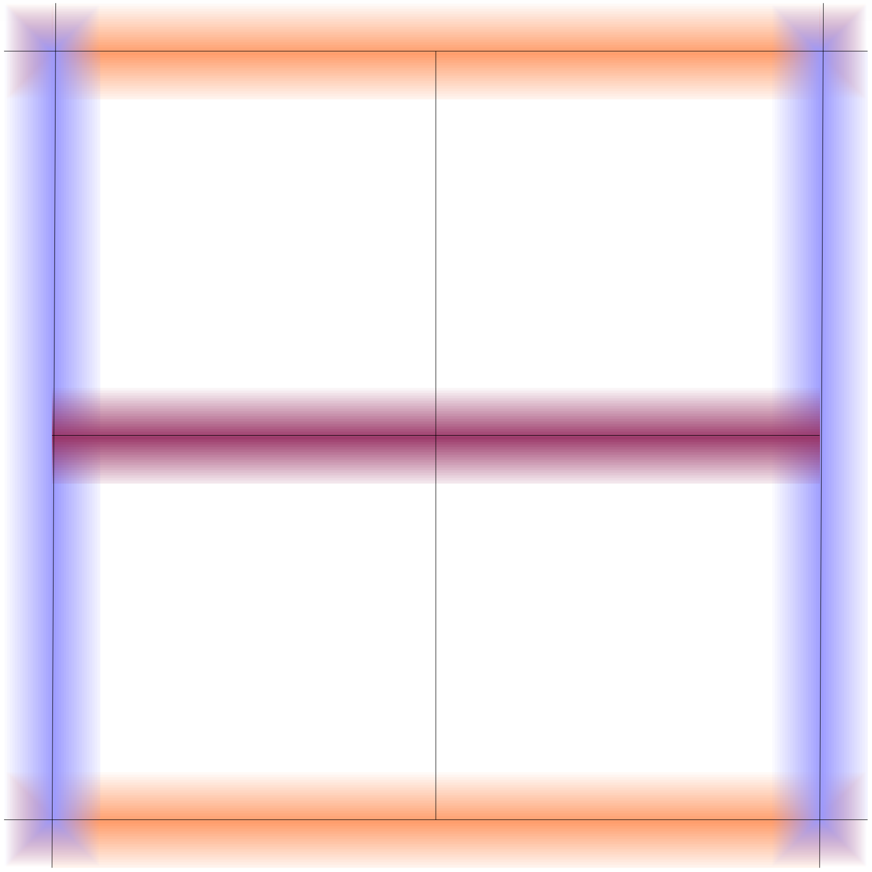
New Filter Order

- Filter left/right superblock (64×64) edges next



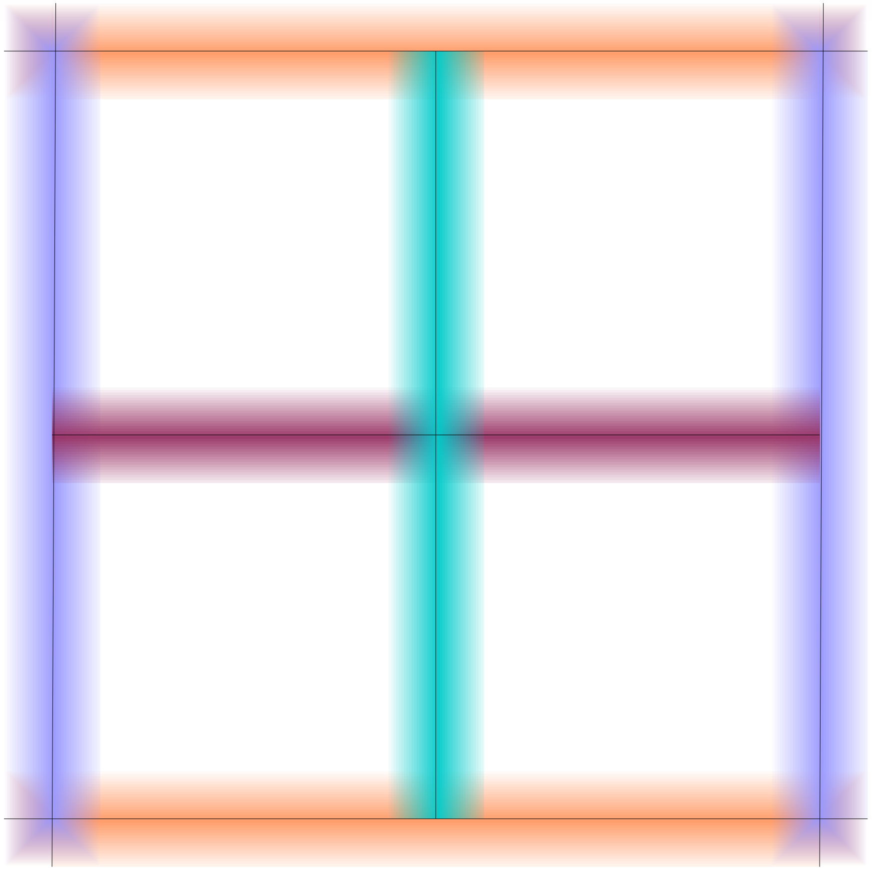
New Filter Order

- Splitting: Filter interior edges



New Filter Order

- Splitting: Filter interior edges



  - 4×4 blocks:
    - Exterior edges use 8-point filter (from previous levels)
    - Interior edges use 4-point filter (overlaps 8-point filter)

Results

- Big boost in metrics
  - Almost all from decision
  - Used fixed lapping decision with old lapping scheme and got *almost* all of the gains

	RATE (%)	DSNR (dB)
PSNR	-10.36612	0.40904
PSNRHVS	-4.48956	0.25806
SSIM	-12.32547	0.38397
FASTSSIM	-5.20467	0.17350

- Smaller lapping means less ringing but more blockiness (especially on gradients)
  - Didn’t save much on ringing: 4×4 blocks have 12-pixel support instead of 8
  - Eventually dropped to 4-point lapping everywhere

Challenge 2: Frequency Domain Intra Prediction

Frequency Domain Intra Prediction

- Perform prediction in transform domain
  - Shorter pipeline dependency for hardware
- Multiple (linear) prediction matrices trained from large dataset (approx. equiv. to spatial directions)
- Computational complexity controlled by enforcing “sparsity” (4 muls per output coefficient)

	DCT+VP8 Intra			LT+FDIP (full)			LT+FDIP (sparse)	
Transform size	C_g	P_g	Total	C_g	P_g	Total	P_g	Total
4×4	13.8511	2.9154	16.7665	14.9600	2.2103	17.1703	2.0799	17.0399
8×8	15.1202	0.86940	15.9894	15.6468	0.72486	16.3716	0.58957	16.2364
16×16	15.5870	0.19483	15.7818	15.8721	0.37593	16.2480	0.09541	15.9675

Frequency Domain Intra Prediction

- Variable block sizes make this worse
  - Best results: convert all neighbors to 4×4 with “TF”
- Most multiplies spent on predicting DC
- A simpler approach:
  - Haar DC: combine DCs from smaller blocks with Haar transform (down to one DC per 64x64 block)
    - Hugely effective, no multiplies
  - Use first row/column of neighbors’ coefficients as sole AC predictor (only when block sizes match)
    - Works just as well as orig. FDIP (not very), much simpler

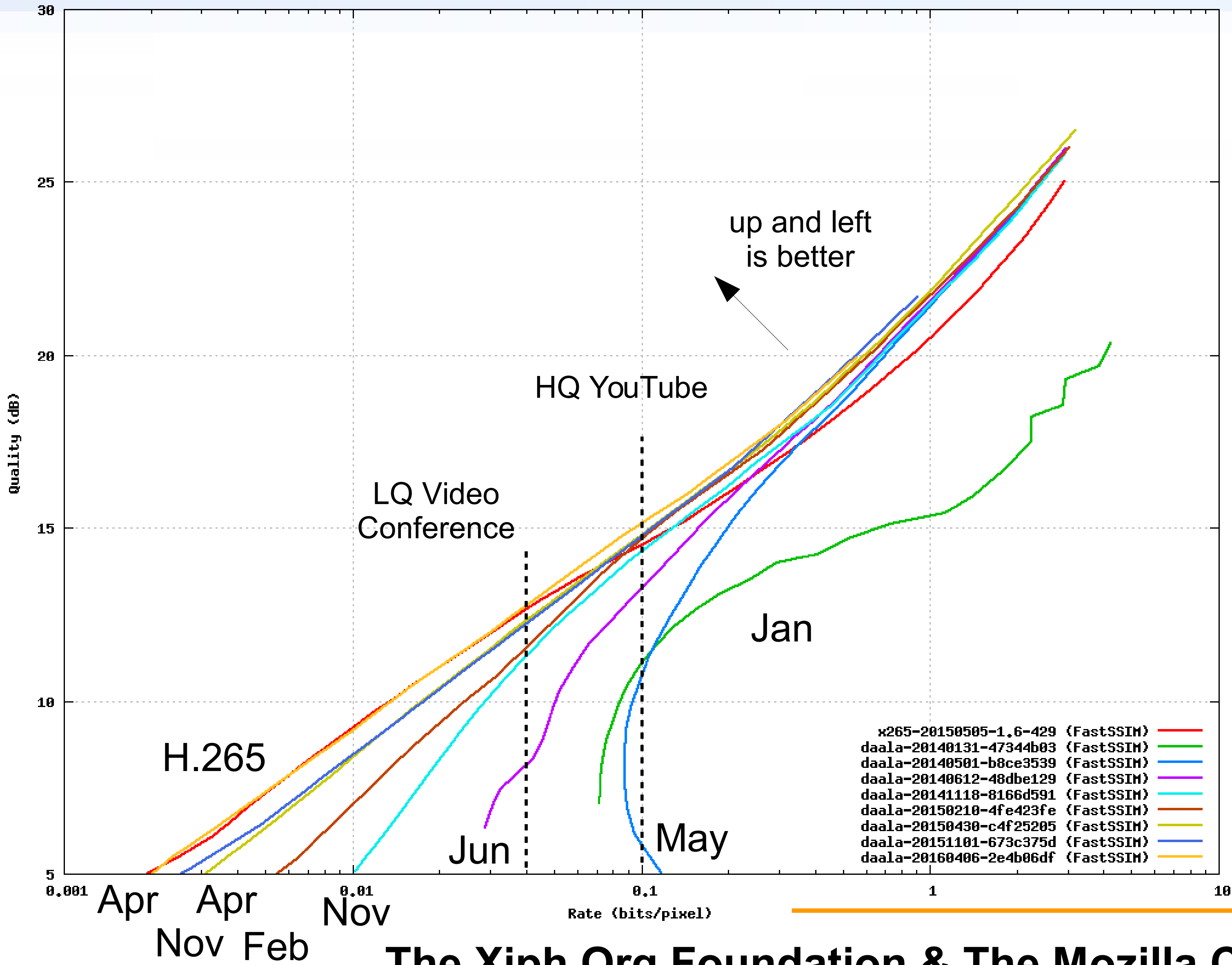
Things We Did Not Try

- Spatial prediction from outside lapping region
  - Very complicated with original lapping scheme
  - Feasible with fixed lapping scheme
- Correcting for biorthogonal basis function scales
  - Intractable with original lapping
- “Smart” factorization of prediction matrices
  - Only improves up to the limit of non-sparse predictors

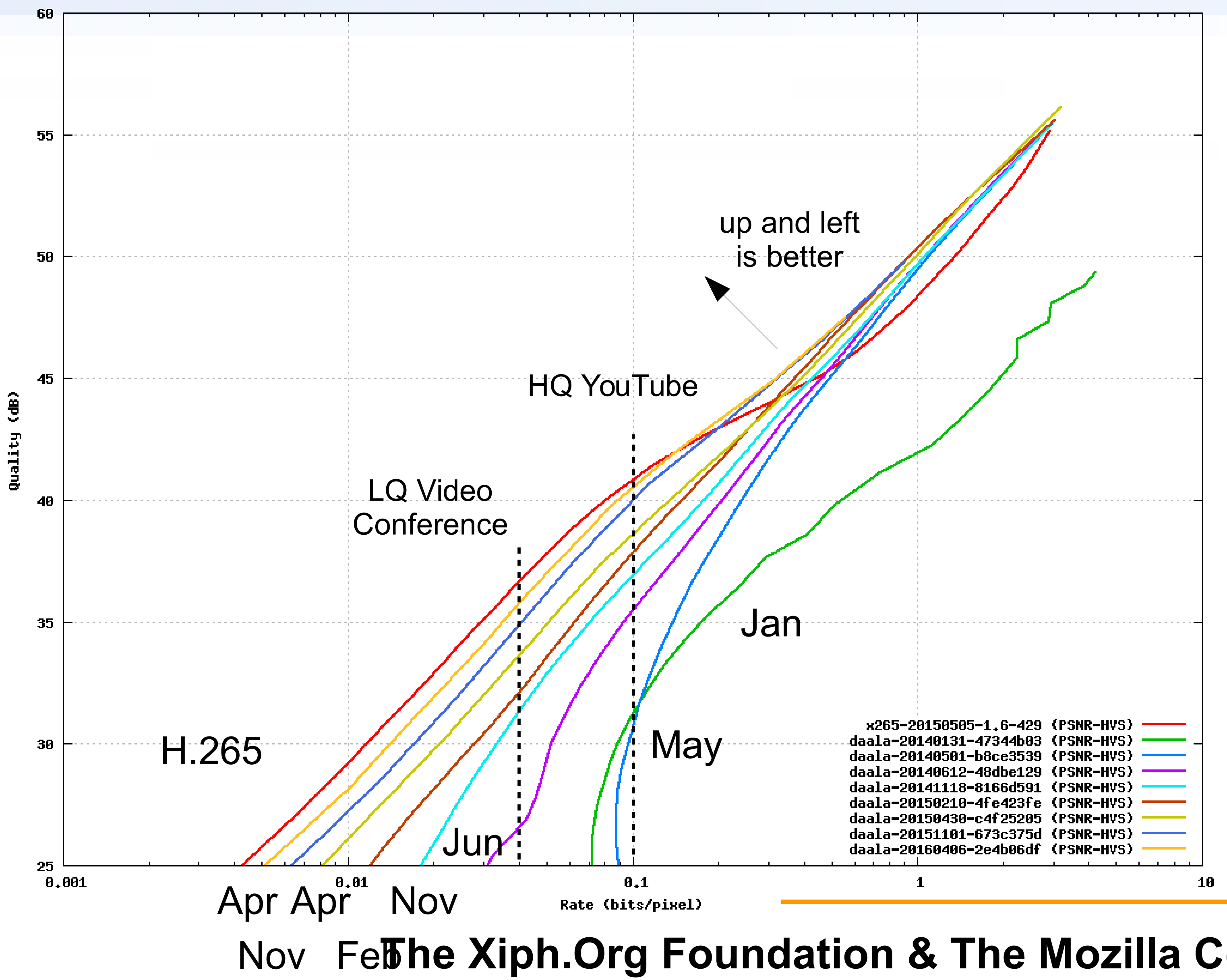
Directions for AV1

- Directional Deringing
  - Fully SIMDable, good perceptual improvements
- Non-binary Arithmetic Coding
  - Small effective parallelism in entropy coding
- Perceptual Vector Quantization
  - Already showing small gains vs. scalar on PSNR
  - Potential for large perceptual improvements
  - Enables freq. Domain Chroma-from-Luma, others
- Rate control improvements

Daala Progress (Fast MS-SSIM): January 2014 to April 2016



Daala Progress (PSNR-HVS): January 2014 to April 2016



Questions?