Video codec comparison using the dynamic optimizer framework

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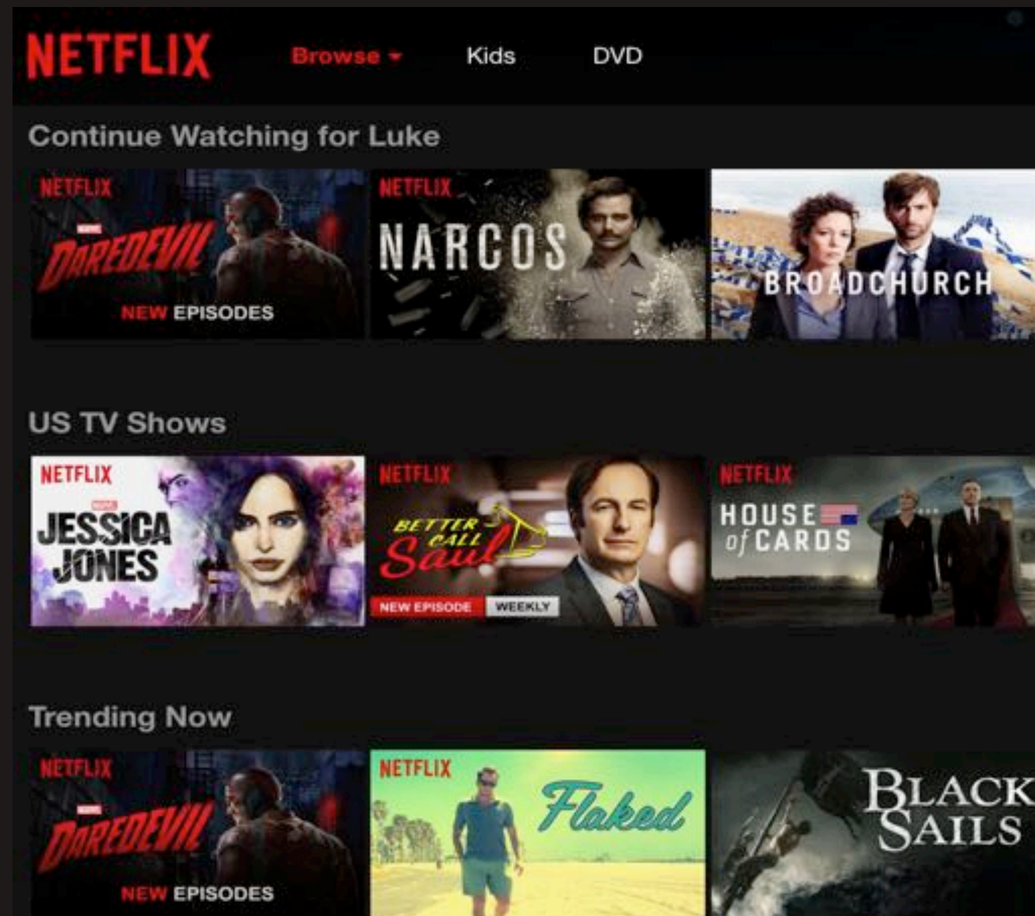
Video Algorithms
Netflix

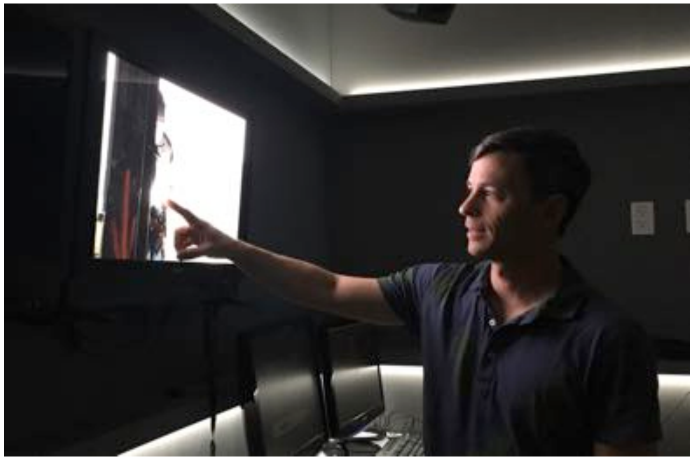
World's Leading Internet Entertainment Service



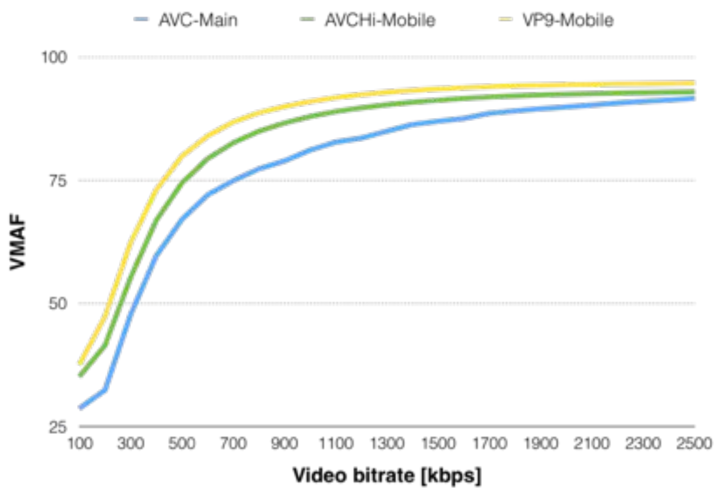
Outline

- Measuring video quality – VMAF
- Dynamic Optimizer framework
- Proposed testing methodology
- Results

Ways to measure video quality



Subjective Assessment



Automated Assessment
using PSNR, SSIM, or VMAF


PSNR 37.3 dB


PSNR 32.9 dB

Need a better perceptual metric

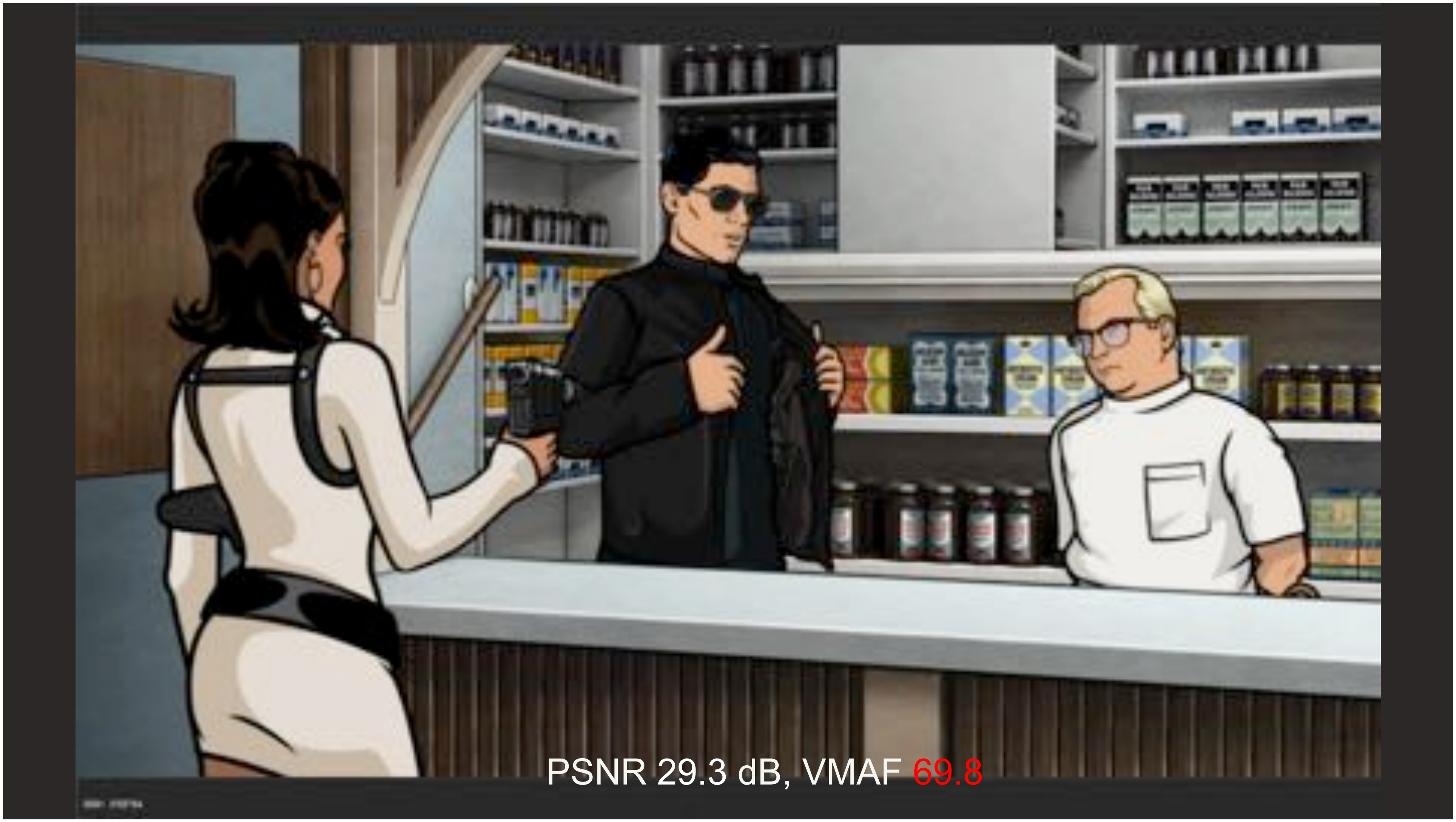
- Accurately measures **human perception** of quality
- Consistent across content
- Can be run at scale
- Works well relevant to adaptive streaming
  - Compression artifacts
  - Scaling artifacts

VMAF: Video Multimethod Assessment Fusion


PSNR 37.1 dB, VMAF 71.1


PSNR 32.9 dB, VMAF 70.2


PSNR 29.1 dB, VMAF 20.4


PSNR 29.3 dB, VMAF 69.8

Video Multimethod Assessment Fusion

- Full-reference video quality metric

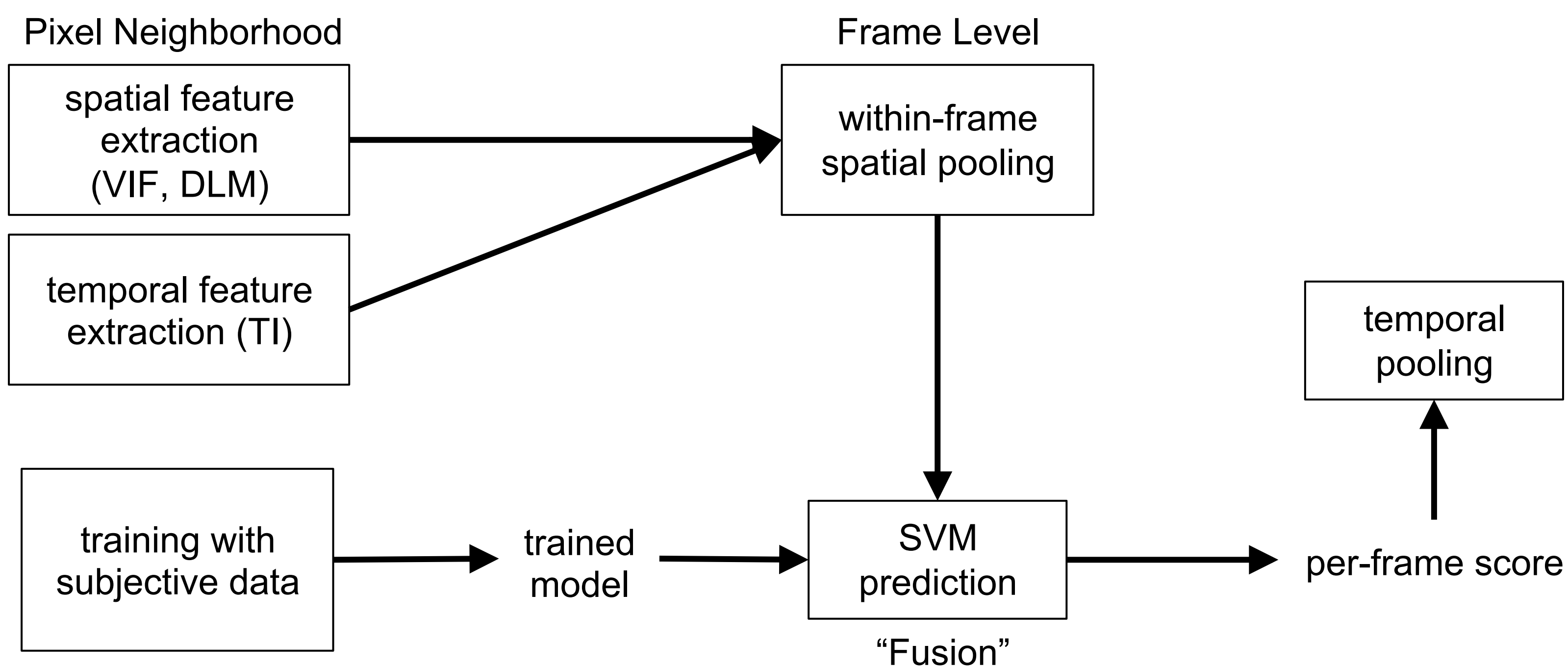
- Combines multiple elementary quality metrics
  - Visual quality fidelity (VIF*) @ 4 scales
  - Detail loss measure (DLM**)
  - Temporal information (TI) - average pixel difference between adj. frames

- Machine-learning regression to predict a final “fused” score, guided by subjective data

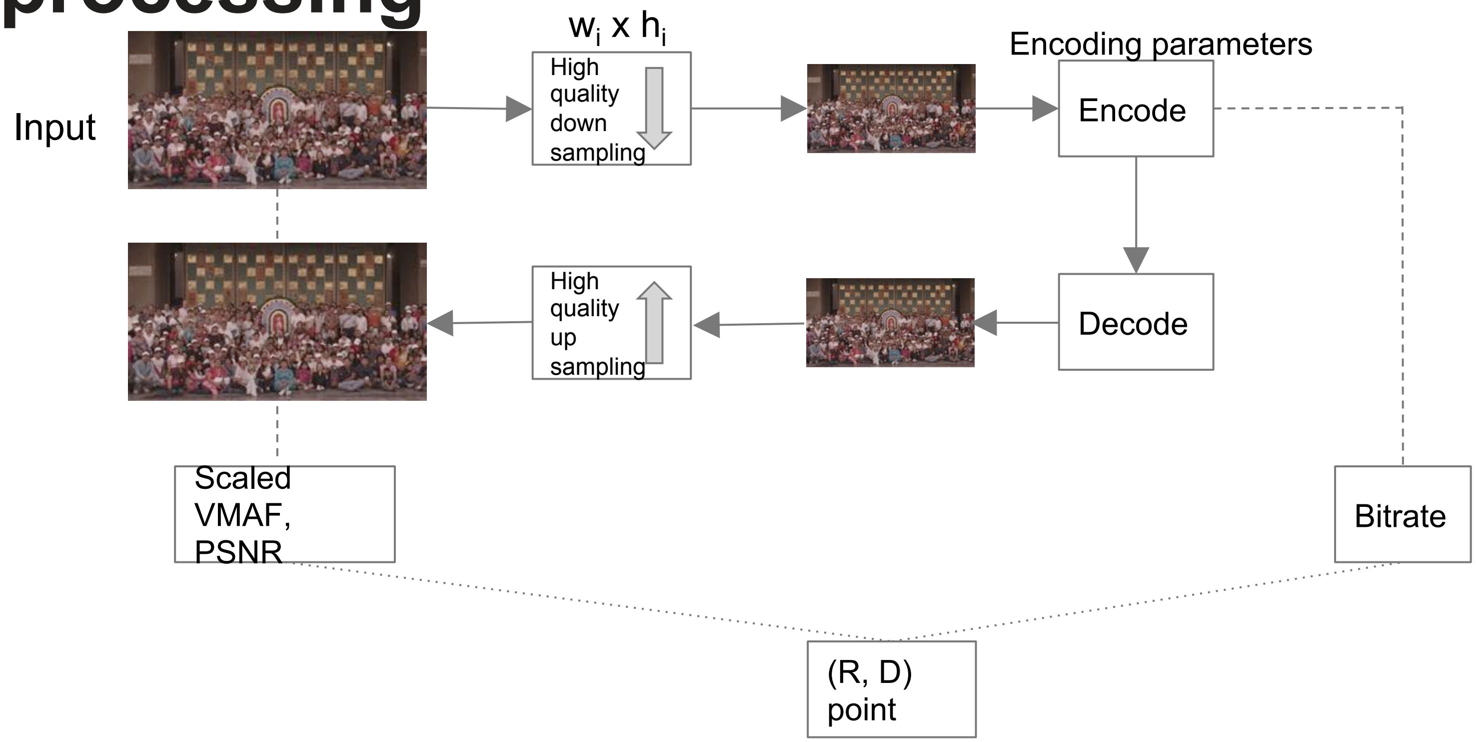
***Visual Information Fidelity -** H. Sheikh and A. Bovik, “Image Information and Visual Quality”.

****Detail Loss Measure -** S. Li, F. Zhang, L. Ma, and K. Ngan, “Image Quality Assessment by Separately Evaluating Detail Losses and Additive Impairments”.

How VMAF works



Dynamic Optimizer framework: Single shot processing



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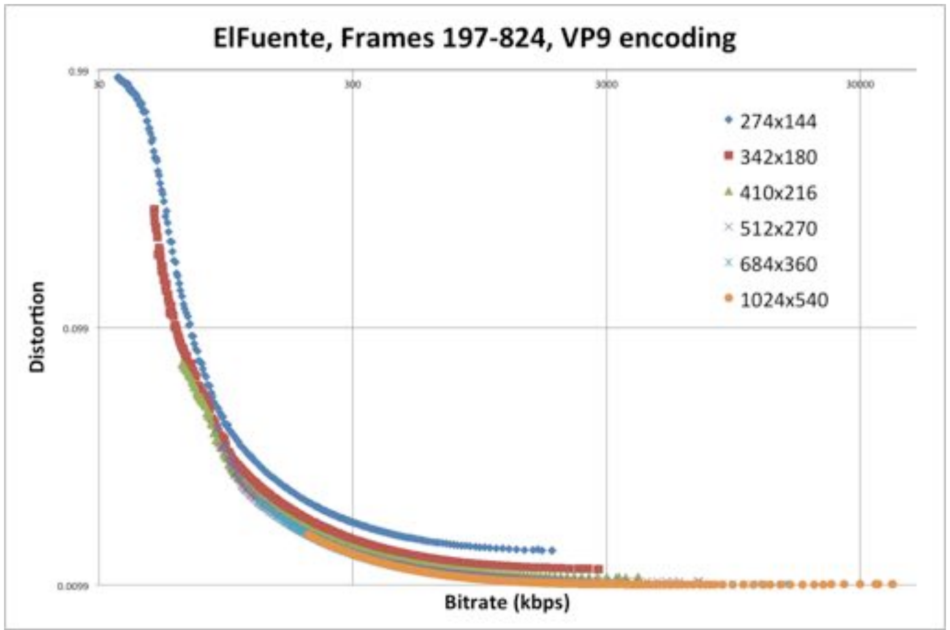
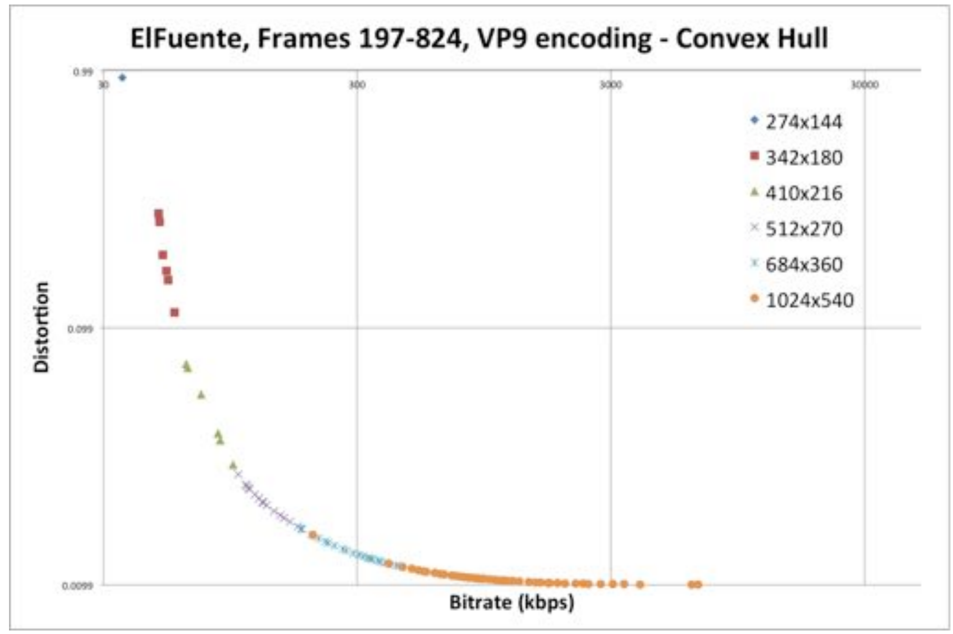
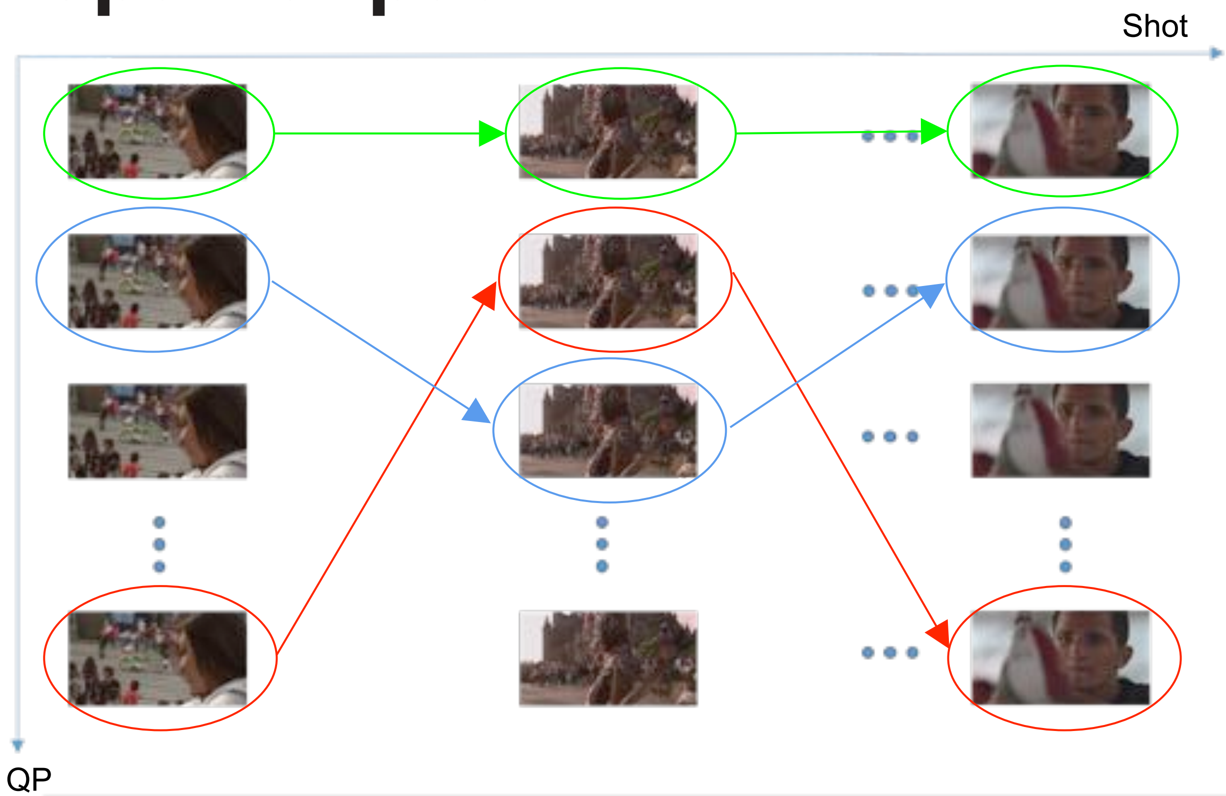
Dynamic Optimizer framework: Convex hull of optimal shot encodes





Dynamic Optimizer framework: Trellis optimal path

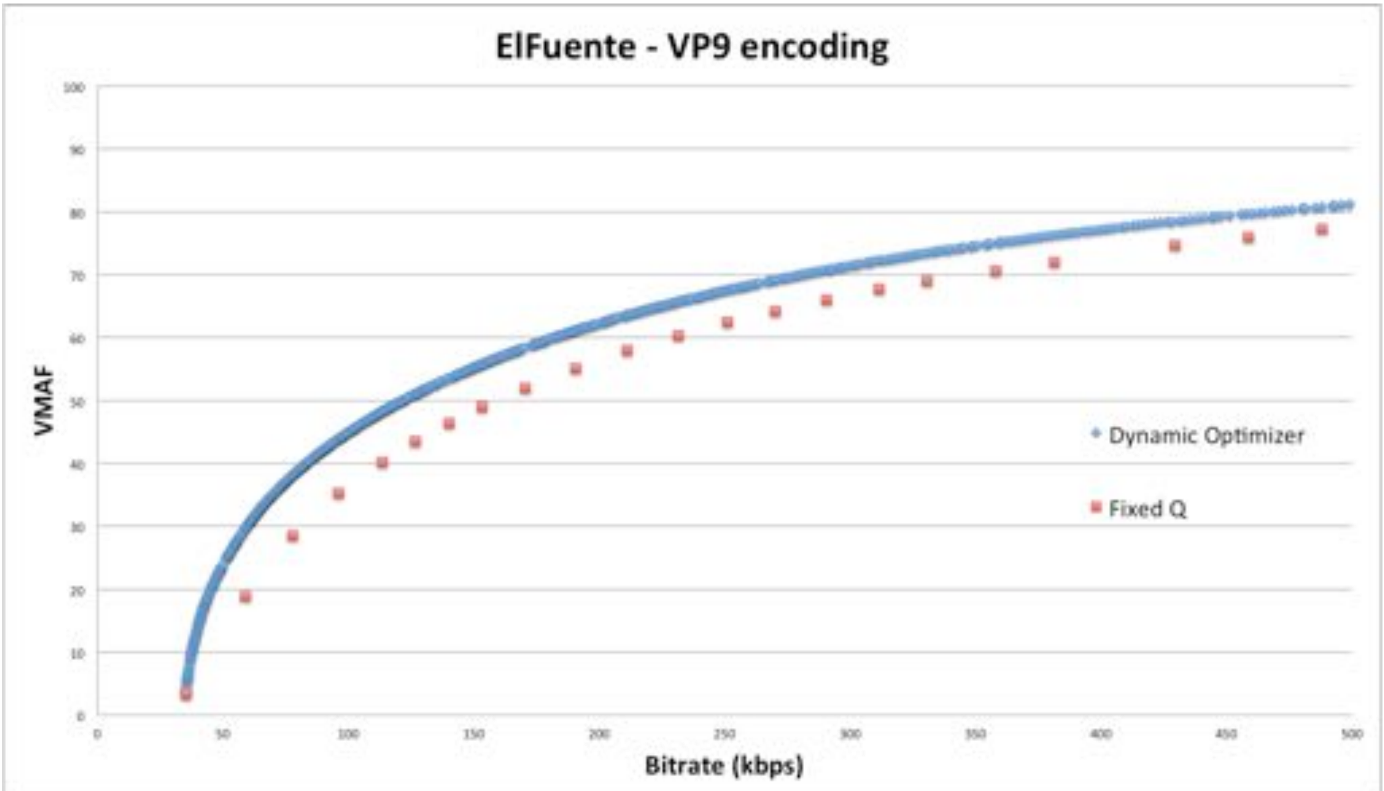


Fixed QP encode

Highest (average) quality encode, with bitrate x kbps

Lowest (average) bitrate encode, with quality y

Results: DO VP9 vs. Per-Title Optimal QP



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Video encoders used

- X264: open-source practical AVC encoder
- x265: open-source practical HEVC encoder
- EVE-VP9: practical VP9 encoder
- All in dual-tuning configuration

settings	x264	x265	EVE-VP9
profile	high	main	profile 0
preset	placebo	placebo	speed 1
number of titles	n/a	1	1
multi-threading	off	off	off
pass	1	1	1
PSNR-tuning	psy-rd=0	psy-rd=0 psy-rdoq=0	tune=psnr
perceptual-tuning	psy-rd=1.00	psy-rd=1.00 psy-rdoq=1.00	tune=visual

Quality metrics used

- TPSNR:

$$PSNR_{true} = 10\log_{10}(\frac{1}{N}\sum_{n=0}^{N-1}10^{-PSNRY_n} + 0.25\frac{1}{N}\sum_{n=0}^{N-1}10^{-PSNRCb_n} + 0.25\frac{1}{N}\sum_{n=0}^{N-1}10^{-PSNRCr_n})$$

- CPSNR:

$$PSNR_{classic} = \frac{1}{N}\sum_{n=0}^{N-1}PSNRY_n$$

- LVMAF:

$$VMAF_{linear} = \frac{1}{N}\sum_{n=0}^{N-1}VMAF_n$$

- HVMAF:

$$VMAF_{harmonic} = \frac{N}{\sum_{n=0}^{N-1}\frac{1}{1+VMAF_n}} - 1$$

Proposed codec testing methodology

- Use multiple encoding resolutions and QP values for each video sequence
- Use scaled metrics (PSNR, VMAF, ??) to construct R-D convex hull for each shot in a sequence
- Use dynamic optimizer to determine optimal encoding parameters for long sequences
- Use points equally spaced on the quality axis to calculate BD-rate
- Break down quality in ranges, when cross-over of R-D curves among different encoder configurations is observed


Breaking
Bad


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ORANGE
is the new BLACK


NETFLIX
HOUSE
of CARDS


MARVELS
AVENGERS

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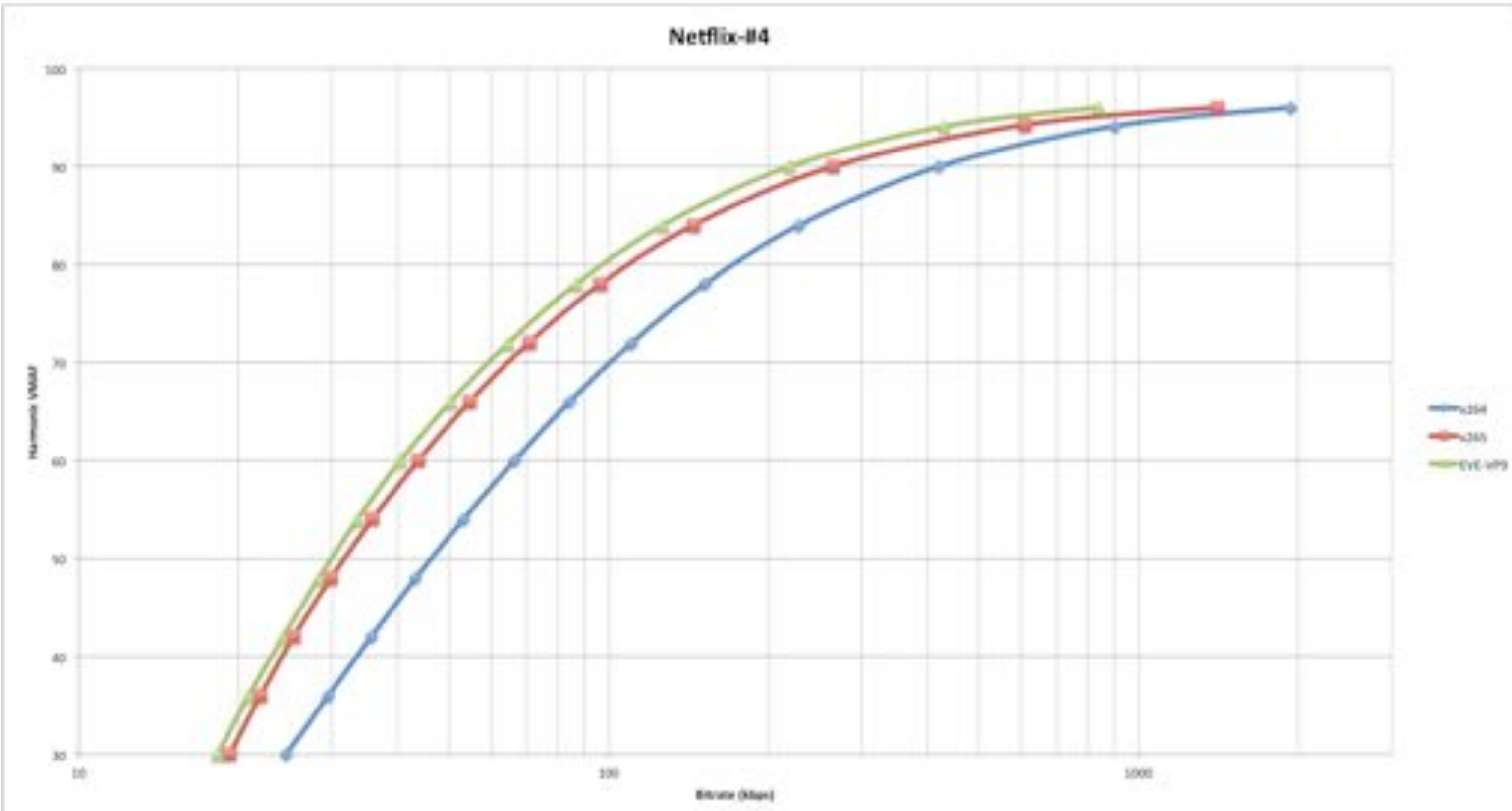
NETFLIX
BLOODLINE


NETFLIX
WET HOT
AMERICAN SUMMER
FIRST DAY OF CAMP

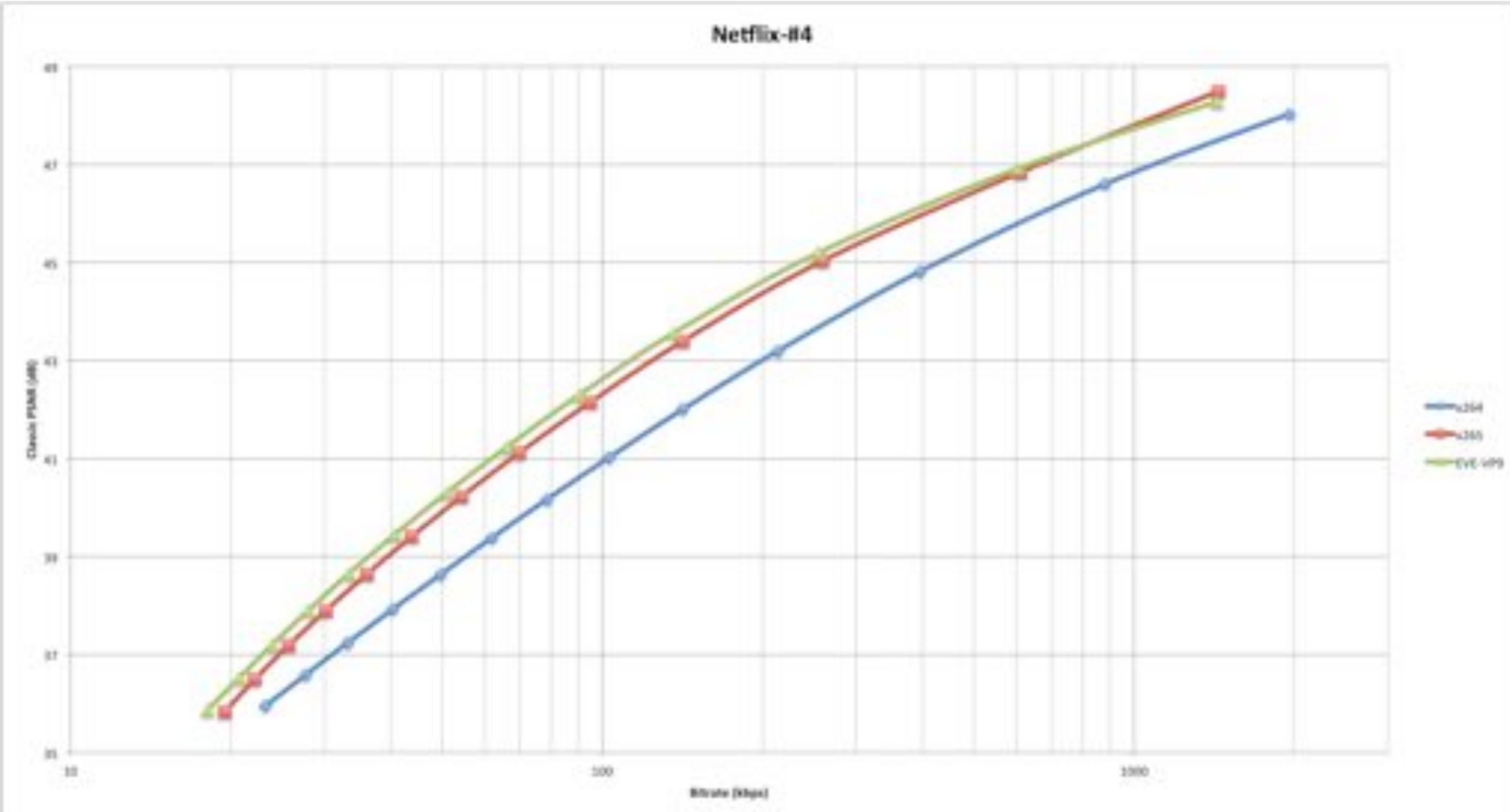

NETFLIX
MARVEL
DAREDEVIL


NETFLIX
BOJACK
HORSEMAN
HOLLYWOO

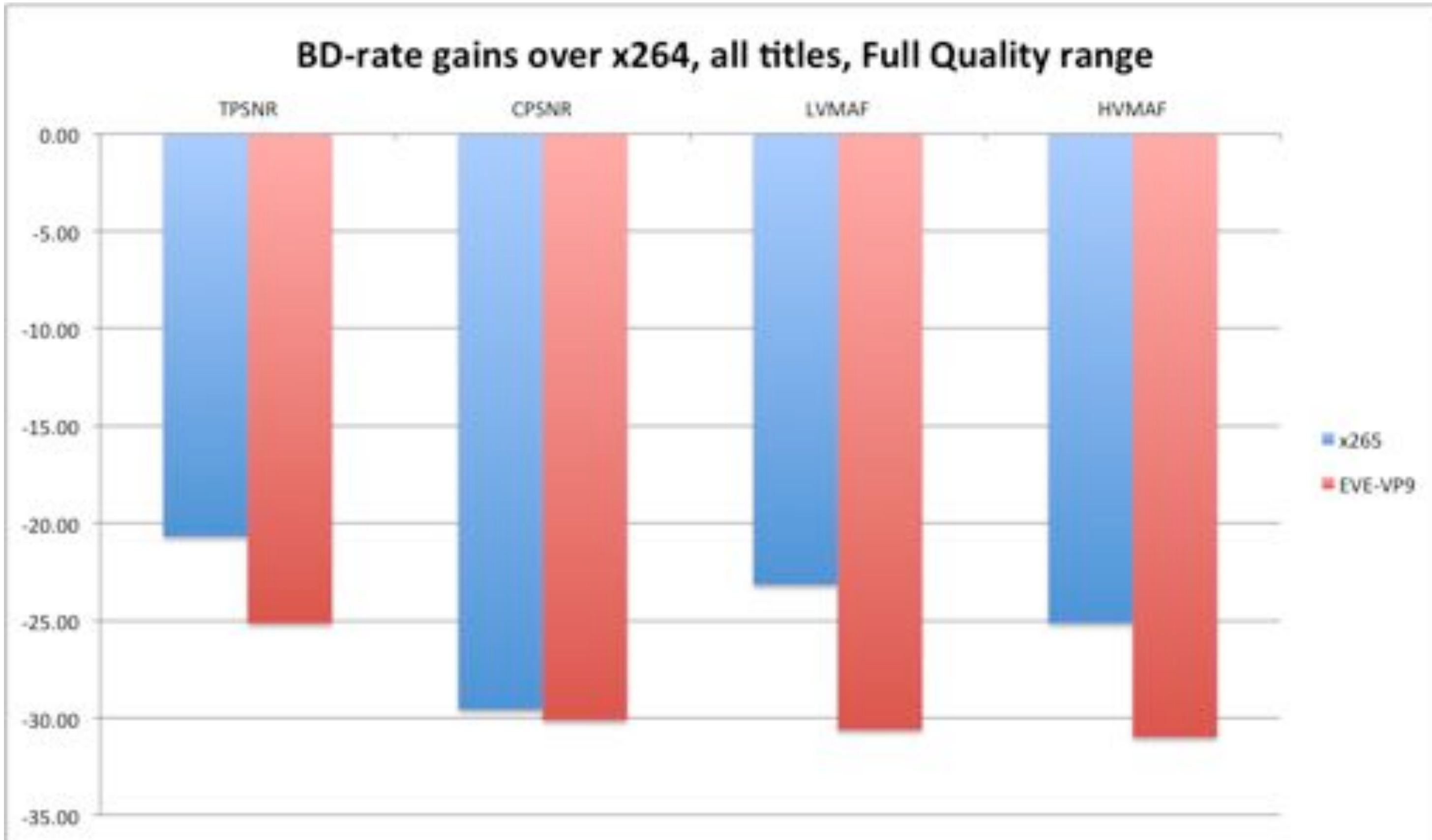
Results - 1



Results - 2



Results - 3



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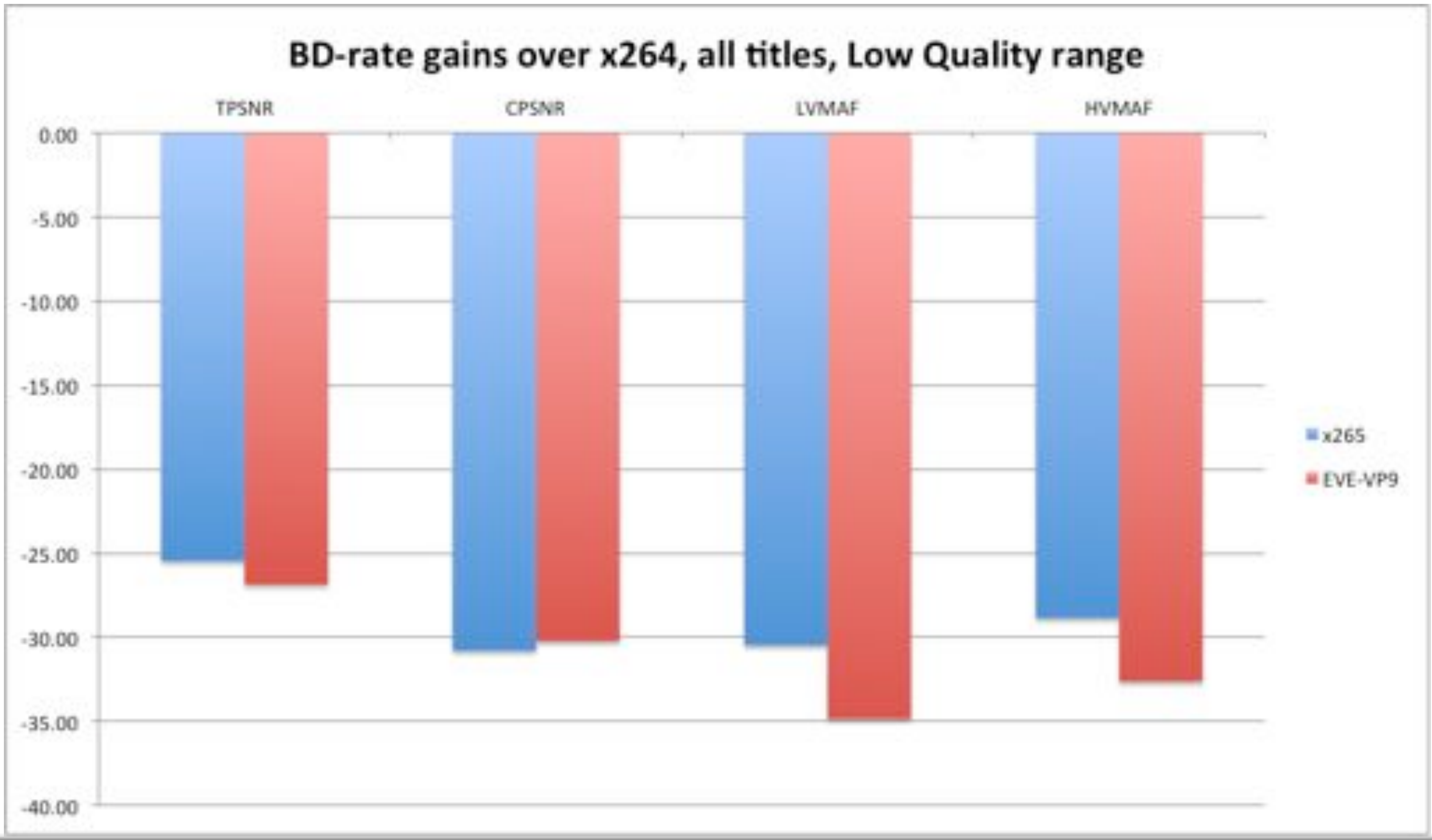
Results - 4



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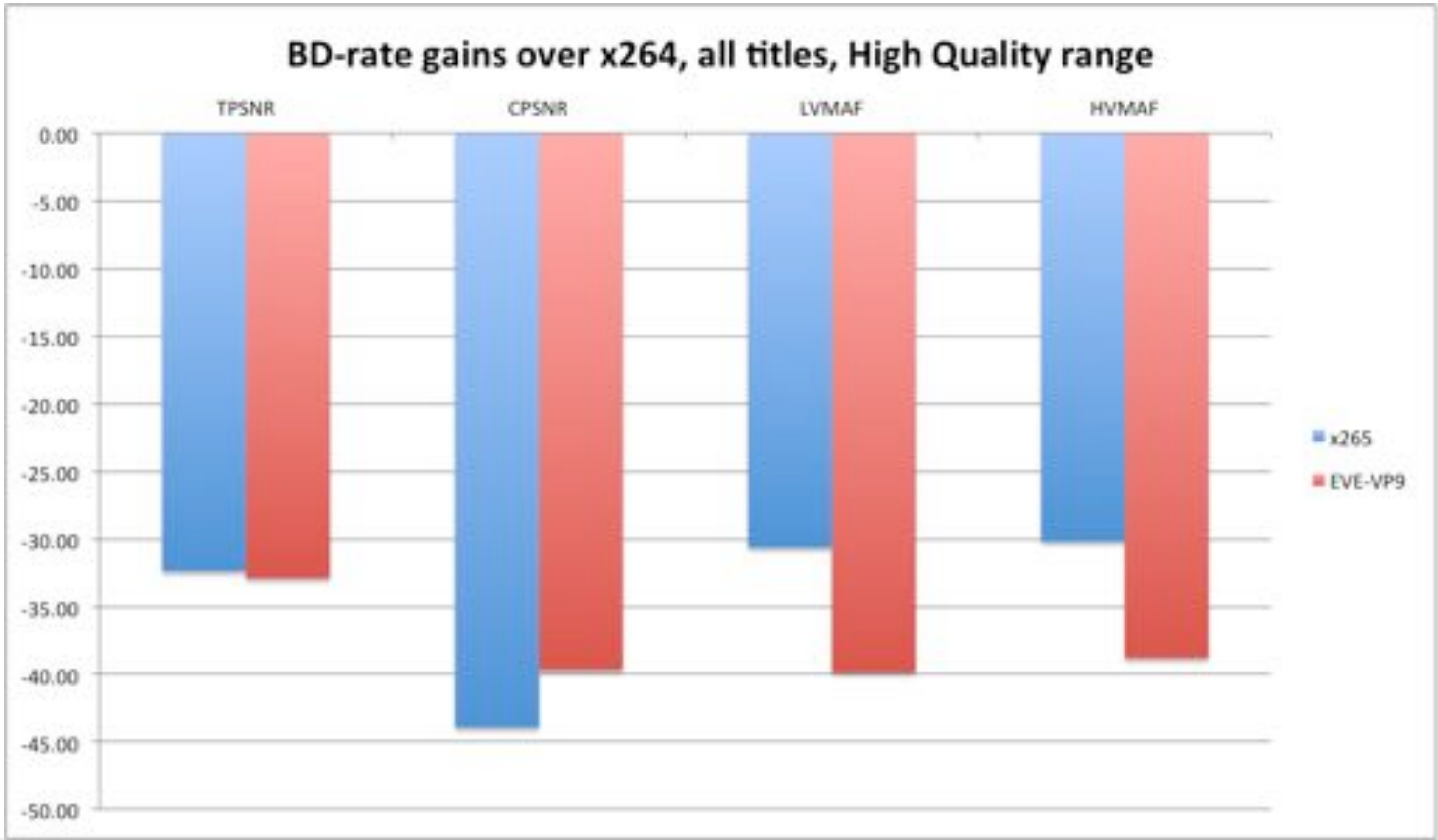
Results - 5



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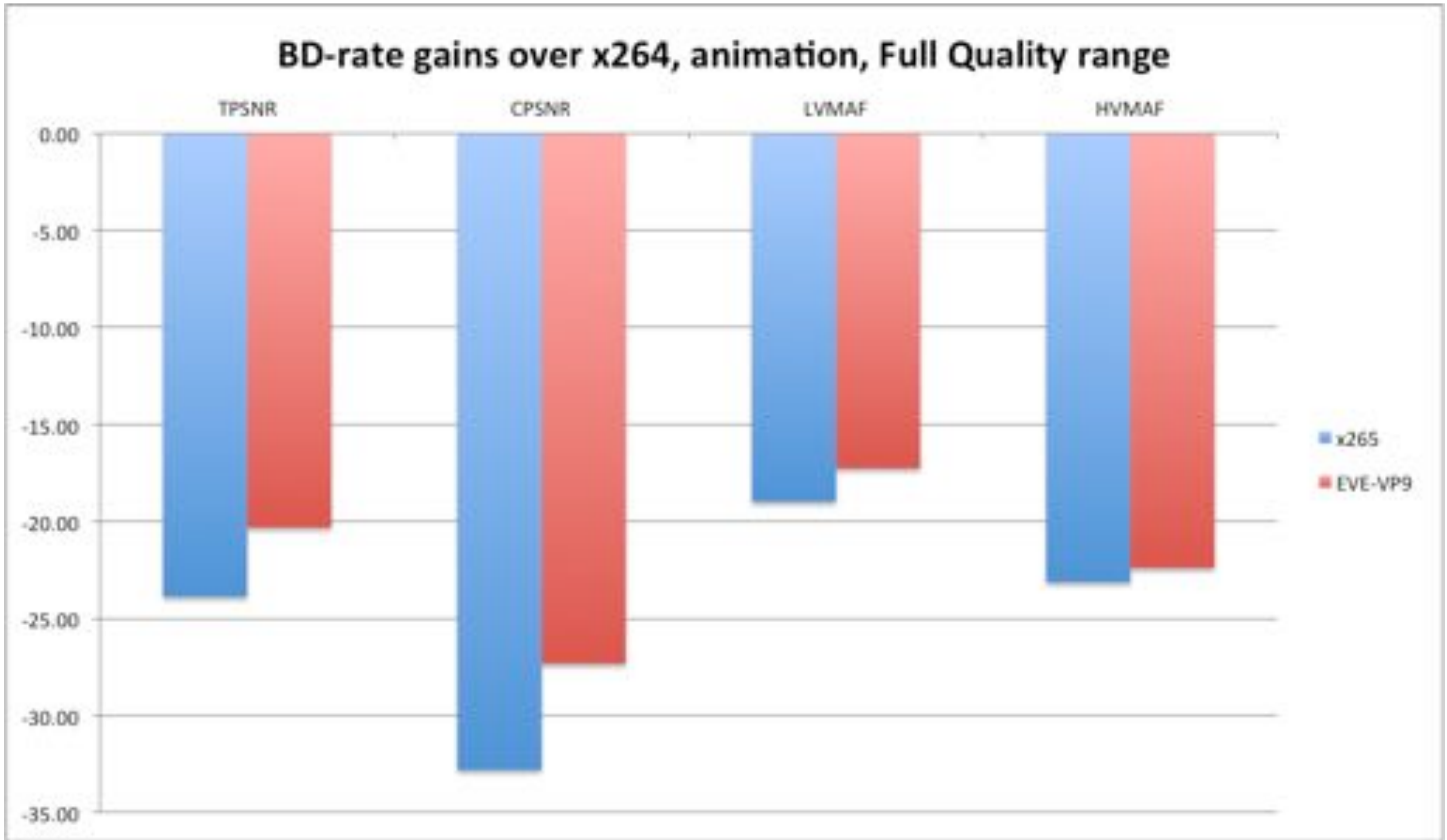
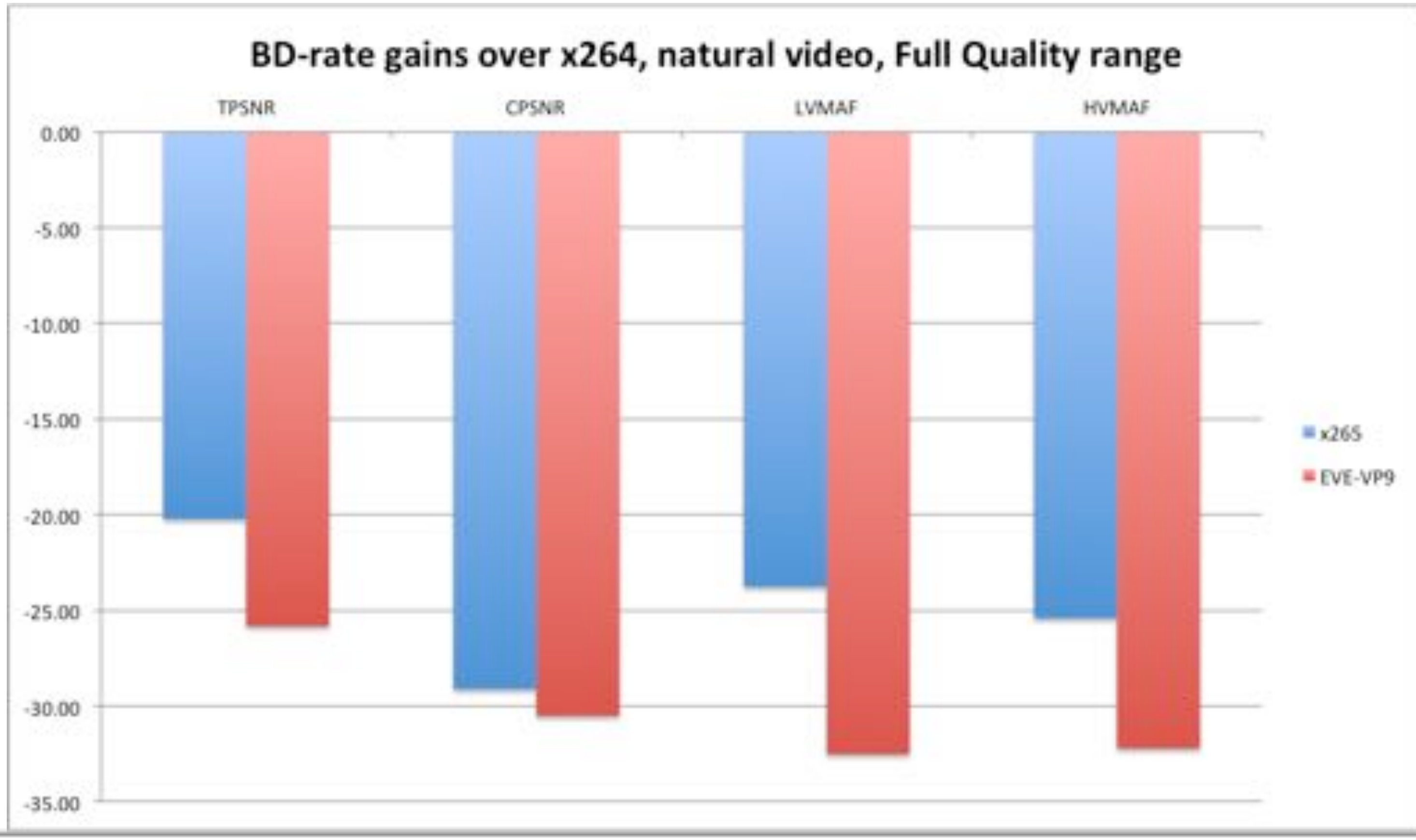
Results - 6


BD-rate gains over x264, animation, Full Quality range
TPSNR
CPSNR
LVMAF
HVMAF
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
x265
EVE-VP9

Results - 7



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A few facts

- x265 is about 20x slower than x264; EVE-VP9 is about 5x slower
- Test sequences represent about 8 hours of visual content
- Running these experiments took about 3 weeks to conclude
- 10M encodes produces
- 1M CPU hours – using cloud compute resources

Summary

- Scaled objective metrics better reflect adaptive streaming application video quality – VMAF more so than PSNR
- Using convex hull provides relevant QP ranges for each encoding resolution
- Dynamic optimizer offers an upper bound on RD-performance for long sequences
- DO allows for more fair comparison between codecs
- EVE-VP9 outperforms x265 for natural video sequences
- x265 outperforms EVE-VP9 for animation titles, mostly in low quality range

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