On VMAF's Property in the Presence of Image Enhancement Operations

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Outline

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  - VMAF in codec evaluation
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  - Correlation on compression/scaling public datasets
  - VMAF monotonicity with quantization
  - VMAF vs. VMAF NEG

VMAF and image enhancement

- The origin of VMAF
  - Video quality of professionally generated movies and TV shows
  - Adaptive streaming
    - Compression artifacts
    - Scaling artifacts
- Emerging new use cases
  - UGC, Gaming, VR
  - Quite common to include image enhancements
    - Sharpening
    - Contrasting
    - Histogram equalization
    - ...
- VMAF-driven video enhancement and encoding
  - MSU paper
  - libaom tune=vmaf mode

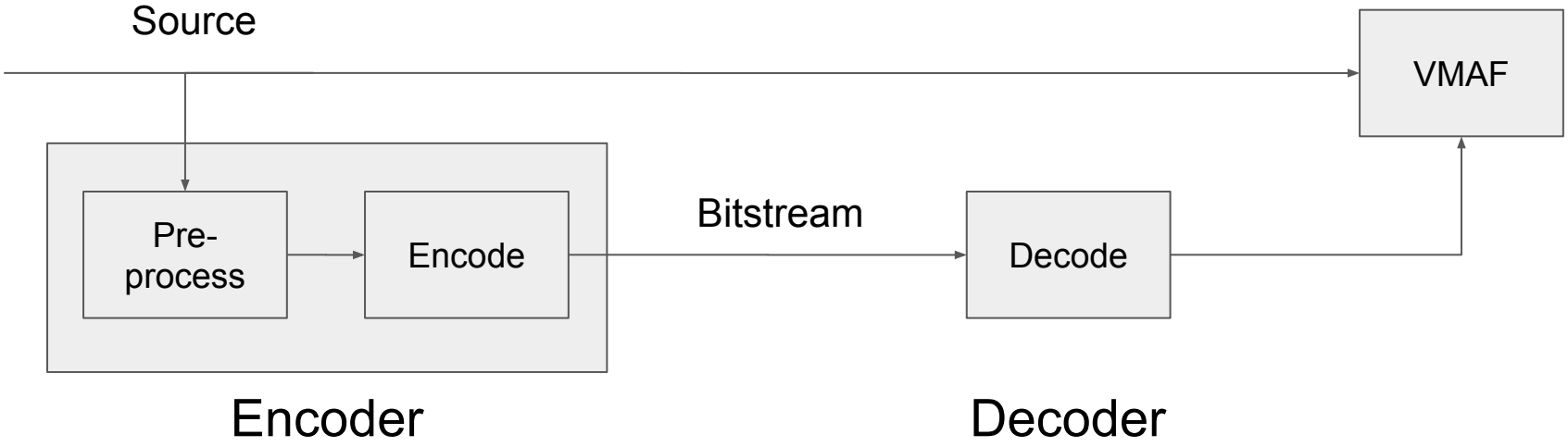
Original
VMAF 97.4277

Sharpening
VMAF 111.9868*

Histogram Equalization
VMAF 144.0195*

*By default, VMAF score is clipped between [0, 100] in the last step.
Here the clipping is disabled using the option `disable_clip`.

VMAF in codec evaluation



- Desirable to measure gain from compression without measuring pre-processing
- Difficult to strictly separate encoder from pre-processing steps
  - Especially for proprietary encoders
- It may become difficult to use VMAF to assess pure compression gain

Vasileios

April 3, 2020 at 10:37 pm

"The video looks better, sure, but you could have/should have achieved the same impact by optimizing contrast before encoding."

Doesn't this realization contradict the claim that VMAF can be hacked. VMAF measures perceptual quality which cannot be assessed by SSIM, so it's not necessary to observe the same trends between the two metrics. An experiment that you could do in your article would be to conduct some crowd sourced MOS survey (e.g. through Amazon Turk) to illuminate whether VMAF increases in line with MOS for those videos. If VMAF aligns with MOS but SSIM doesn't it means that it's not hacking, or at least it means that human perception of visual quality is hackable which is something that video encoding should use.

Jan Ozer

April 7, 2020 at 1:38 pm

Good point, and understood, and that's why I gauged BitSave as a valid technology. However, as I showed with the table, there are times where increasing contrast darkens the video and makes it look noticeably worse, though the VMAF score is improved.

And yes, subjective observations are the gold standard which is why I say in my Streaming Media article, "After many hours of testing, I found that BitSave's technology is valid and valuable, though the proof of the pudding will be how it performs in subjective testing with your test clips. Subjective evaluations of the BitSave clips would have been great, but was outside the time and expense budget for the review.

https://streaminglearningcenter.com/blogs/vmaf-is-hackable-what-now.html

First ever VMAF meme

NO!!!!!!!!!!!!!! YOU
CAN'T JUST SHARPEN THE
INPUT FILE TO BOOST VMAF SCORES

haha
tune=vmaf go brrr

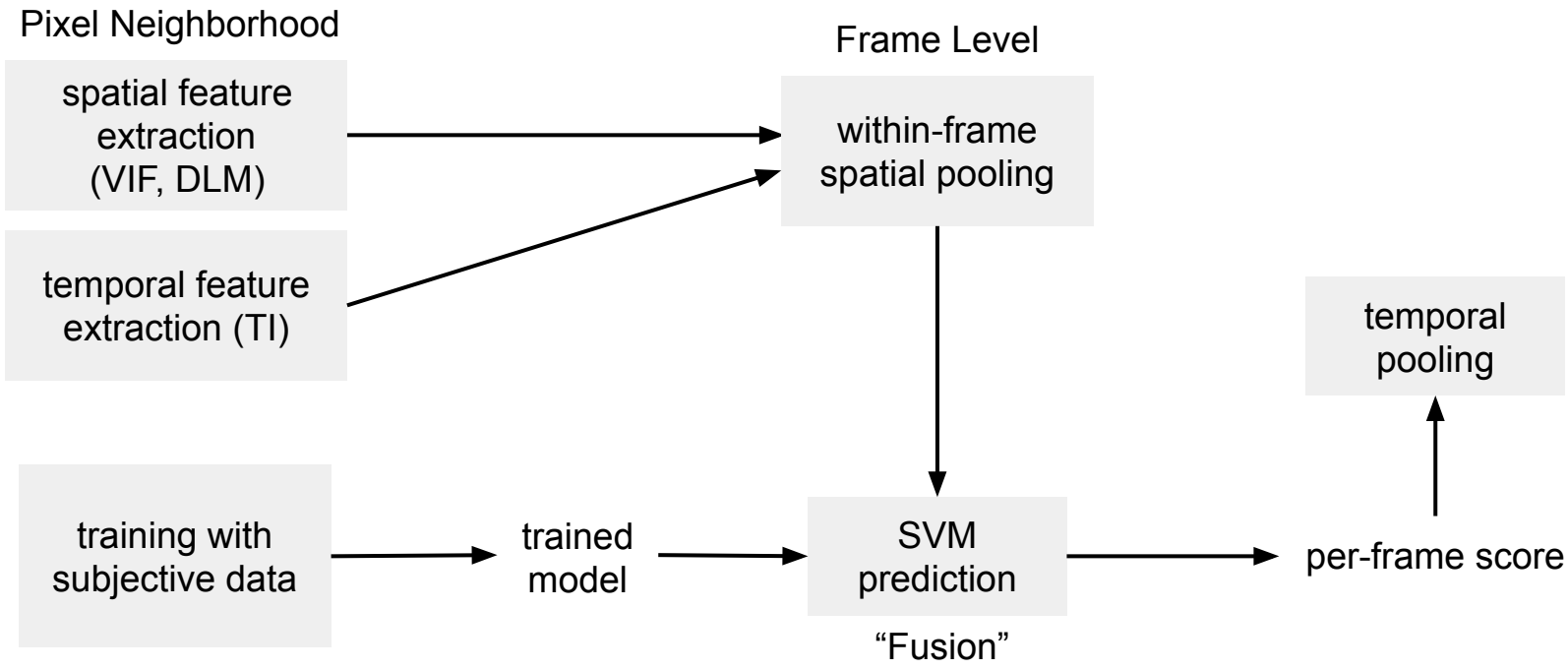
https://www.reddit.com/r/AV1/comments/g19ary/more_vmaf_more_better

Our position

- There is value for VMAF to disregard image enhancement gain that is not part of the codec
- There is also value for VMAF to preserve the measure of image enhancement gain to reflect quality perceived by end users
- Solution
  - Introduce knobs in VMAF to control the measured enhancement gain
  - Currently, two models:
    - Default model
    - NEG (“No Enhancement Gain”) model
- Recommendation
  - Use **NEG** model for codec evaluation
  - Use **default** model to assess compression and enhancement combined
    - In future versions, we will address overprediction issue related to overusing (abusing) of image enhancement operations

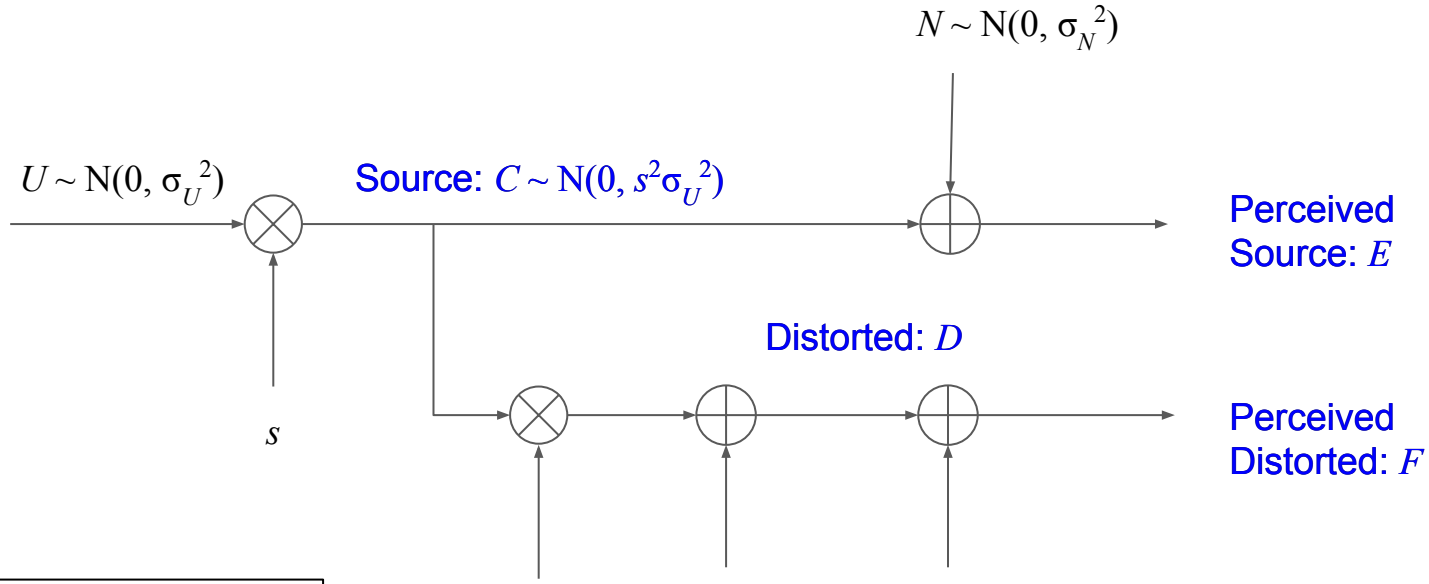
Foundations

VMAF framework



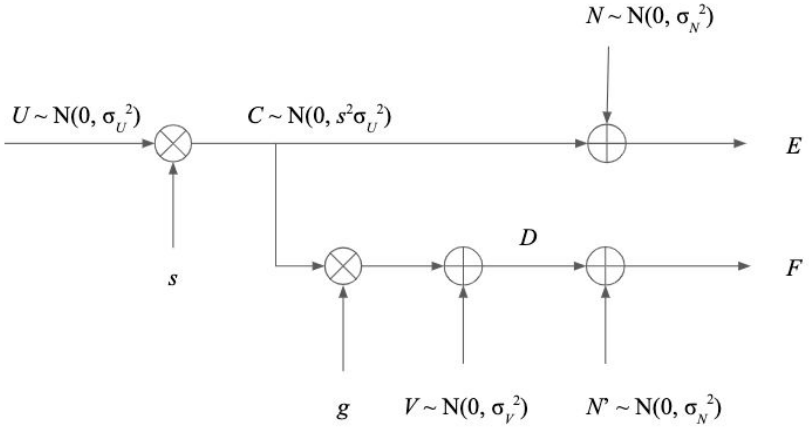
*VMAF stands for Video Multi-method Assessment Fusion

Visual Information Fidelity (VIF)



$$g = \sigma_{CD}/\sigma_C^2$$
$$\sigma_V^2 = \sigma_D^2 - g \cdot \sigma_{CD}$$

Visual Information Fidelity (VIF) - Cont'd



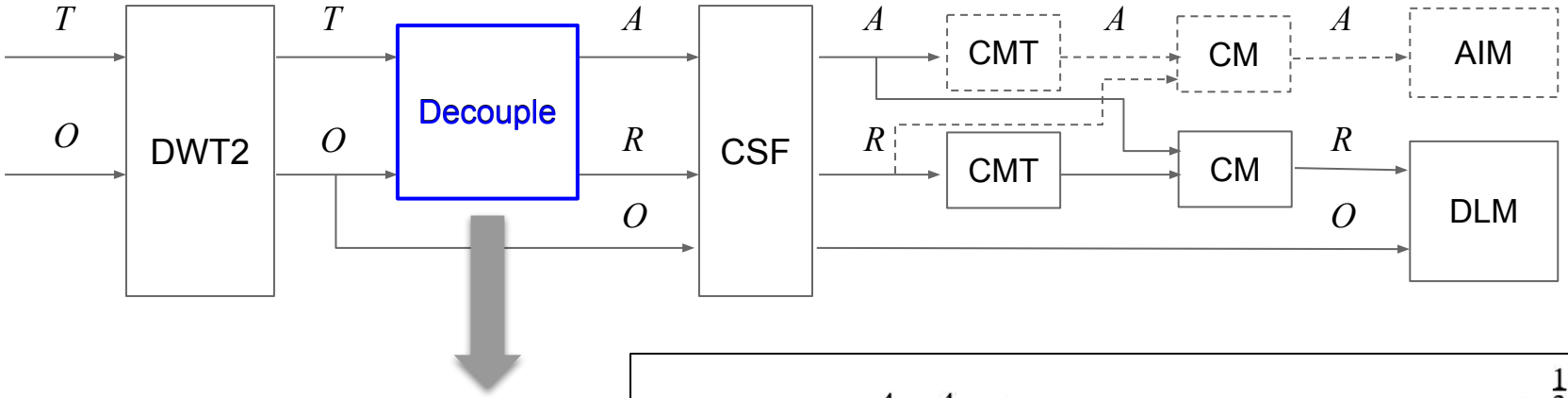
$$VIF_\lambda = \frac{\sum_{i=1}^{N} \log_2\left(1+\frac{g_i^2 s_i^2 \sigma_u^2}{\sigma_{v_i}^2+\sigma_N^2}\right)}{\sum_{i=1}^{N} \log_2\left(1+\frac{s_i^2 \sigma_u^2}{\sigma_N^2}\right)}$$

$$g = \sigma_{CD}/\sigma_C^2$$
$$\sigma_V^2 = \sigma_D^2 - g \cdot \sigma_{CD}$$

i: pixel position; λ: scale (1, 2, 3, 4)

Detail Loss Measure (DLM)

Wavelet coefficients:
O: original (source)
T: target (distorted)
R: restored
A: additive



$$R = clip_{[0,1]}\left(\frac{T}{O}\right) \cdot O$$

$$R = T, \text{ if } |\psi_O - \psi_T| < 1^\circ$$

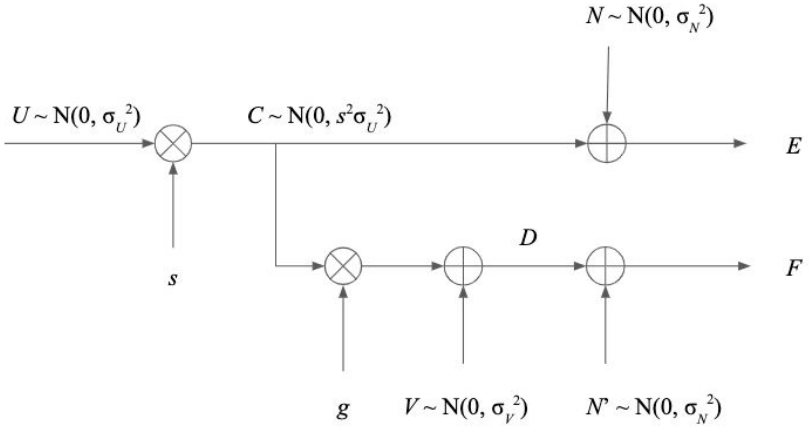
ψ: arctan of coefficients collocated in the vertical and horizontal bands

$$DLM = \frac{\sum_{\lambda\in1}^{4}\sum_{\theta=2}^{4}\left(\sum_{i,j\in center} CM(CSF(R(\lambda,\theta,i,j)))^3\right)^{\frac{1}{3}}}{\sum_{\lambda\in1}^{4}\sum_{\theta=2}^{4}\left(\sum_{i,j\in center} CM(CSF(O(\lambda,\theta,i,j)))^3\right)^{\frac{1}{3}}}$$

i, j: pixel position; λ: scale (1, 2, 3, 4); θ subbands (1, 2, 3, 4)

Proposed Modifications

Visual Information Fidelity (VIF) - Cont'd



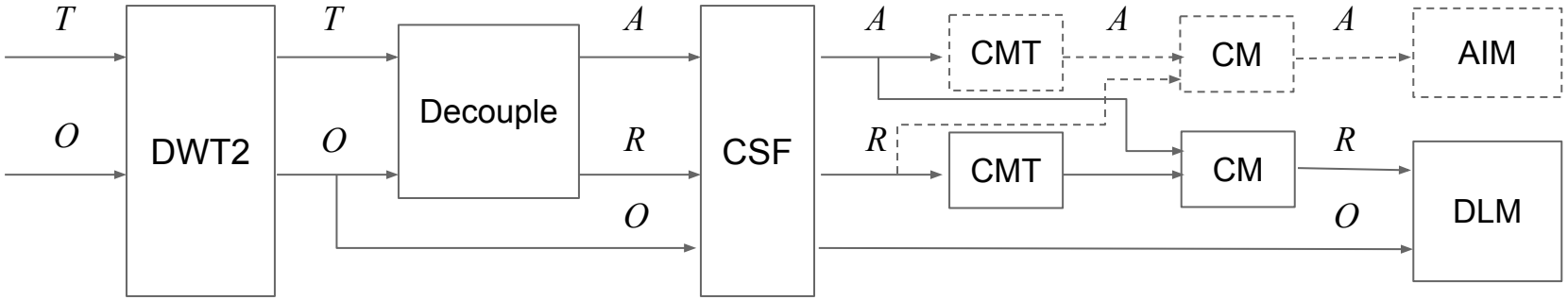
$$g_i = \min(g_i, EGL_{VIF}), \text{ where } EGL_{VIF} \geq 1.0$$

$$VIF_\lambda = \frac{\sum_{i=1}^{N} \log_2\left(1+\frac{g_i^2 s_i^2 \sigma_u^2}{\sigma v_i^2+\sigma_N^2}\right)}{\sum_{i=1}^{N} \log_2\left(1+\frac{s_i^2 \sigma_u^2}{\sigma_N^2}\right)}$$

$$g = \sigma_{CD}/\sigma_C^2$$
$$\sigma_V^2 = \sigma_D^2 - g \cdot \sigma_{CD}$$

EGL_{VIF}: VIF enhancement gain limit

Detail Loss Measure (DLM)



$$R = clip_{[0,1]}\left(\frac{T}{O}\right) \cdot O$$

$$R = T, \text{ if } |\psi_O - \psi_T| < 1^{\circ}$$

R = min (R □ EGL_{DLM}, T), if | ψ_O - ψ_T| < 1° and R > 0;
R = max (R □ EGL_{DLM}, T), if | ψ_O - ψ_T| < 1° and R < 0,
where $EGL_{DLM} \geq 1.0$.

EGL_{DLM}: DLM enhancement gain limit

Summary of modifications

- Introduce two knobs
  - VIF enhancement gain limit $EGL_{VIF} \geq 1.0$
  - DLM enhancement gain limit $EGL_{DLM} \geq 1.0$
- For default model
  - Set both limits to a large value (example: 100.0)
- For NEG (“No Enhancement Gain”) model
  - Set both limits to 1.0
- Future work
  - Future models will provide standard values for these limits

Results

Pure image enhancement operations

Original
VMAF 97.4277
VMAF NEG 97.4280

Sharpening
VMAF 111.9868*
VMAF NEG 85.3330

Histogram Equalization
VMAF 144.0195*
VMAF NEG 78.7122

*By default, VMAF score is clipped between [0, 100] in the last step.
Here the clipping is disabled using the option `disable_clip`.

libaom encoding

Original
VMAF 97.4277
VMAF NEG 97.4280

libaom CQ 43
VMAF 95.1425
VMAF NEG 93.4151

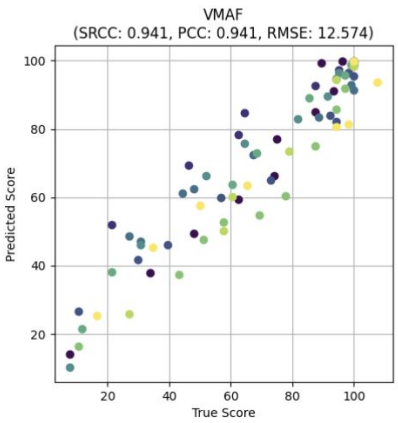
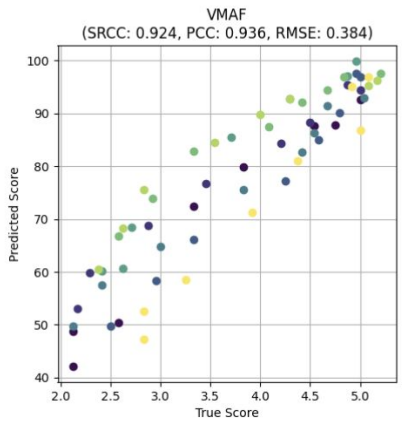
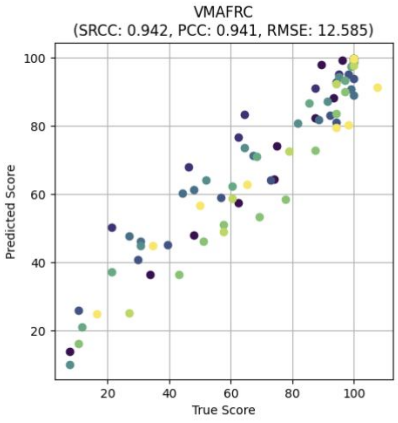
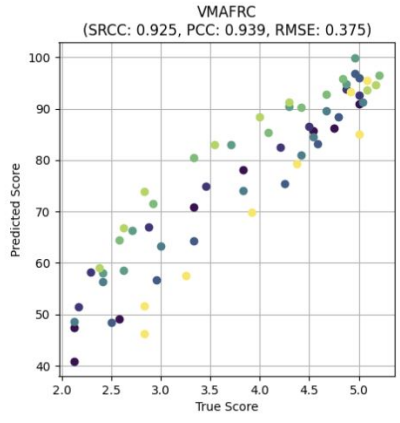
Libaom tune=vmaf CQ 43
VMAF 104.8277*
VMAF NEG 87.6951

*By default, VMAF score is clipped between [0, 100] in the last step.
Here the clipping is disabled using the option `disable_clip`.

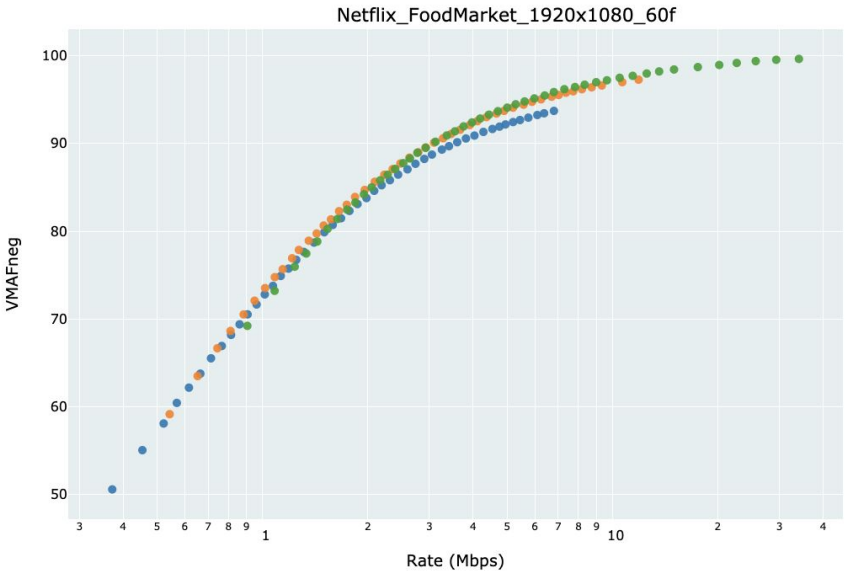
BD rate: libaom vs. libaom tune=vmaf 540p

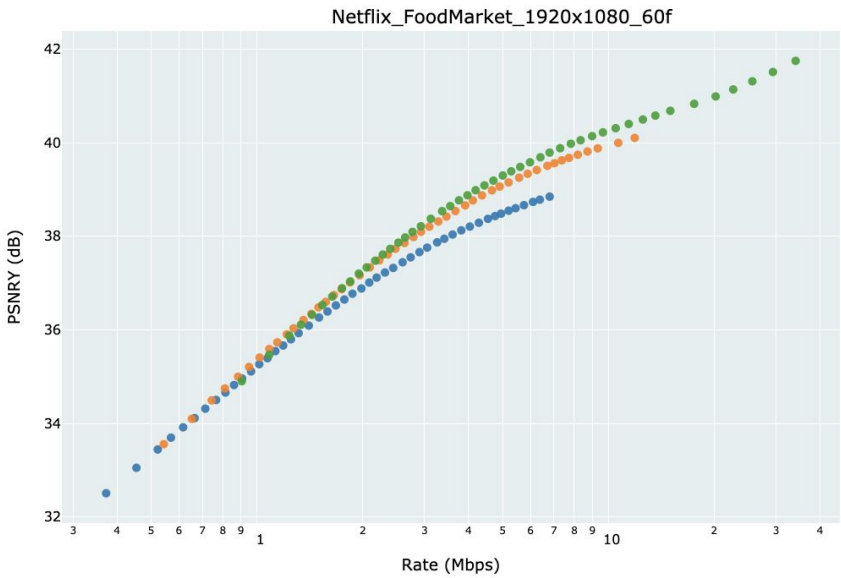
Sequence	CPSNRY	TPSNRYUV	VMAF	VMAF NEG	SSIM	MSSSIM
DOTA2_60f_420	746.605	452.357	-55.475	48.116	57.826	46.032
MINECRAFT_60f_420	76.24	77.044	-26.241	13.359	41.991	26.887
Netflix_Aerial_1920x1080_60fps_8	209.234	200.622	-38.326	55.3	85.949	40.925
Netflix_Boat_1920x1080_60fps_8bi	46.338	44.377	-13.049	21.354	33.888	12.438
Netflix_Crosswalk_1920x1080_60fp	44.529	43.662	-35.379	9.403	13.461	11.632
Netflix_FoodMarket_1920x1080_60f	155.067	147.682	-37.414	43.302	43.733	35.534
Netflix_PierSeaside_1920x1080_60	-	-	-61.555	203.436	248.369	140.171
Netflix_SquareAndTimelapse_1920x	71.071	69.108	-19.333	19.872	35.237	23.625
Netflix_TunnelFlag_1920x1080_60f	-	-	-18.212	108.605	88.316	77.793
STARCRAFT_60f_420	289.836	250.835	-53.268	55.257	78.509	48.717
aspen_1080p_60f	65.496	63.017	-31.592	12.528	18.869	16.457
ducks_take_off_1080p50_60f	-	1132.993	-44.217	55.551	145.881	97.535
life_1080p30_60f	667.974	462.457	-46.887	60.56	78.882	55.956
rush_hour_1080p25_60f	50.529	49.277	-40.064	0.177	12.795	13.188
touchdown_pass_1080p_60f	48.519	48.327	-22.572	15.544	25.821	16.755
wikipedia_420	91.43	77.198	-59.998	36.168	-	109.07

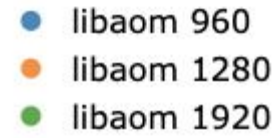
Prediction accuracy: correlation with public datasets (compression and scaling-only)

	NFLX Public	VQEG HD3
VMAF		
VMAF NEG		

VMAF (PSNR) vs. QP: Monotonicity



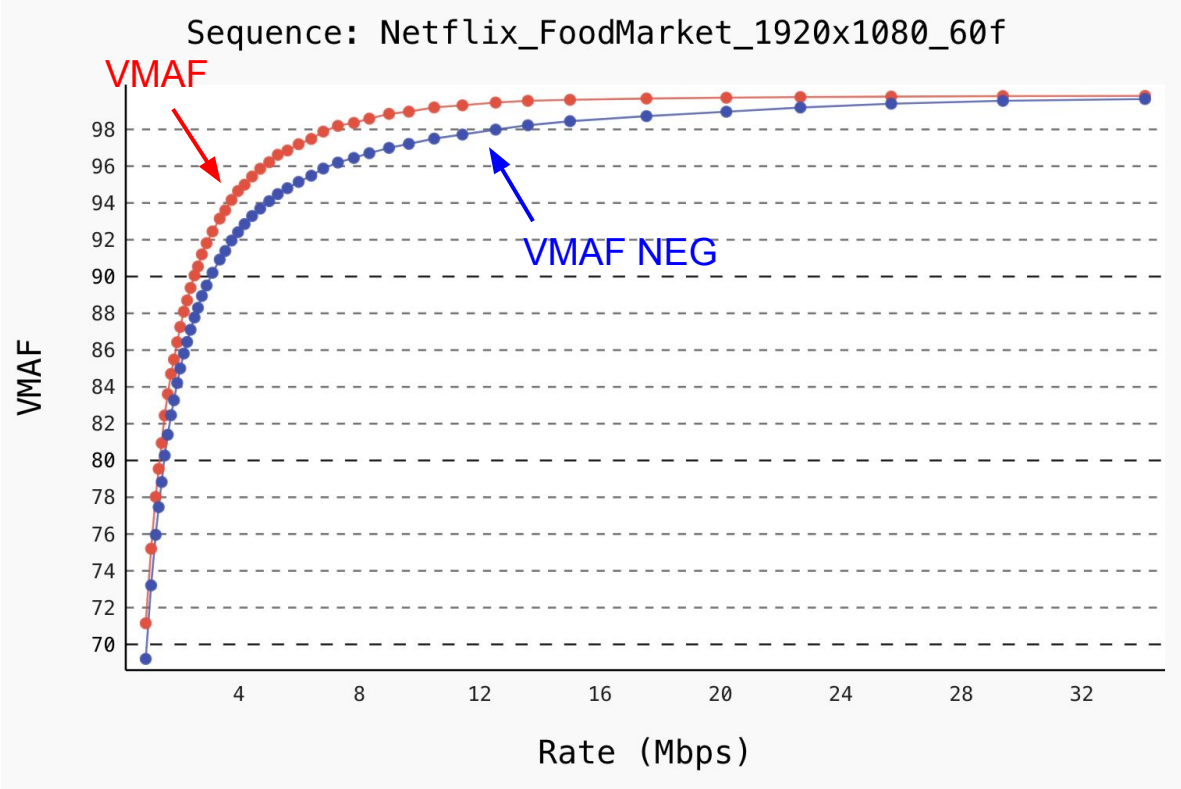




- VMAF (NEG) can capture small changes in quality with QP (or other coding parameters) just like PSNR

More data points at:
https://drive.google.com/drive/folders/1XwM1Vf0PYEvUF9sSMWRDg3Xa0P-aykim?usp=sharing

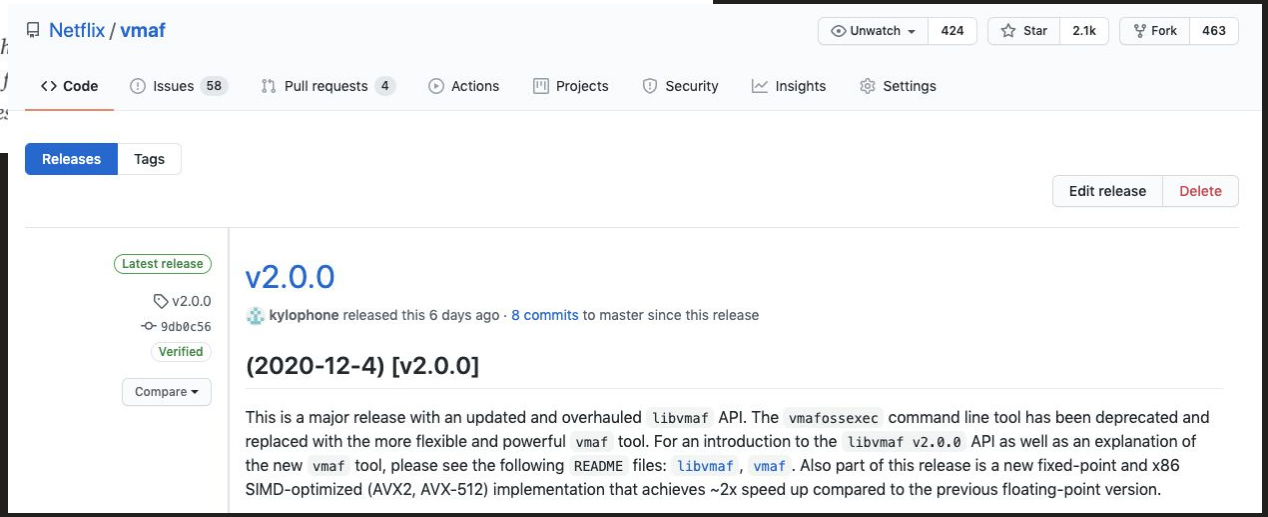
VMAF vs. VMAF NEG: 1080p



More data points at:
https://drive.google.com/drive/folders/1_xUKe8_Mn-HZjC7MPUGEgBSsPIhyq-kO?usp=sharing

Conclusions

- One unique feature of VMAF that differentiates it from PSNR and SSIM is that VMAF captures visual gain from image enhancements
- For codec evaluation, it is often desirable to evaluate the pure gain from compression
- Our recommendations
  - Use **NEG** model for codec evaluation
  - Use **default** model to assess compression and enhancement combined
- In future versions, we will address overprediction issue related to overusing (abusing) of image enhancement operations



Memo: https://tinyurl.com/y34mgafa
Tech Blog: https://netflixtechblog.com/toward-a-better-quality-metric-for-the-video-community-7ed94e752a30
libvmaf v2.0.0: https://github.com/Netflix/vmaf/releases/tag/v2.0.0

Backup Slides

utack 3 points · 4 months ago

Looks completely insane to me just how much better it fot at the 1mbit point.
How long did it take to encode all 15s? I am getting 1fpm at cpu-used 4

> MrSmilingWolf 4 points · 4 months ago
>
> It took 12.5h running all three VMAF encodes together.
>
> As a side note, `--tune=vmaf_with_preprocessing` takes 2.5h for the same encode and gives more or less comparable results, so that might be a better tradeoff.
>
> > utack 1 point · 4 months ago
> >
> > Thanks for letting me know

> AutoAltRef6 2 points · 4 months ago
>
> The speed levels are probably going to be pretty close to each other when using this tune. As far as I've been able to determine, the VMAF tune parts are entirely single-threaded and hugely bottleneck the encoder.
>
> > **shananalla88** 2 points · 4 months ago · *edited 4 months ago*
> >
> > Purely from a visual perspective, the 500k Tears of Steel vmaf-tune clip looks only slightly worse (IMO) that the 1000k psnr-tune clip.
> >
> > This is more evidence that the quality-improvements/bit-rate savings mentioned in the commit message are quite big (30-40% at least). I hope they speed this mode up soon so it can be used for practical encodes, and not just testing.

https://www.reddit.com/r/AV1/comments/f0g3yx/libaom_adds_vmaf_tune/

Enhancement gain visualization

(a) Original
VMAF 97.42 VMAF NEG 97.42

(b) Sharpening
VMAF 100 VMAF NEG 85.33

(c) Histogram Equalization
VMAF 100 VMAF NEG 78.71

(d) libaom CQ 43
VMAF 95.14 VMAF NEG 93.41

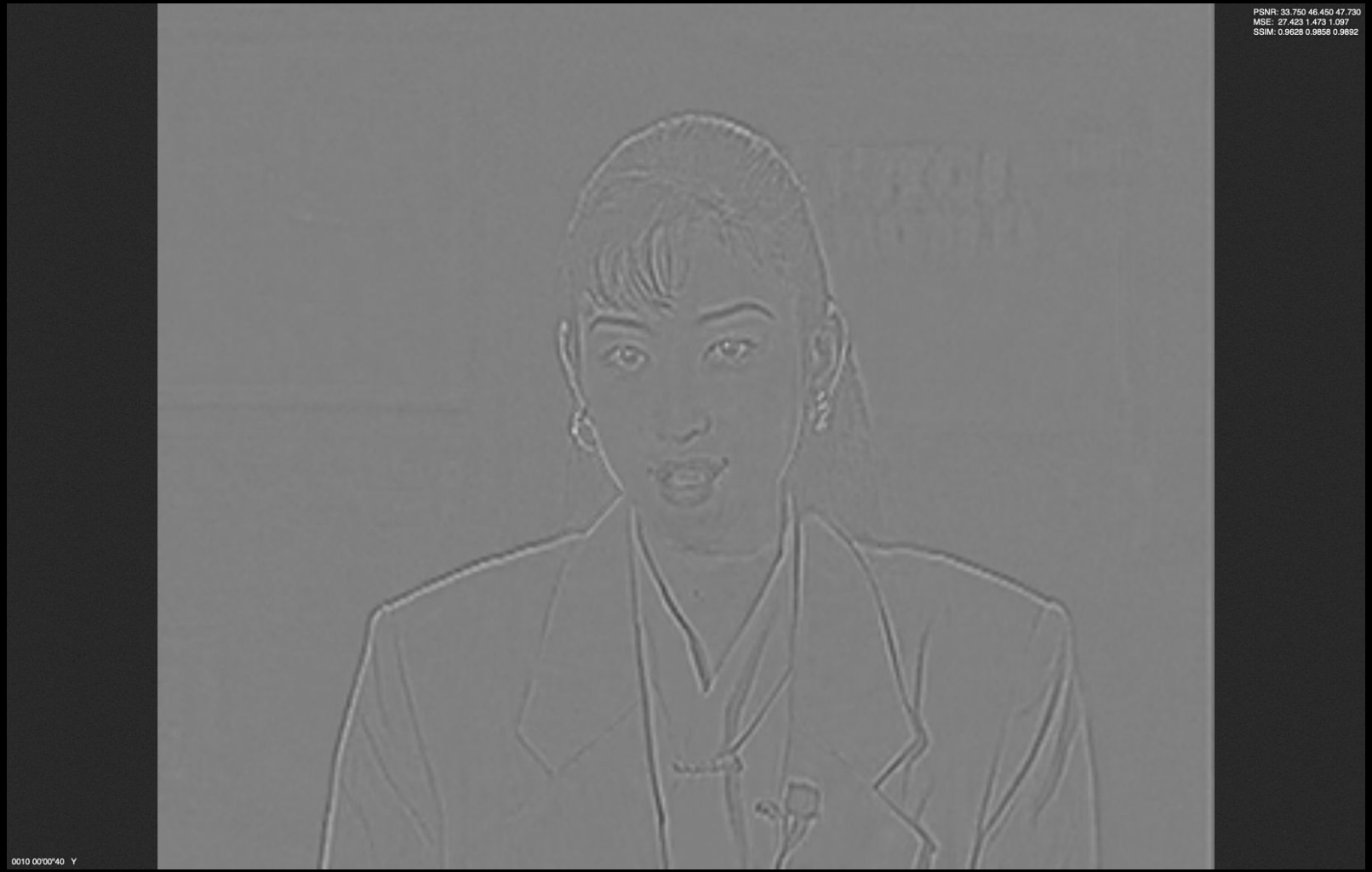
(e) libaom CQ 43 tune=vmaf
VMAF 100 VMAF NEG 87.69

(f) libaom CQ 43 tune=vmaf
Enhancement Gain Visualization

Analyzing libaom tune=vmafneg mode

source

tune=vmaf, qp43



diff (source, tune=vmaf, qp43)

Frame value:
PSNR 44.14
VMAF 95.35
VMAF NEG 93.03

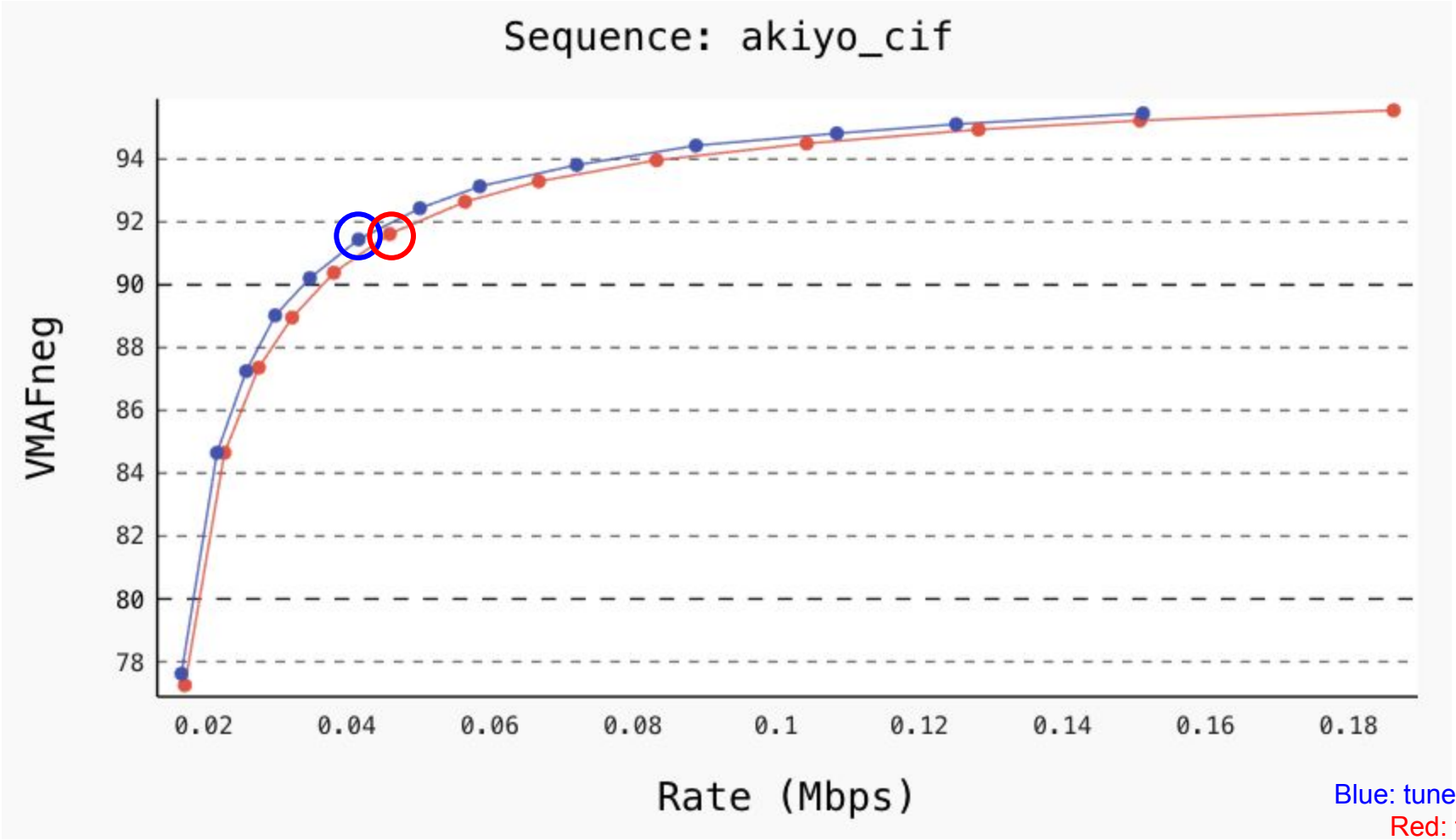
300 frames:
41.64 Kbps

tune=vmafneg, qp43

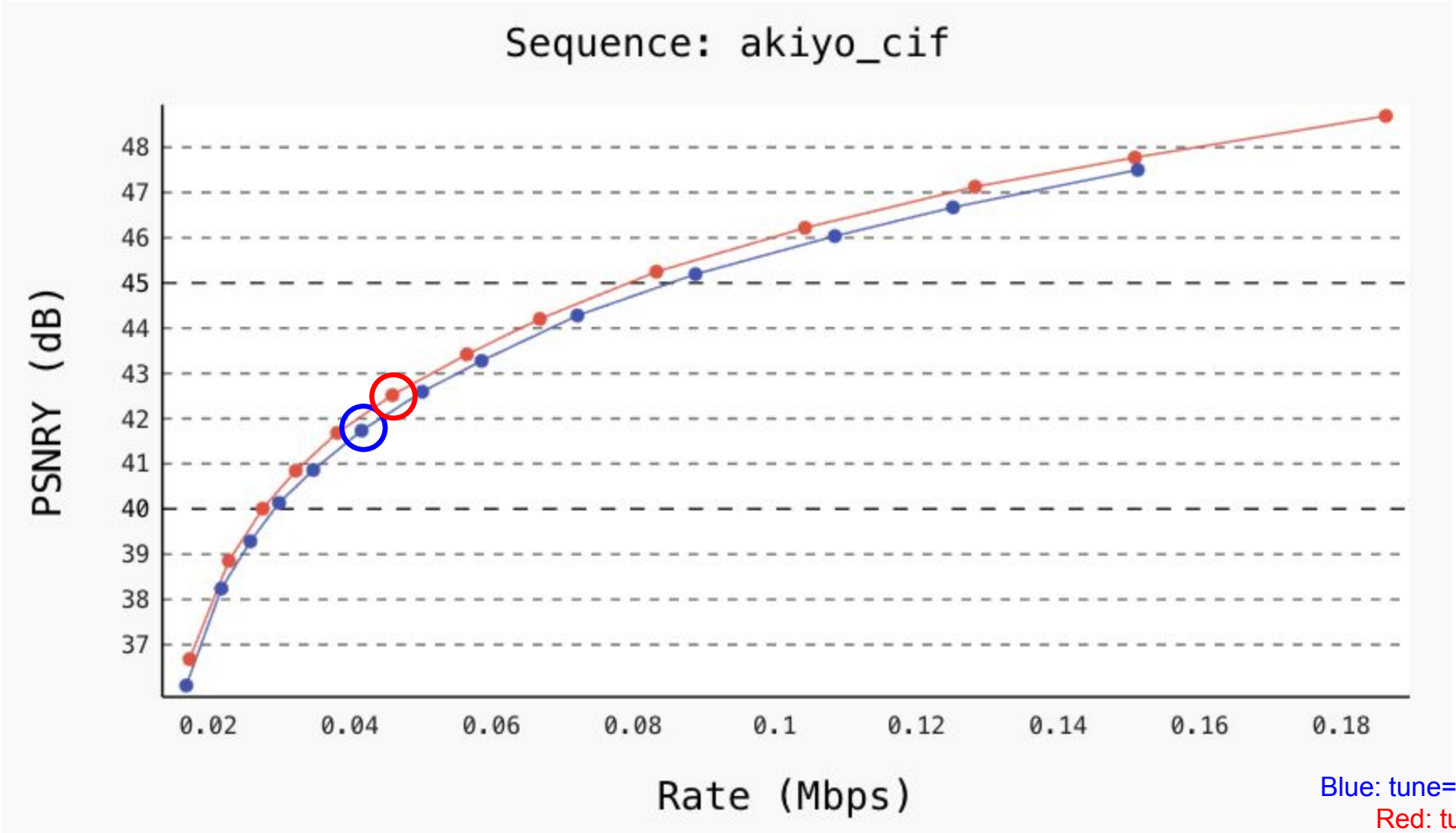
Frame value:
PSNR 44.14
VMAF 95.35
VMAF NEG 93.03

300 frames:
41.64 Kbps

diff (source, tune=vmafneg, qp43)



Blue: tune=vmafneg
Red: tune=psnr
BD-VMAFneg -6.2%



Blue: tune=vmafneg
Red: tune=psnr
BD PSNR 5.9%