AV1-Compatible Film Grain Modeling for HEVC Decoders

D. Grois (*grois@ieee.org*), A. Giladi,
T. Guionnet, T. Burnichon, N. Tverdokhleb, M. Raulet

Brief Agenda

I. Introduction

- Motivation: Film Grain Processing
- Carrying Film Grain Information
- Why using AFGS1 with HEVC is interesting?

II. Methodology and Evaluation Setup

III. Detailed Experimental Results

IV. Summary and Conclusions

Motivation: Film Grain Processing

Film Grain:

- Inherent in film acquisition, popular cinematic effect in digital
- Film grain is notoriously hard to encode
  - Grain removal may be aesthetically unpleasing and lose creative intent
  - Keeping grain intact requires extra bitrate
- What is we encode grain separately?
  - Transmit grain parameters along with denoised coded video
- What if we apply grain to non-grainy content?

Motivation: Film Grain Processing

Main Use-Cases:

- **Artistic Intent:** the goal is to preserve subjective quality of the film grain, as originally designed;
- **Artifact masking:** the goal is to minimize compression artifacts.

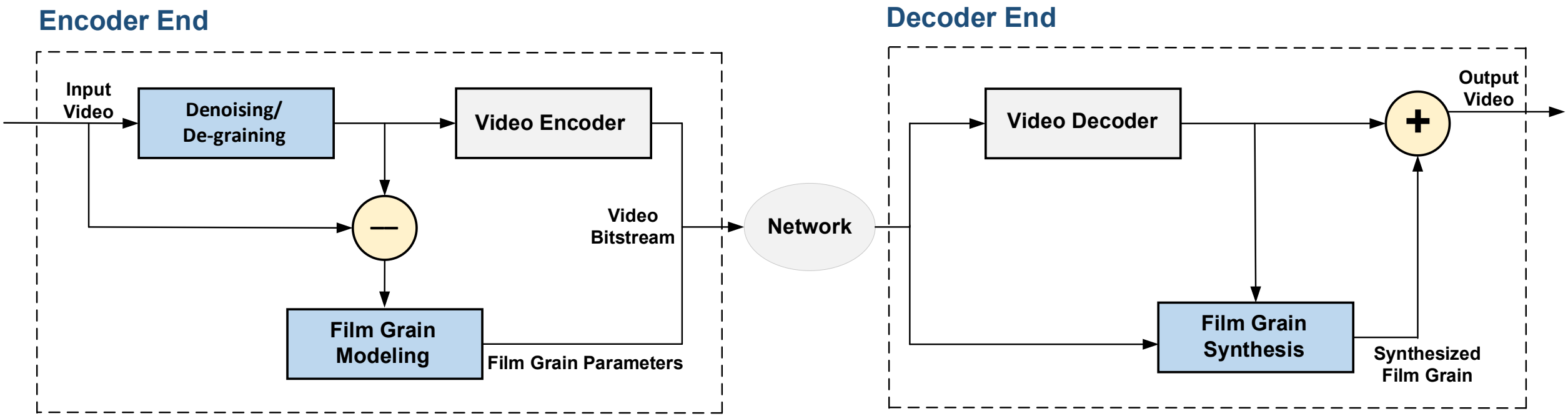
Main Benefits/Potential:

- **Increasing a coding gain** of the video coding systems, when processing video content that contain film grain;
- Delivering content with **much better visual quality and much higher resolution** for the video streaming applications.

Motivation: Film Grain Processing

Approach:

- Remove grain and encode cleaned-up video;
- Model grain and send grain parameters
- Decode video and overlay synthesized grain



Carrying Film Grain Information

H.264 SEI

- Optional message carried in AVC/HEVC/VVC bitstream
- Parameters defined, but not conformance

AV1

- Mandatory, conformance defined

AV1-compatible Film Grain

- Carry AV1 film grain parameters in a T.35 SEI message
- a.k.a. AFGS1

Why using AFGS1 with HEVC is interesting?

Technology is well-known for several years

- **not used in AVC/HEVC/VVC**

Modern SoCs implement multiple codecs

- **AV1-capable SoC has FGS in silicon**
- **FGS typically is implemented as post-processing**

It is possible to use FGS with HEVC

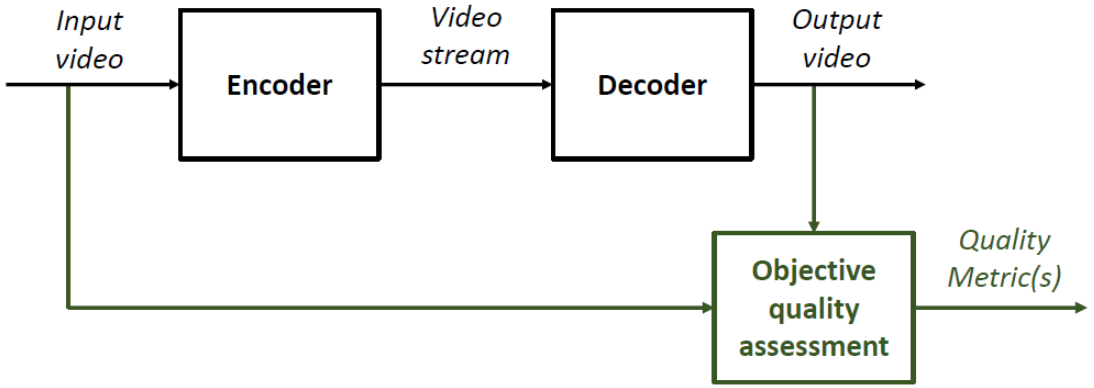
- **Software change, not silicon**

Experimentation status

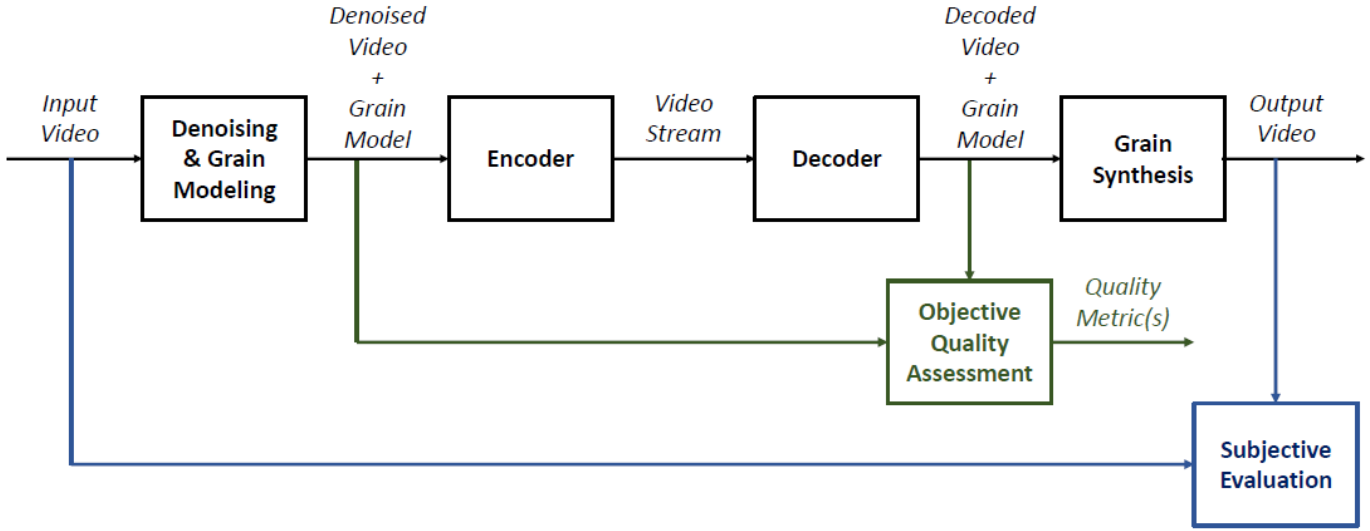
- **Realtek: successful decoding on RTD1319 SoC**
- **ffmpeg: patch available, to be merged (1st edition of AFGS1 is finalized)**

Methodology and Evaluation Setup

Typical video content objective evaluation:



Film grain video content and film grain synthesis evaluation:



- **Film grain content → The objective comparison should be performed between the decoded output video (i.e. before adding a film grain prior to display) and the denoised input video (i.e. after the film grain removal).**
- **The final output video can be assessed subjectively.**

Methodology and Evaluation Setup (Cont.)

Ateme Titan encoder was selected to run experiments:

- **Performs extraction of film grain parameters prior to denoising and encoding:**
  - **Luma and chroma ranges segmentation:**
    - Luminance and chrominance ranges are split into bands, each band having its own scaling, or grain “strength”;
    - First, the range must be split into small enough bands for ensuring fine scaling adaptation;
    - Second, each band must contain enough data to be statistically significant.
  - **Identification of reference picture blocks:**
    - For each band, a subset of blocks is selected for grain parameters estimation;
    - These blocks are selected either on the source image, or on the residual image after motion compensation (as performed by the MCTF filter);
    - The blocks with the lowest energy are supposed to contain only film grain. As such, they can be used as references for grain parameters estimation.

Methodology and Evaluation Setup (Cont.)

- **Performs extraction of film grain parameters prior to denoising and encoding (Cont.):**
  - **Grain variance estimation:**
    - for each band, the variance of the grain is estimated in the reference blocks, and the scaling values are set accordingly.
  - **Auto-Regressive (AR) coefficients estimation:**
    - the reference blocks are used for AR coefficients estimation;
    - AR coefficients are defined once for all the range, the reference blocks from the highest scaling bands are gathered.
  - **Seed selection:**
    - the seed for the pseudo-random generator is selected.
- **Signals film grain parameters by using the ITU-T T.35 SEI message.**

Methodology and Evaluation Setup (Cont.)

HEVC-based encoding:

HEVC Titan encoder configuration			
Coding options	**Chosen parameters**	**Coding options (cont.)**	**Chosen parameters (cont.)**
Encoder Version	36.0.0.0, Aug. 7, 2023	Rate Control	Enabled
Profile	Main 10	Intra Period	1 sec
Level	5.0	Coding Unit Size/Depth	64/3
GOP	32	Transform Unit Size (Min/Max)	4/32
Threads	8	Deblocking Filter	Enabled
Lookahead	23	Sample adaptive offset (SAO)	Enabled
Optimizations	AVX2	Asymmetric Motion Partitioning	Enabled

AV1-based encoding:

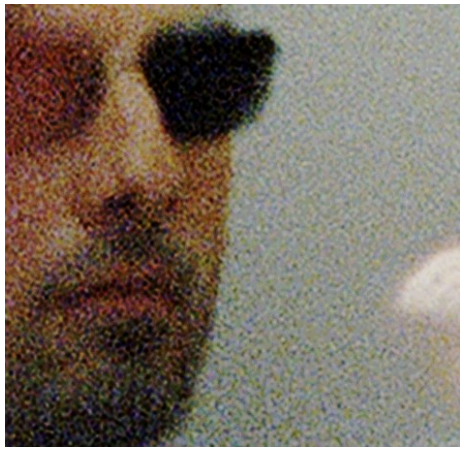
AV1 Titan encoder configuration			
Coding options	**Chosen parameters**	**Coding options (cont.)**	**Chosen parameters (cont.)**
Encoder Version	36.0.0.0, Aug. 7, 2023	Rate Control	Enabled
Profile	Main	Intra Period	1 sec
GOP	32	SB size	64
Threads	8	Coding Unit Size/Depth	64/3
Lookahead	23	Transform Unit Depth	3
Optimizations	AVX2	Deblocking Filter	Enabled

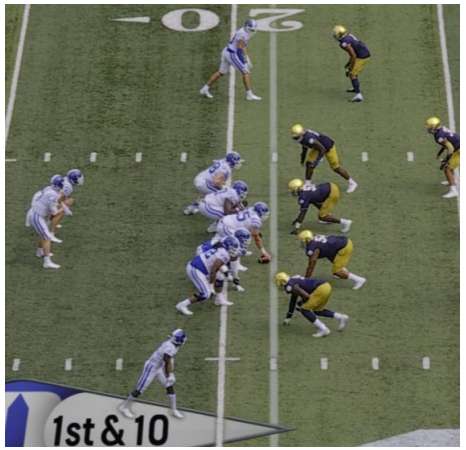
Methodology and Evaluation Setup (Cont.)

Test video sequences:

Sequence name	Collateral	Notre Dame Football	Blues Brothers	Scene 004 (Tears of Steel) (Apple Test Material/JVET-AE0250/JVET-AF0262)
Resolution	3840×2160 (4K)	1920×1080 (1080p)	1920×1080 (1080p)	3840x1714
Bit-Depth	10 bits	10 bits	10 bits	10 bits
Duration	10 minutes	10 min	7 min 44 sec	15 sec
Frame Rate	23.976 fps	59.94 fps	23.976 fps	24 fps
Color primaries	BT.709	BT.2020	BT.709	BT.709

Frame samples:





Experimental Results

- **First**, each video sequence was encoded at the **Constant Quality (CQ) mode**
  - variable bitrate mode where target quality is set
- **Second**, each video sequence was encoded in the **Constant Bit Rate (CBR) mode**
  - bitrates reflecting the CQ encodes observations
- **4 Rate-Distortion points with the film grain synthesis turned ON/OFF**
  - *i.e. with and without adding film grain after the decoding and prior to display*

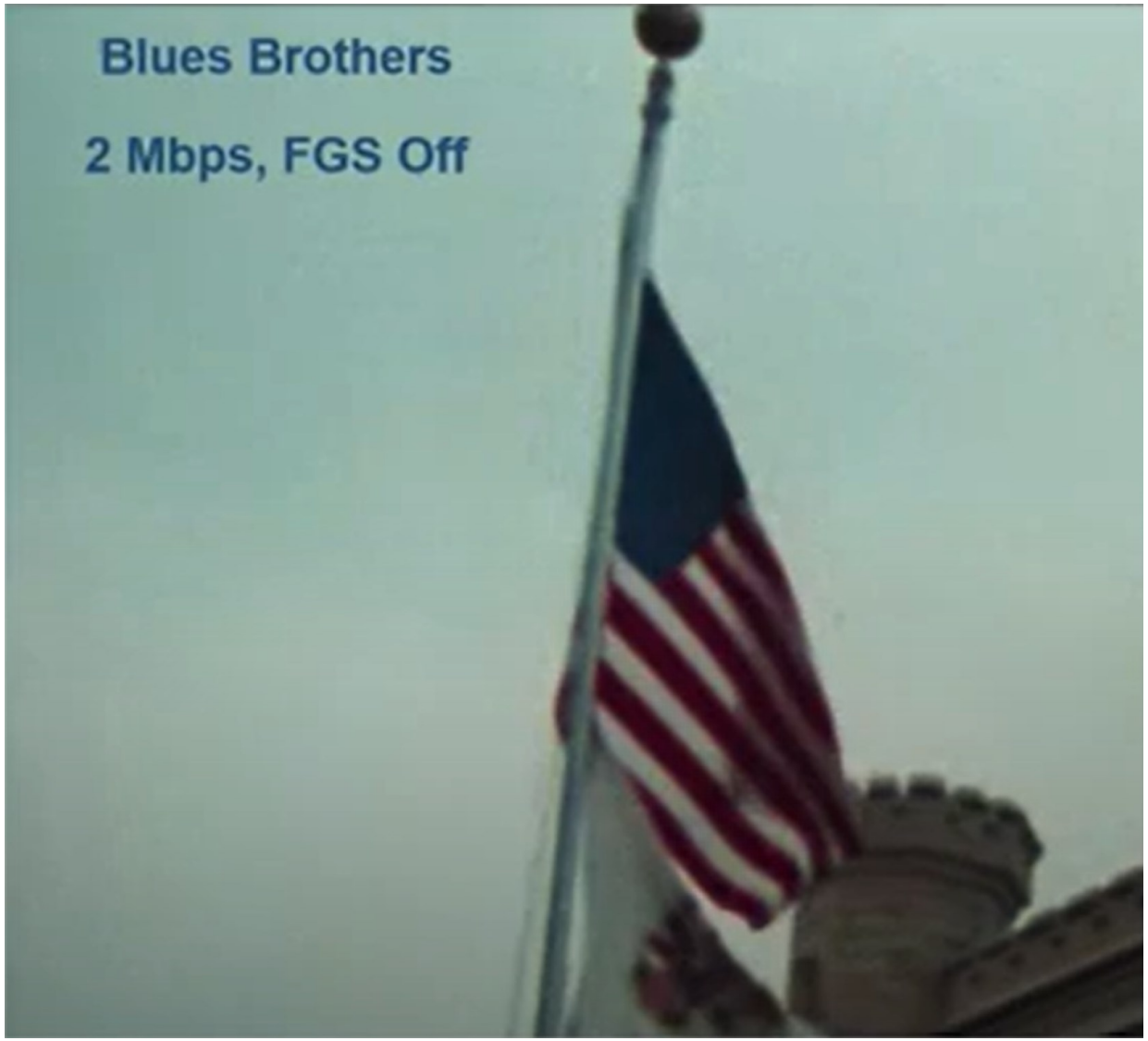
Experimental Results (Cont.)

Summary of the BD-BR bit rate savings:

Sequence	HEVC Bit Rate Savings FGS ON vs. FGS OFF	AV1 Bit Rate Savings FGS ON vs. FGS OFF
Collateral	-79.83%	-68.12%
Notre Dame Football	-10.02%	-12.27%
Blues Brothers	Gain of more than 90%	Gain of more than 90%
Scene 004 (Tears of Steel) (Apple Test Material/JVET-AE0250/JVET-AF0262)	Gain of ~90%	Gain of ~90%

* “Notre Dame Football” video sequence has VERY light film grain, but still more than 10% coding gain is achieved, which proves that there are significant benefits for using the FGS technique even in such cases.

Experimental Results (Cont.)



Summary and Conclusions

- Efficient implementation of the existing AV1 film grain post-processing support for the H.265/MPEG-HEVC based video codecs
- The estimated film grain parameters were provided within the ITU-T T.35 SEI message
- Prototype implementation of AFGS1 with HEVC:
  - Commercial encoder (Ateme)
  - Hardware decode (Realtek)
  - Open-source software decode (ffmpeg)
- Very significant bitrate savings we achieved
  - Substantially the same subjective video presentation quality
- In case of the very light film grain
  - Significant benefits for using the FGS technique for achieving large coding gains