Summer Streaming Bootcamp

SESSION 1. ENCODING FUNDAMENTALS AND VIDEO QUALITY METRICS

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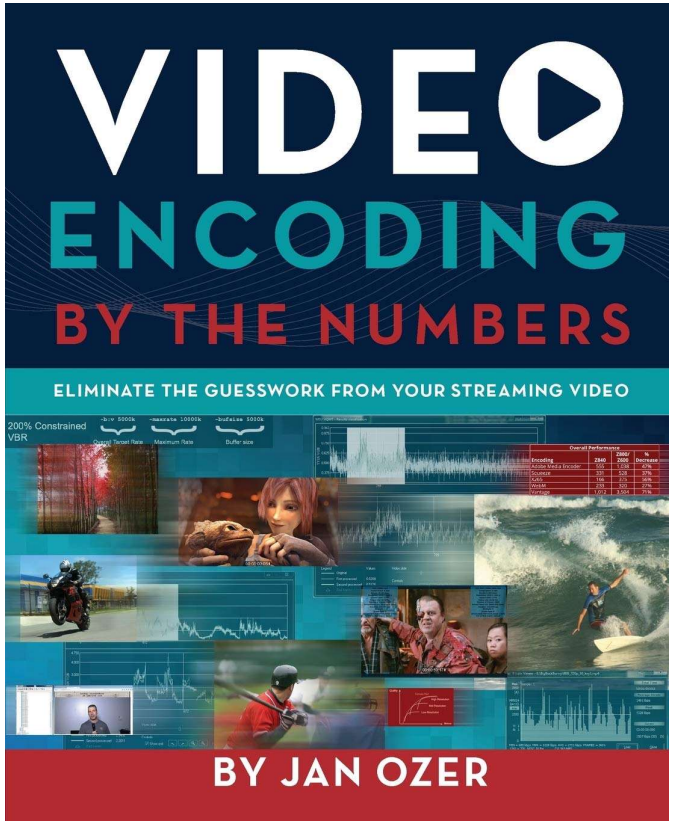
Agenda

- Lesson 1: Introduction to Video Compression
- Lesson 2: Codecs
- Lesson 3: Container formats
- Lesson 4: Configuration basics
- Lesson 5: Distribution alternatives
- Lesson 6: Essential tools
- Lesson 7: Intro to objective quality metrics

Background – Updating Book

- Lesson 1 – prelims for newbies
- Lesson 2 – encoding H.264
- Lesson 3 – encoding HEVC
- Lesson 4 – encoding AV1
- Lesson 5 – encoding VVC
- Lesson 6 – encoding LCEVC
- Lesson 7 – Live encoding and transcoding



Why?

- All lessons ***after*** this one
- Lots of research goes into the book
  - Manifests as only a few charts
- Share the research, get feedback
- Keep me on schedule

Agenda

- Lesson 1: Introduction to Video Compression
- Lesson 2: Codecs
- Lesson 3: Contain
- Lesson 4: Configu
- Lesson 5: Distribu
- Lesson 6: Essenti
- Lesson 7: Intro to

Very introductory course from start to finish.

Not particularly useful for anyone other than total newbies.

Online Course for New Streaming Professionals

Streaming Media 101:

Technical Onboarding for Streaming Media Professionals

Learn the technologies, techniques, and skills to succeed in a streaming media-related role, whether it's producing and distributing streaming video or creating the tools and services necessary to do so.

https://bit.ly/StreamingMedia101

Regularly $299.95. Use coupon code ssbc_20 (lower case) For 20% discount through September 30, 2024).

What You Will Learn

In about 11 hours, this online course will teach you the terms, technologies, best practices, and skills needed to excel in a technical role in the streaming media industry. You will learn:

- How to encode and deploy streaming video using the H.264, HEVC, VP9, and AV1 codecs
- How to encode for single file and adaptive bitrate encoding and packaging for HLS, DASH, and CMAF
- About digital rights management (DRM) and distribution issues like choosing a CDN and how to measure and ensure Quality of Service and Quality of Experience
- Critical production-level decisions, like whether to encode on-premise or in the cloud, how to choose a per-title encoding technology and cloud encoder, and how to compute the breakeven on deploying an advanced codec like HEVC or AV1

You will learn to:

- Analyze files with MediaInfo, Bitrate Viewer, Apple's AVQT, and the Moscow State University Video Quality Measurement Tool
- Encode in FFmpeg and Handbrake
- Produce mezzanine files for upload to a streaming service
- Connect to YouTube Live and Facebook Live
- Embed a live or on-demand video into a web page

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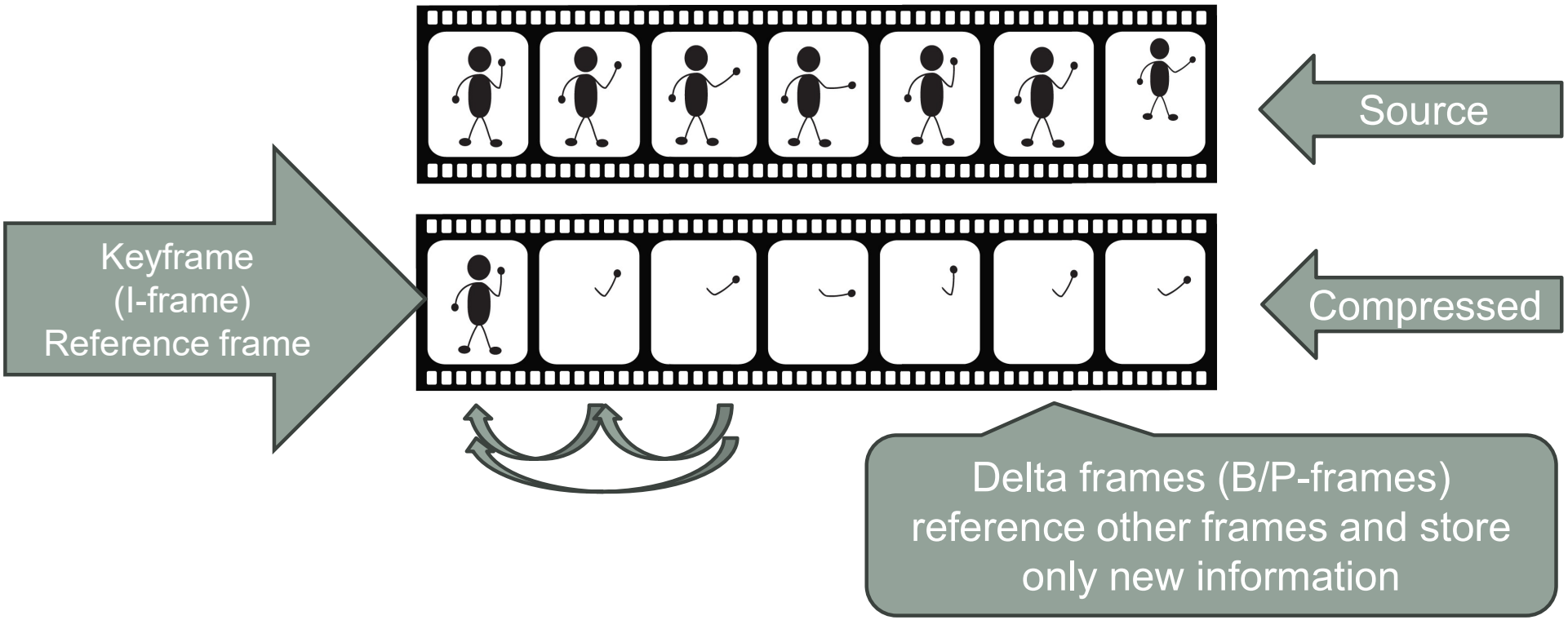
Lesson 1: About Video Compression

- How does compression work?
- The implications of lossy compression

How Does Compression Work?

- Two kinds:
  - Inter-frame – removes redundancy between frames
  - Intra-frame – encodes using JPEG-like technology
- Both are “lossy”
  - Don’t restore original bit for bit – returns facsimile of original
  - The more you compress – the more you lose

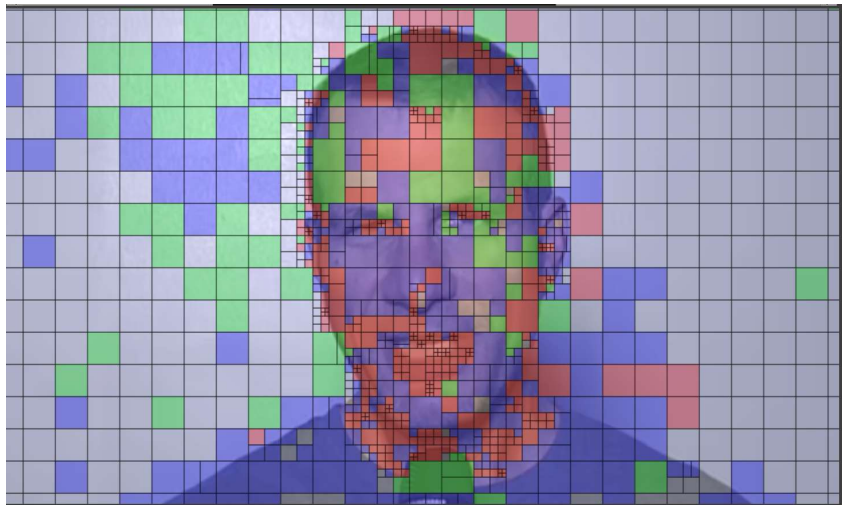
Interframe Compression – Simple View



https://www.bhphotovideo.com/explora/video/tips-and-solutions/things-you-wanted-to-know-about-compression-but-were-afraid-to-ask

Works in Blocks – Step 1: Partitioning

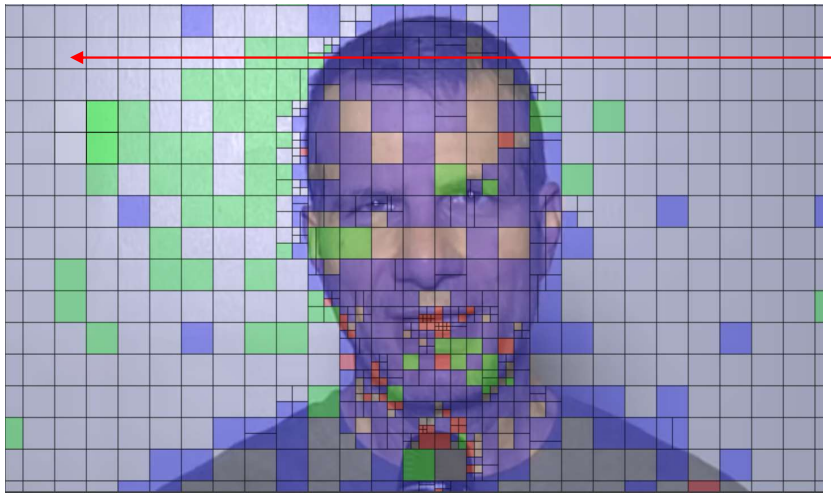
Original Frame (frame 17)



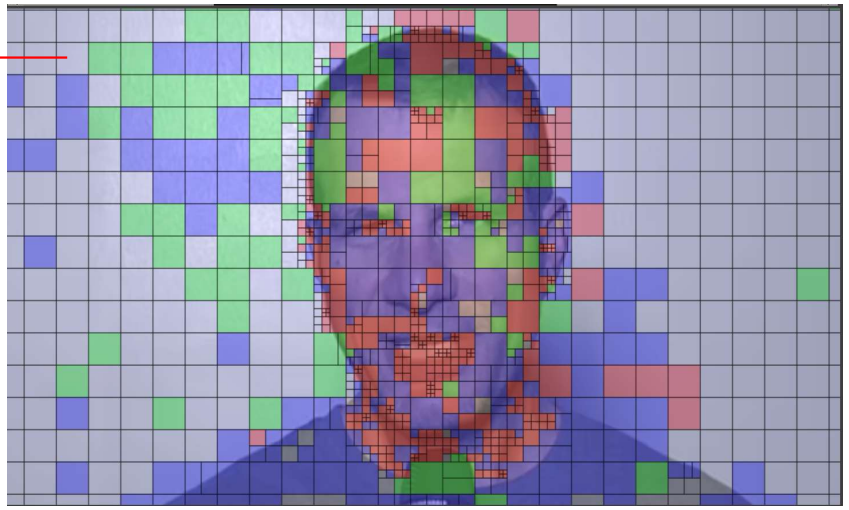
Block Partitioning

- Macroblocks H.264
- Coding Tree Units (HEVC)

How Compression Works – Finding Redundancies



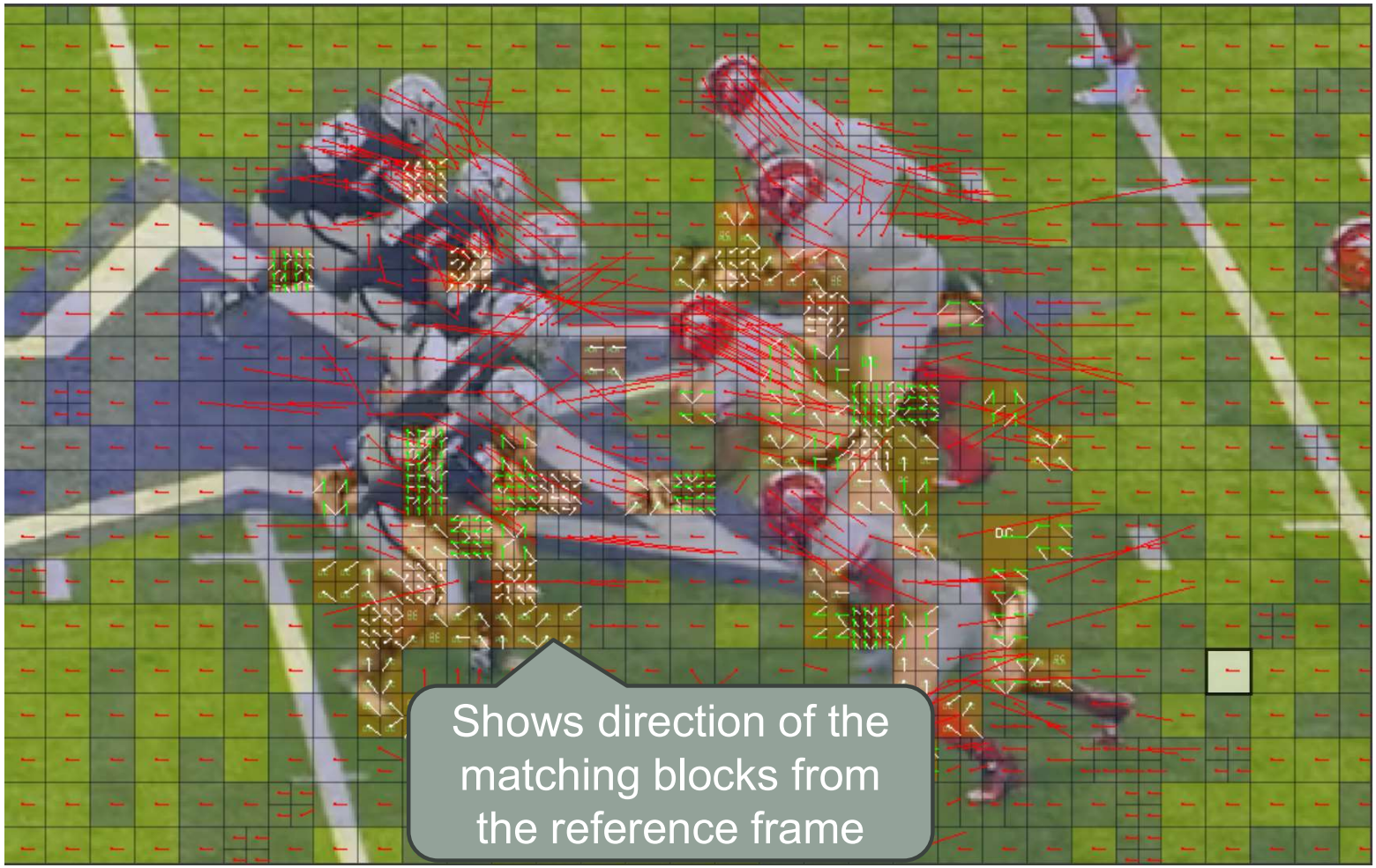
Reference Frame (Frame 9)



Target frame (Frame 17)

- Encoder searches for similar blocks in reference frames
- Doesn't have to be in the same place (can track moving objects)
- Doesn't re-encode – just references (play this block here)

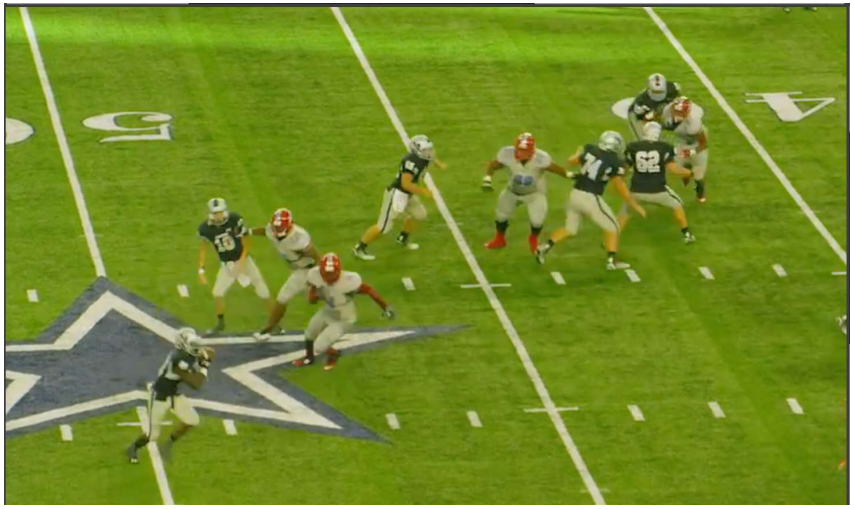
Motion Vectors (Sources of Redundant blocks

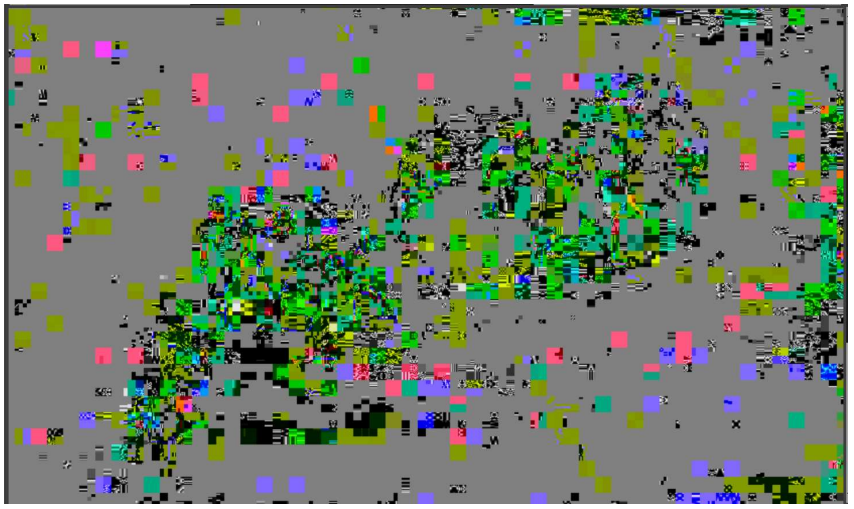


“Residual” Blocks Are Compressed with Intraframe

- Residuals are the information remaining after all redundancies
  - Very slight detail around the face
- This information is compressed with intra-frame techniques (like JPEG)
- Intra-frame is much more efficient than intraframe
  - Which is why talking head videos encode more efficiently than soccer matches
    - The more redundancies, the less intraframe
    - Less intraframe means higher quality

Residuals – in High Motion File





- More residuals in high motion files (with lots of detail)
  - This means more blocks compressed with intraframe compression

- Intra-frame compression is much less efficient
- High motion files need higher bitrate to avoid quality issues

Implications of Lossy Compression

Talking Head

Elements	%	bits
residuals	4.74	994
mvd	39.20	8217
coded_block_pattern	4.20	880
mb_skip_flag	29.93	6274
mb_type	13.12	2750
slice header	0.21	44
intra pred modes	0.32	68
ref_idx	5.79	1213
others	1.14	238
mb_qp_delta	1.35	282

MB types	%	Pixels
intra	0.21	4352
inter	99.79	2084608

Football

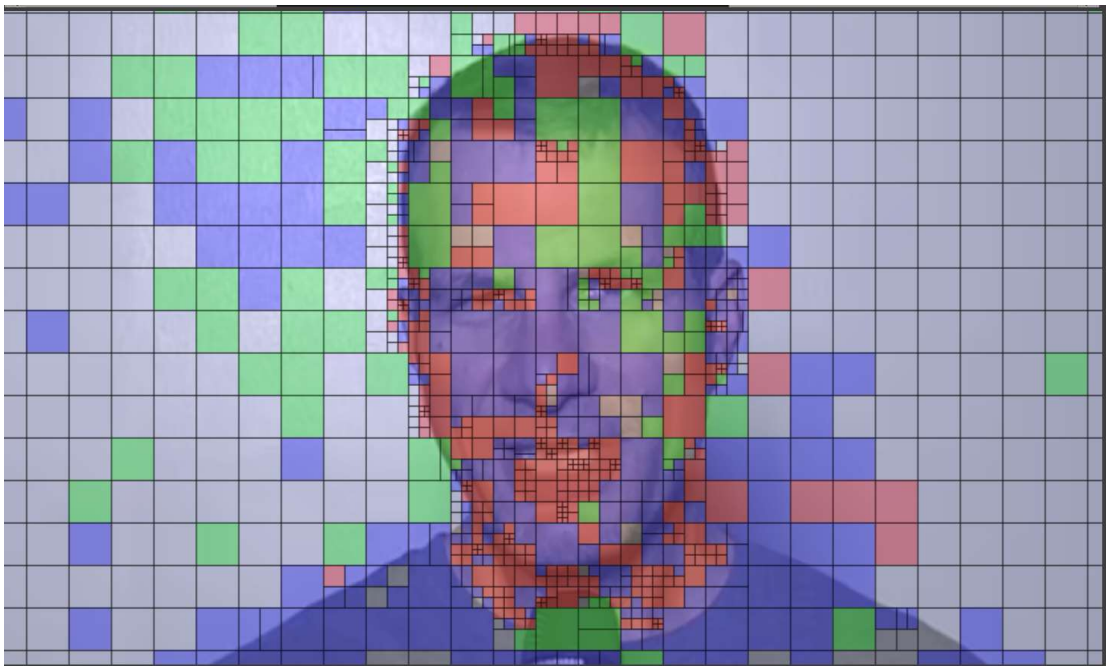
Elements	%	bits
residuals	64.36	178672
mvd	12.15	33742
coded_block_pattern	7.79	21625
mb_skip_flag	2.34	6500
mb_type	3.41	9465
slice header	0.02	57
intra pred modes	4.70	13041
ref_idx	0.00	0
others	1.18	3289
mb_qp_delta	4.04	11225

MB types	%	Pixels
intra	7.94	165888
inter	92.06	1923072

- Residuals are far greater
- More intraframe compression
- Lower quality (all else being equal)

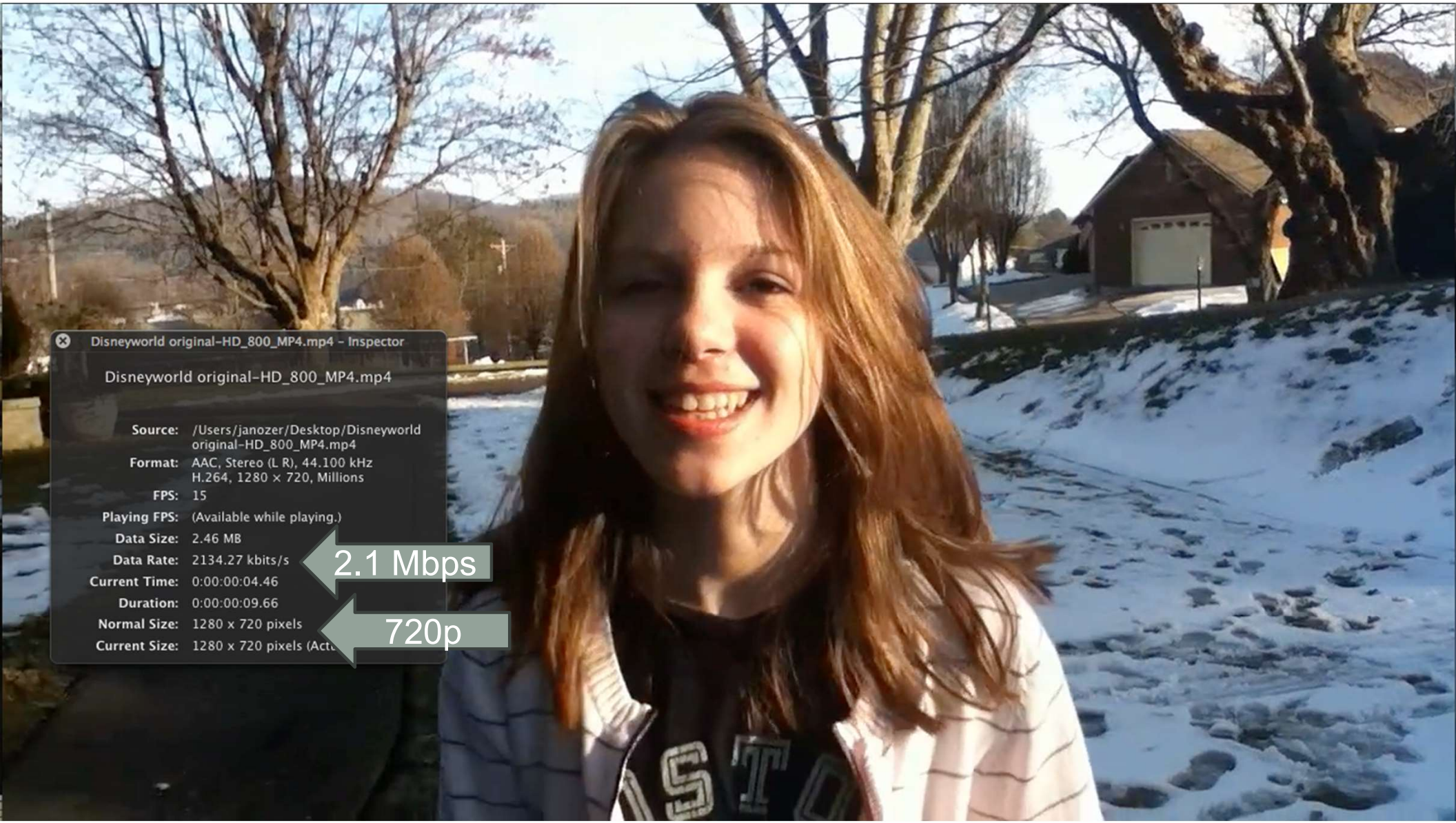
Lossy Compression – the Origins of Blockiness

- At higher compression rates, pixels within blocks become more homogenous, so blocks become more distinct
- That's why you see blockiness in highly compressed videos
- H.264 uses 16x16 blocks, which is less efficient than the variable sized coding tree units (CTUs) used in HEVC (shown)



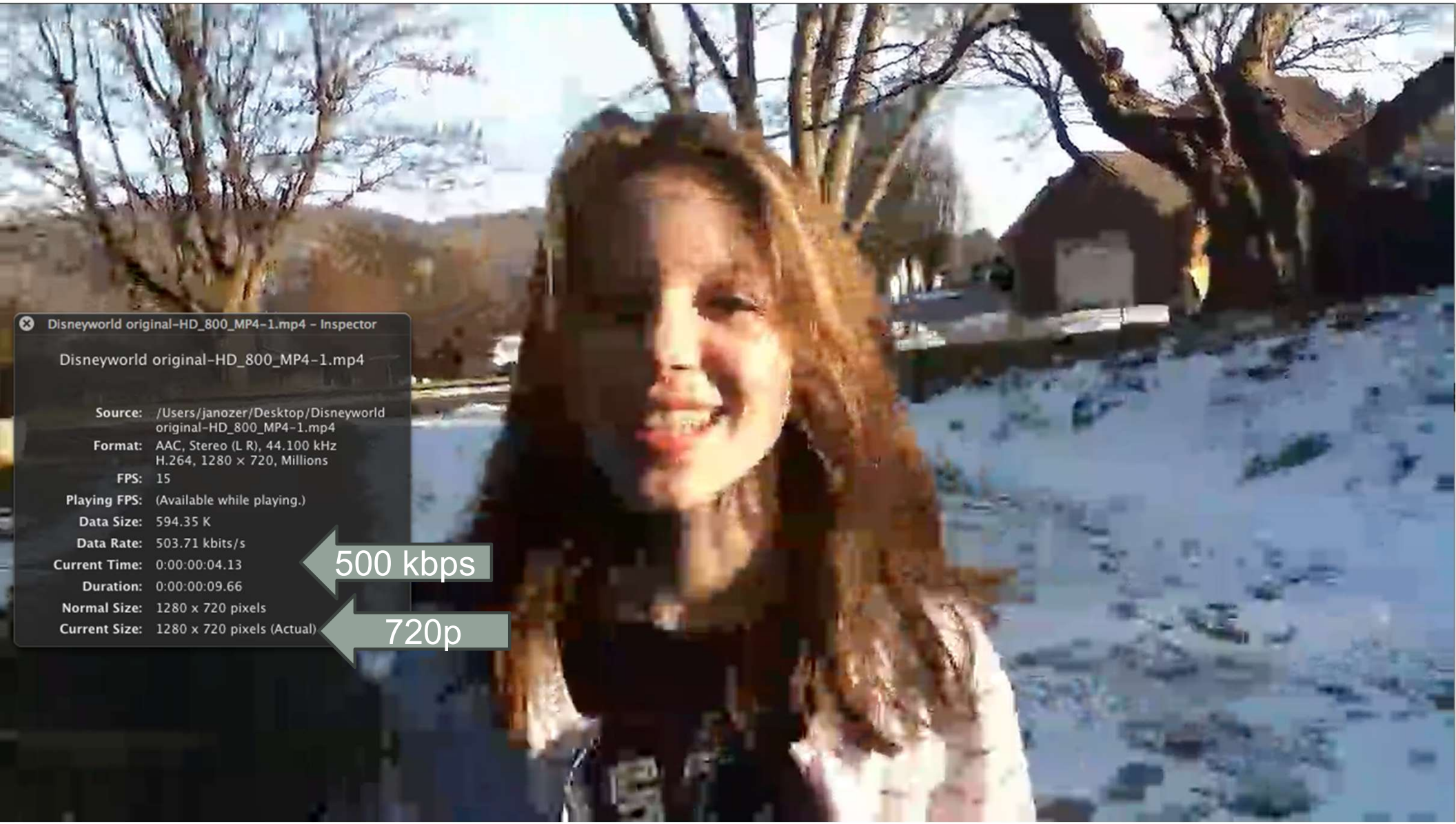
Implications of Lossy Compression

- The more you compress, the more quality you lose
  - Video at 2.1 mbps
    - Pretty good


Disneyworld original-HD_800_MP4.mp4 – Inspector
Disneyworld original-HD_800_MP4.mp4
Source: /Users/janozer/Desktop/Disneyworld original-HD_800_MP4.mp4
Format: AAC, Stereo (L R), 44.100 kHz
H.264, 1280 × 720, Millions
FPS: 15
Playing FPS: (Available while playing.)
Data Size: 2.46 MB
Data Rate: 2134.27 kbits/s
Current Time: 0:00:00:04.46
Duration: 0:00:00:09.66
Normal Size: 1280 x 720 pixels
Current Size: 1280 x 720 pixels (Act
2.1 Mbps
720p

Implications of Lossy Compression

- The more you compress, the more quality you lose
  - Video at 2.1 mbps
    - Pretty good
  - Video at 500 kbps


Disneyworld original-HD_800_MP4-1.mp4 - Inspector
Disneyworld original-HD_800_MP4-1.mp4
Source: /Users/janozer/Desktop/Disneyworld original-HD_800_MP4-1.mp4
Format: AAC, Stereo (L R), 44.100 kHz
H.264, 1280 × 720, Millions
FPS: 15
Playing FPS: (Available while playing.)
Data Size: 594.35 K
Data Rate: 503.71 kbits/s
Current Time: 0:00:00:04.13
Duration: 0:00:00:09.66
Normal Size: 1280 x 720 pixels
Current Size: 1280 x 720 pixels (Actual)
500 kbps
720p

Implications of Lossy Compression

- The more you compress, the more quality you lose
  - Video at 2.1 mbps
    - Pretty good
  - Video at 500 kbps
    - Pretty awful

Implications of Lossy Compression

- Sometimes we must deliver at 500 kbps
  - Our job - configure video properly to avoid ugly compressed video
- Primary tool – adjusting the data rate and resolution to minimize the effects of compression
  - At lower data rates, also adjust frame rate, say from 30 to 15 fps

Lesson 2: Codecs

- What are codecs
- How do you choose one
- Where do you choose one

What are Codecs?

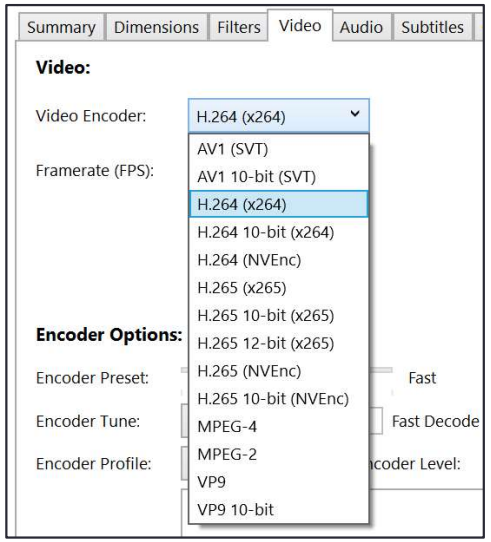
- Codec
  - Any technology that COmpresses in the studio, then DECompresses in the field
- Common codecs
  - Video - H.264/AVC, H.265/HEVC, VP9, AV1, H.266/VVC, LCEVC
  - Audio - AAC, Opus, Dolby Digital

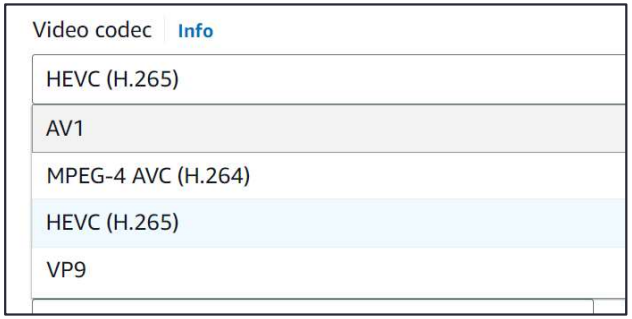
Choosing a Codec

- Multiple Considerations
  - Compatibility (where it plays)
  - Efficiency (how much bandwidth it saves)
  - Encoding cost (encoding time/third-party costs)
  - Feature set
    - Are live transcoders available?
    - Is it compatible with HDR?
  - Royalty cost
- Choosing a codec is not a major focus of the book
  - Focus – using the codec that you've selected

Where You Chose a Codec in Production

- Every encoding application lets you choose the codec
  - HandBrake
  - AWS Elemental MediaConvert





Lesson 3: Container Formats

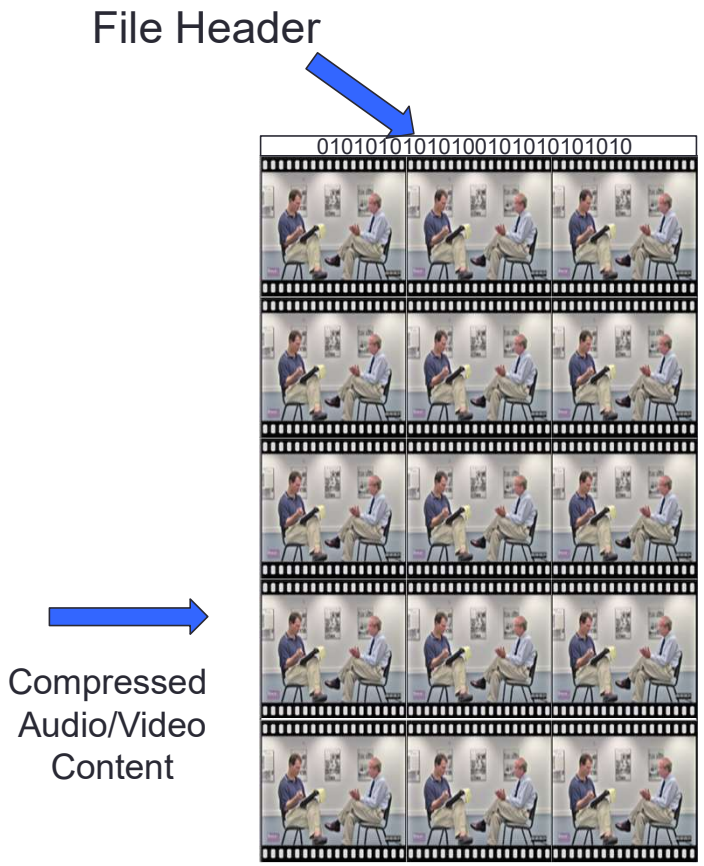
- What is a container format
- Where is a container format
- How are container formats different than codecs

Codecs and Container Formats

- **Codecs:** Compression technologies
  - H.264, VP9, HEVC
- **Container formats**
  - Specs detailing how data/metadata are stored in a file
    - MP4, WEBM, .MPD, .TS, .ISMV, .F4F
  - Also called “wrappers”
    - As in, “encoded the file using the H.264 codec in a QuickTime wrapper”
- Why important?
  - File must be in proper container format to play on target platforms

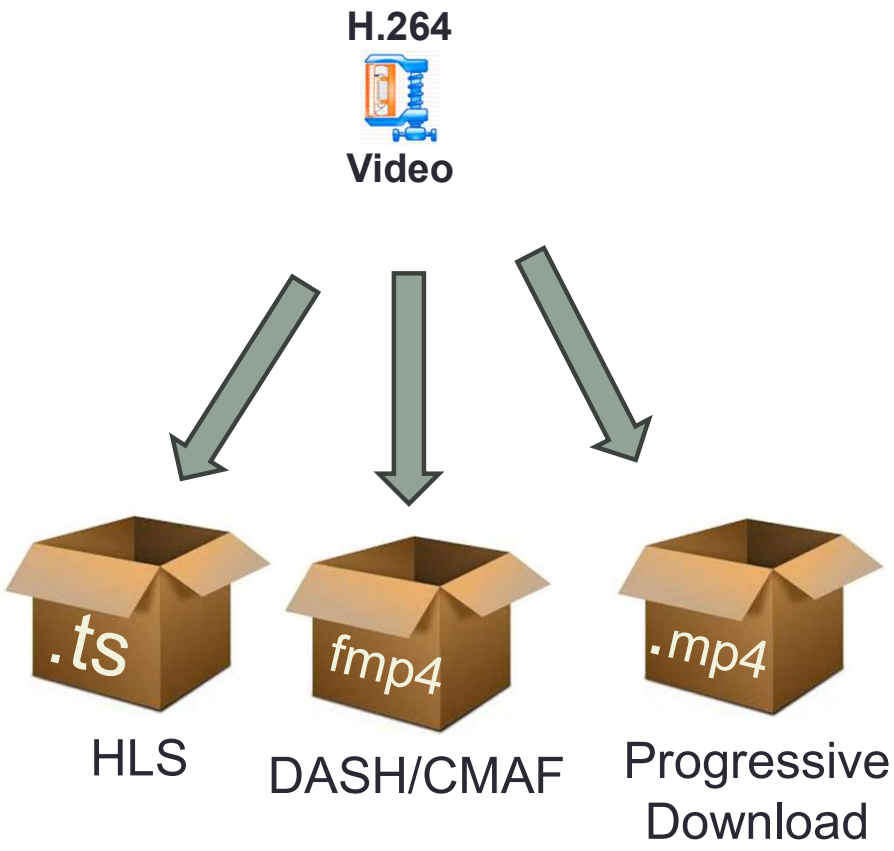
Where is Container Format?

- It's in the file header
  - Very small percentage of overall content
- Can quickly change the container format without affecting A/V content
  - Called transmuxing
  - Very useful when delivering adaptive bitrate video in different formats (like DASH, HLS)



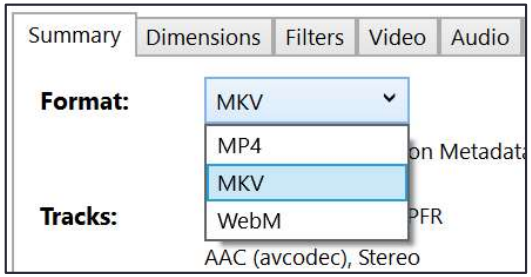
Why is this Important?

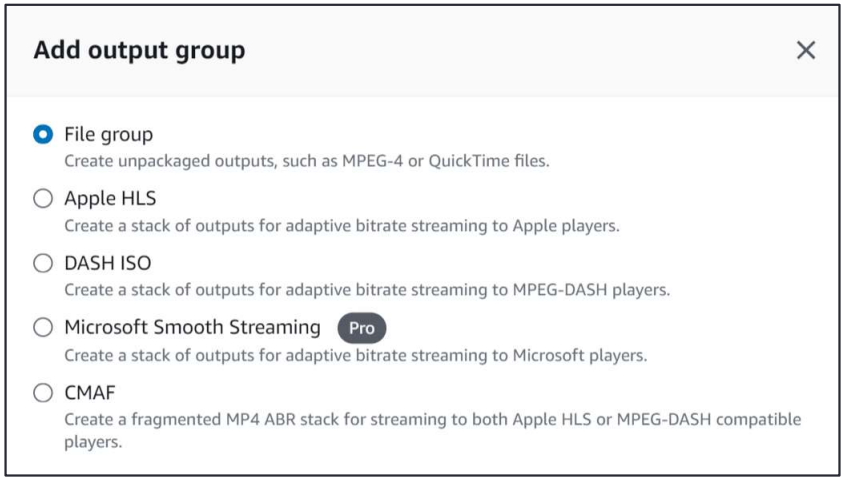
- Single encoded video file
- May need different container format to deliver to different target
  - MPEG-2 transport streams (legacy HLS)
  - Fragmented MP4
    - DASH/CMAF
  - Standard MP4
    - Progressive download / VOD
- Whenever you configure encoder, you must choose codec ***and*** container format



Where You Chose a Container Format

- Again, encoders will enable choice of containers
  - HandBrake
  - AWS Elemental MediaConvert



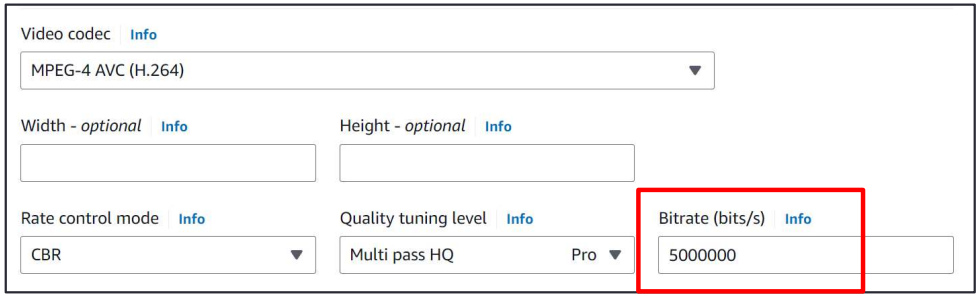


Lesson 4: Configuration Basics

- Encoding options you'll select for every file
  - Data rate
  - Resolution
  - Frame rate
- What is bandwidth, and why is it important

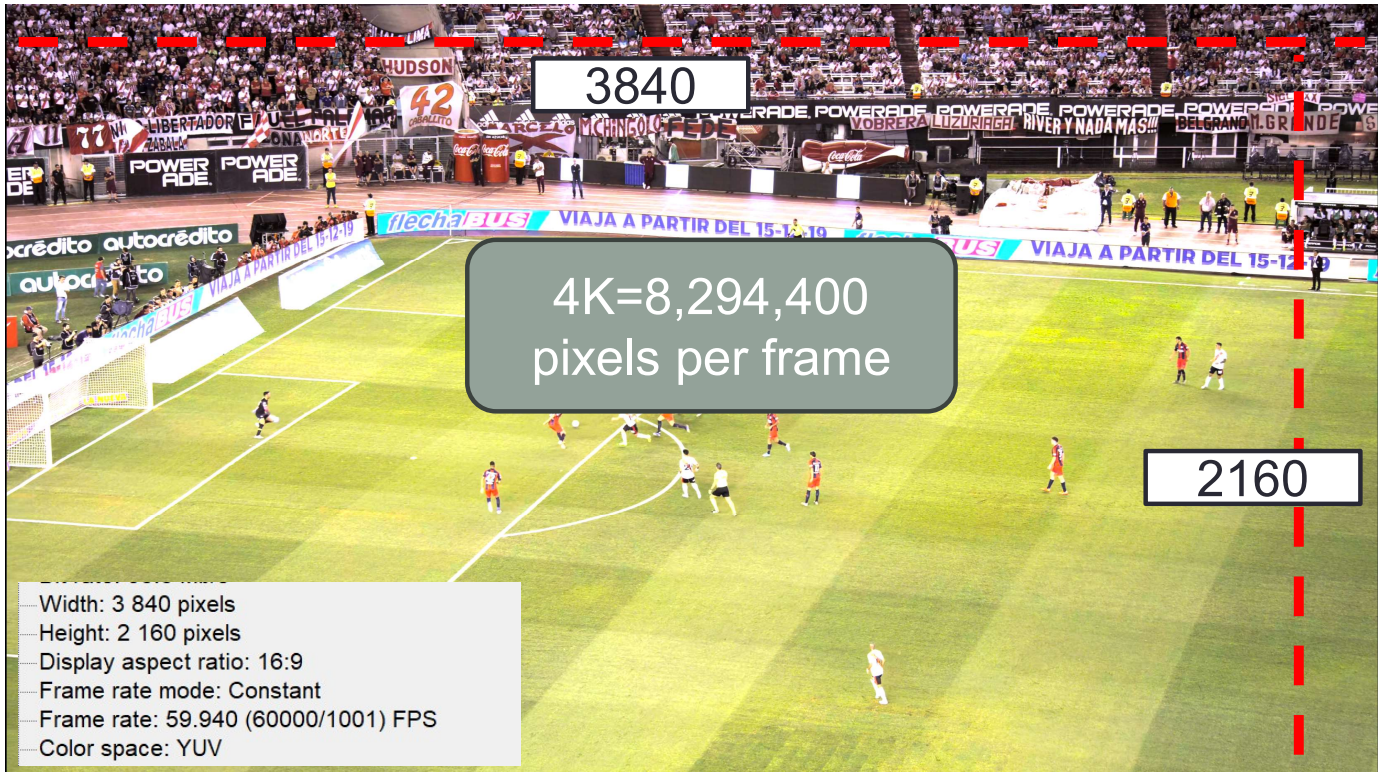
Configuration Basics – Data Rate

- You set data rate for video and audio for every file that you encode for streaming delivery
- Video
  - Data rate is the most important factor in overall quality
  - The higher the data rate, the better the quality; but also harder to deliver
- Audio
  - You also set audio data rates, though typically a fraction of video



Configuration Basics – Video Resolution

- Width and height of video in a file
- Significant determinant of video quality
  - The more pixels, the harder a files is to compress
  - Fewer pixels, easier to compress



Configuration Basics – Video Resolution

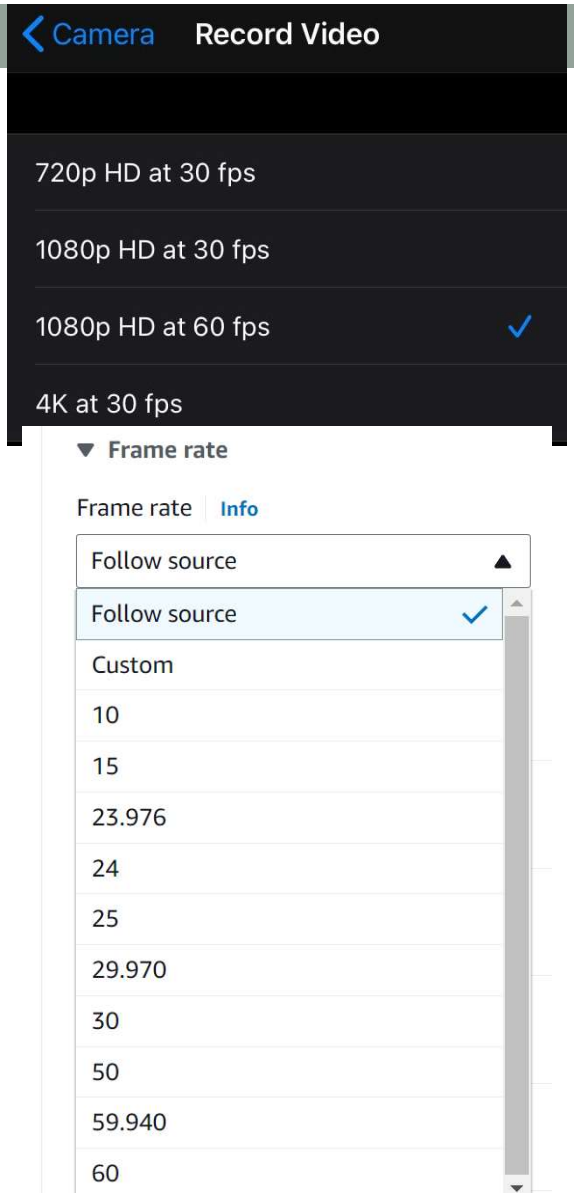
Size	Width	Height	Pixels/Frame	% of 4K
4K	3840	2160	8,294,400	100.00%
2K	2560	1440	3,686,400	44.44%
1080p	1920	1080	2,073,600	25.00%
720p	1280	720	921,600	11.11%
360p	640	360	230,400	2.78%

25% the pixels

- We lower frame sizes to reduce the number of pixels encoded in the files delivered to our viewers
- This allows us retain better frame quality at lower data rates
  - True, we're trading low rez for high rez, but,
  - A small high-quality picture looks better than a big ugly picture

Configuration Basics – Frame Rate

- Frames per second in the file
- Selected during recording (top)
- Selectable during encoding
  - Usually maintained for top quality videos
  - Sometimes reduced for videos targeted for mobile devices



Encoding Ladders – Managing Quality to all Viewers

- Encoding ladder:
  - Multiple files produced from a single live/VOD file
  - To deliver best possible experience to those watching on lower bandwidth connections
- The why:
  - Balance rez/frame rate to enable higher quality at lower bitrates
  - Deliver full experience to devices and connections that can play it
  - Deliver good quality frames to devices with less capable displays/co

low bitrate @ small rez/reduced frame rate

High bitrate @ full rez/frame rate

Apple HLS Specs

16:9 aspect ratio	HEVC/H.265 30 fps	Frame rate
640 x 360	145	≤ 30 fps
768 x 432	300	≤ 30 fps
960 x 540	600	≤ 30 fps
960 x 540	900	≤ 30 fps
960 x 540	1600	Same as source
1280 x 720	2400	Same as source
1280 x 720	3400	Same as source
1920 x 1080	4500	Same as source
1920 x 1080	5800	Same as source
2560 x 1440	8100	Same as source
3840 x 2160	11600	Same as source
3840 x 2160	16800	Same as source

https://apple.co/3KGFtgR

YouTube 4K Video

Data Rate is Like Paint

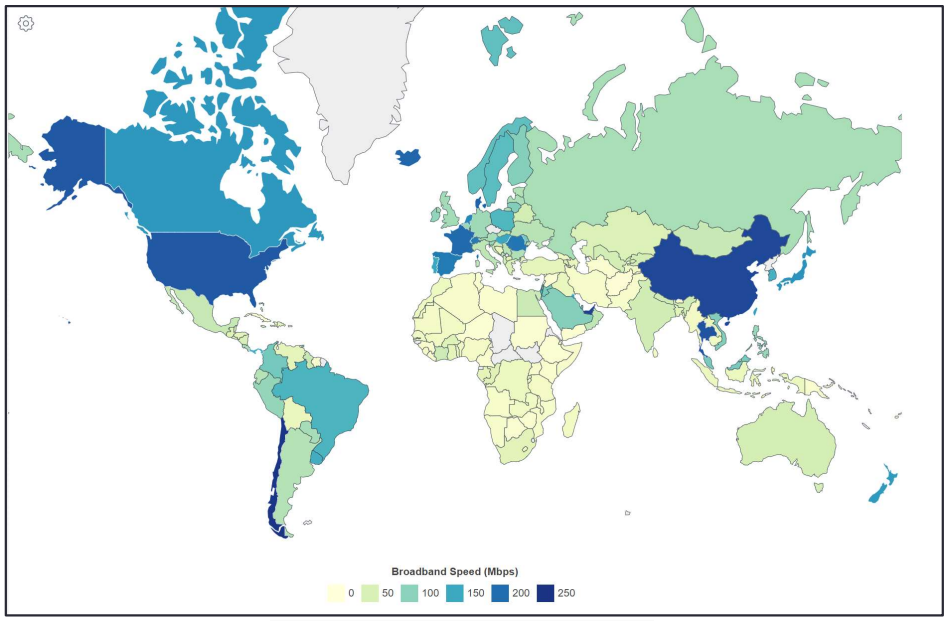
- If you don’t have enough paint to cover the wall it’s going to look ugly
  - The data rate (amount of paint) is set by encoding ladder dynamics. You can’t change this.
- Your only options are to:
  - Paint a smaller wall (reduce resolution or frame rate)
  - Get more efficient paint (HEVC, AV1, VVC)

About Bandwidth

- What is bandwidth?
  - Viewer's connection speed
- Why is it important?
  - Controls your viewer's ability to retrieve and play video smoothly
  - Higher delivery bandwidths mean higher data rates, which means better quality
    - Publishers pay for bandwidth, so it also means more expense

Bandwidth - Where Are We?

- Fastest broadband download speed
  - Per World Population Review
    - US – 215.72 Mbps
    - Canada - 167 Mbps
    - Mexico – 63 Mbps
    - UK – 85 Mbps
    - France – 201 Mbps
    - Germany – 88 Mbps
  - So why does CNN max out at 2 Mbps?



United States

Broadband Speed	Mobile Speed
215.72	103.69

http://worldpopulationreview.com/countries/internet-speeds-by-country/

Paradigm Shift

- Used to be bandwidth constrained
  - Tried to deliver the highest quality customer can retrieve
- Now we're budget constrained
  - Try to deliver the highest quality we can afford
    - Premium content – subscription/advertising
    - Corporate – marketing/training expense
- Choosing your delivery bandwidth should integrate cost considerations
  - Choose your bandwidth first (based on cost)
  - Then configure your video for the best quality at that bandwidth

Lesson 5: Distribution Alternatives

- Download and play
- Progressive download
- Adaptive bitrate delivery (ABR)

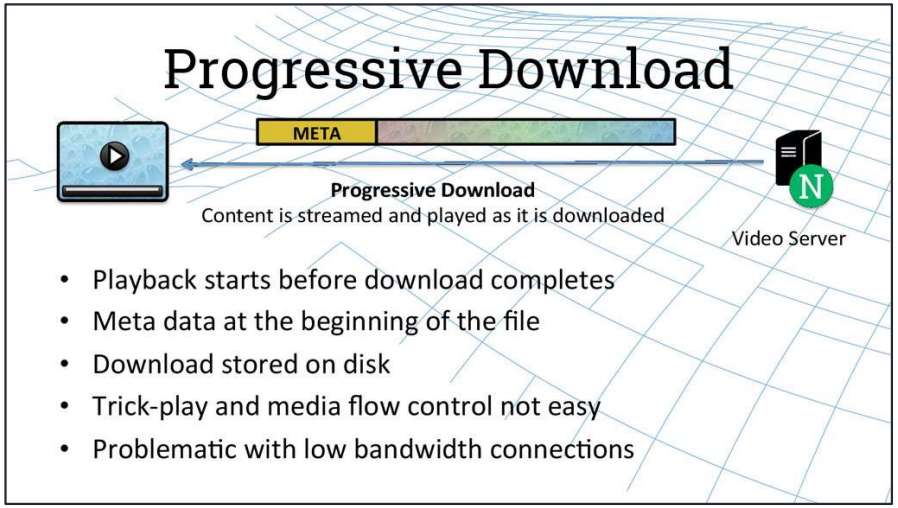
Download and Play

- How it works
  - Click file to begin download
  - Download starts
  - File plays when download is complete
- Pros:
  - Great way to build patience
  - Low encoding cost
- Cons
  - Poor way to build viewers
  - Wastes bandwidth when viewers don't watch the entire video
  - Single quality to all viewers, irrespective of device/connection

- Who uses?
  - Fringe at this point

Download and Play

- How it works
  - Click file to begin download
  - Playback starts once header and a few packets downloaded
- Pros:
  - Very simple; no encoding ladder, no metadata
  - OK experience for short files
  - Cheap encoding (one file)
- Cons
  - Wastes bandwidth when viewers don't watch the entire video
  - Single quality to all viewers, irrespective of device/connection

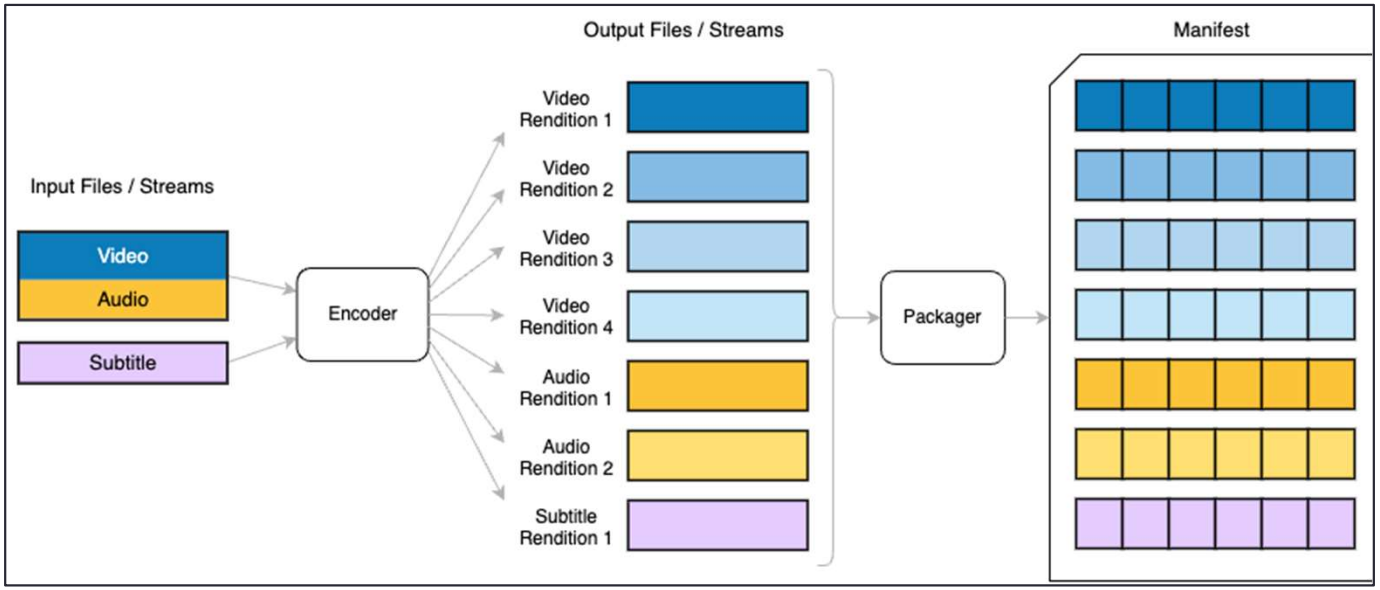


- Who uses?
  - Some social media sites
  - Education and corporate
  - Key point: still in use, still a viable option

https://speakerdeck.com/nginx/video-streaming-with-nginx

Adaptive Streaming

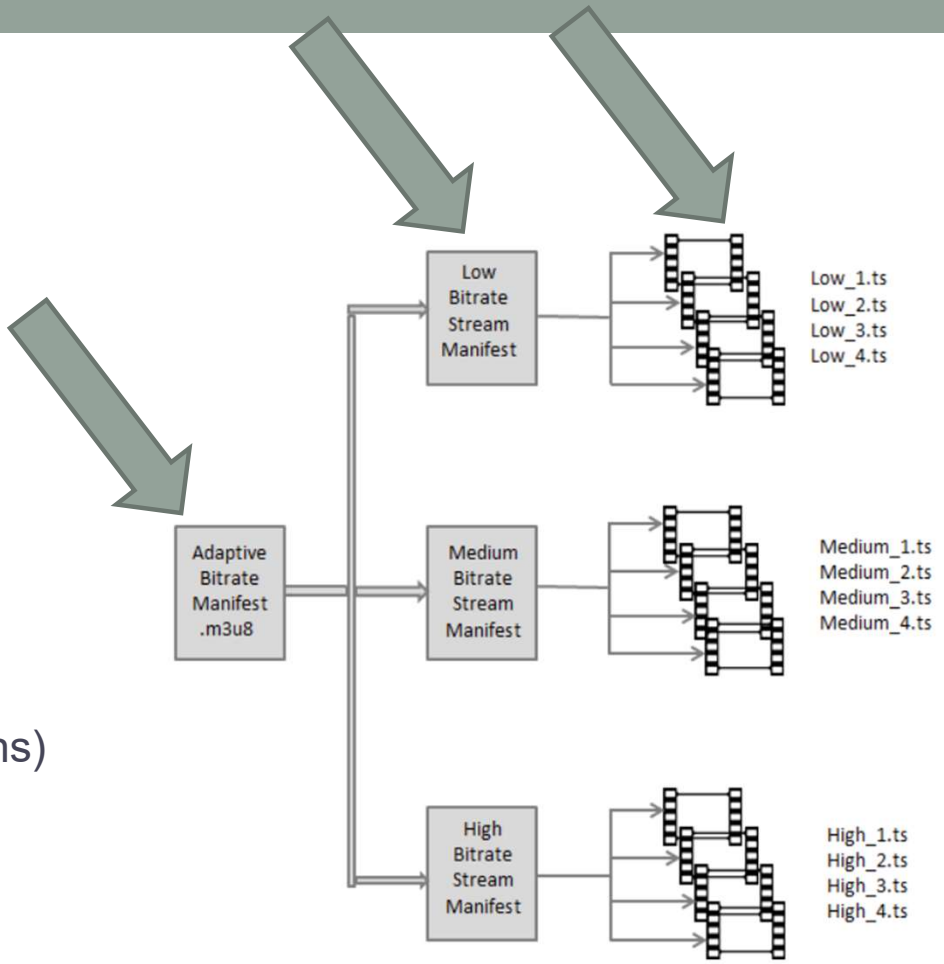
- Adaptive streaming
  - Single input file (live or VOD)
  - Encoded to multiple outputs
- Files are divided into segments (real or virtual)
- Uploaded to web server



https://developers.broadpeak.io/docs/foundations-adaptive-streaming

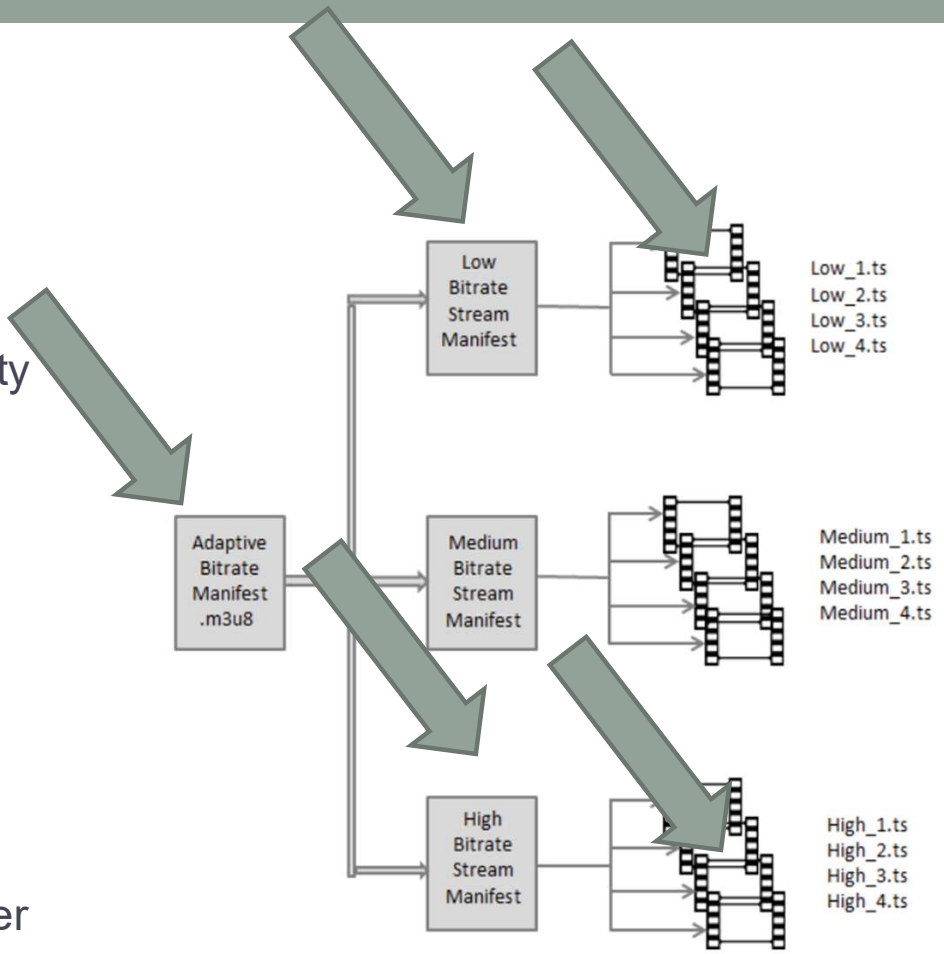
Manifest File Creation

- Playback scheme depends upon two types of manifests
  - Master manifest
    - Identifies location of all content by listing media manifest files
  - Media manifest
    - Each piece of content (audio, video, captions) has its own manifest file
    - These contain locations of all content files

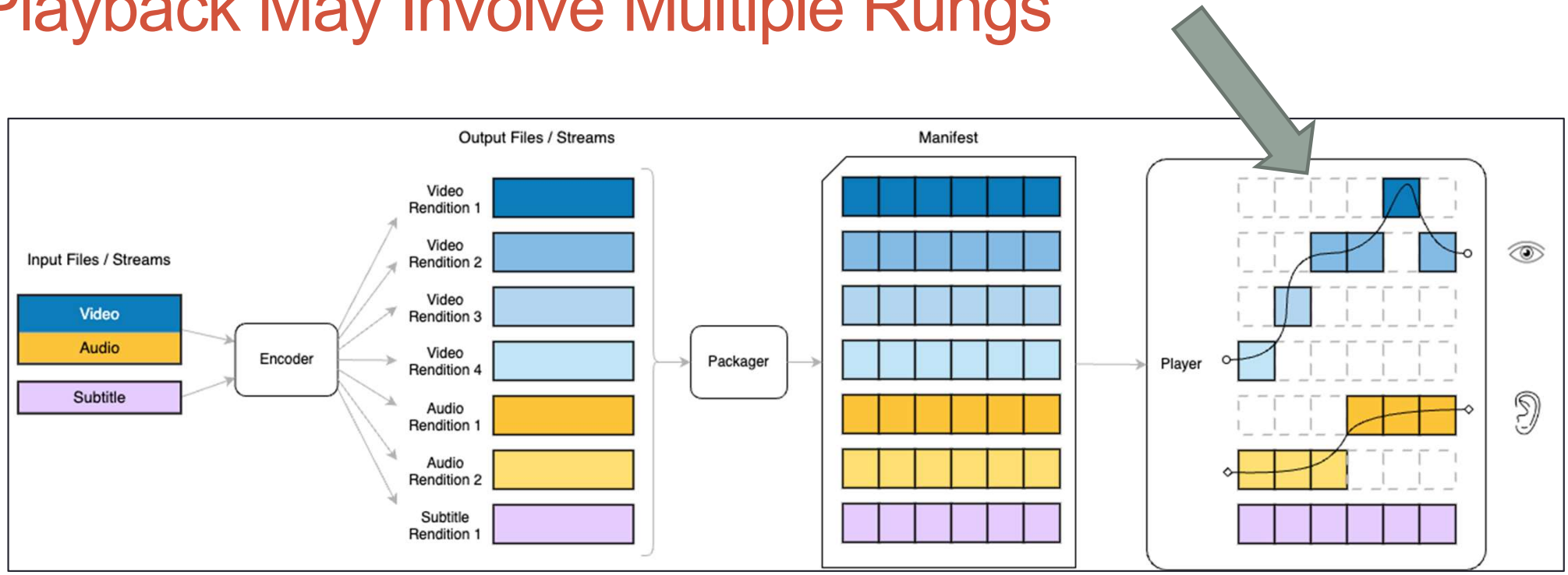


Playback Schema

- Player loads master manifest
  - Chooses best content based on compatibility and bandwidth
- Player loads appropriate media manifest
  - Starts downloading and playing segments
- If conditions change, checks with the master manifest and switches to the best alternative
  - Grabs the next segment from the next ladder rung



Playback May Involve Multiple Rungs



- See path through different rungs
- That's why you may see quality changes during extended playback

ABR Pros, Cons, Usage

- Pros
  - Best experience to all possible viewers
  - Scales more efficiently to handle large viewer counts
- Cons
  - More complex
  - Ladder rungs boost encoding and storage cost

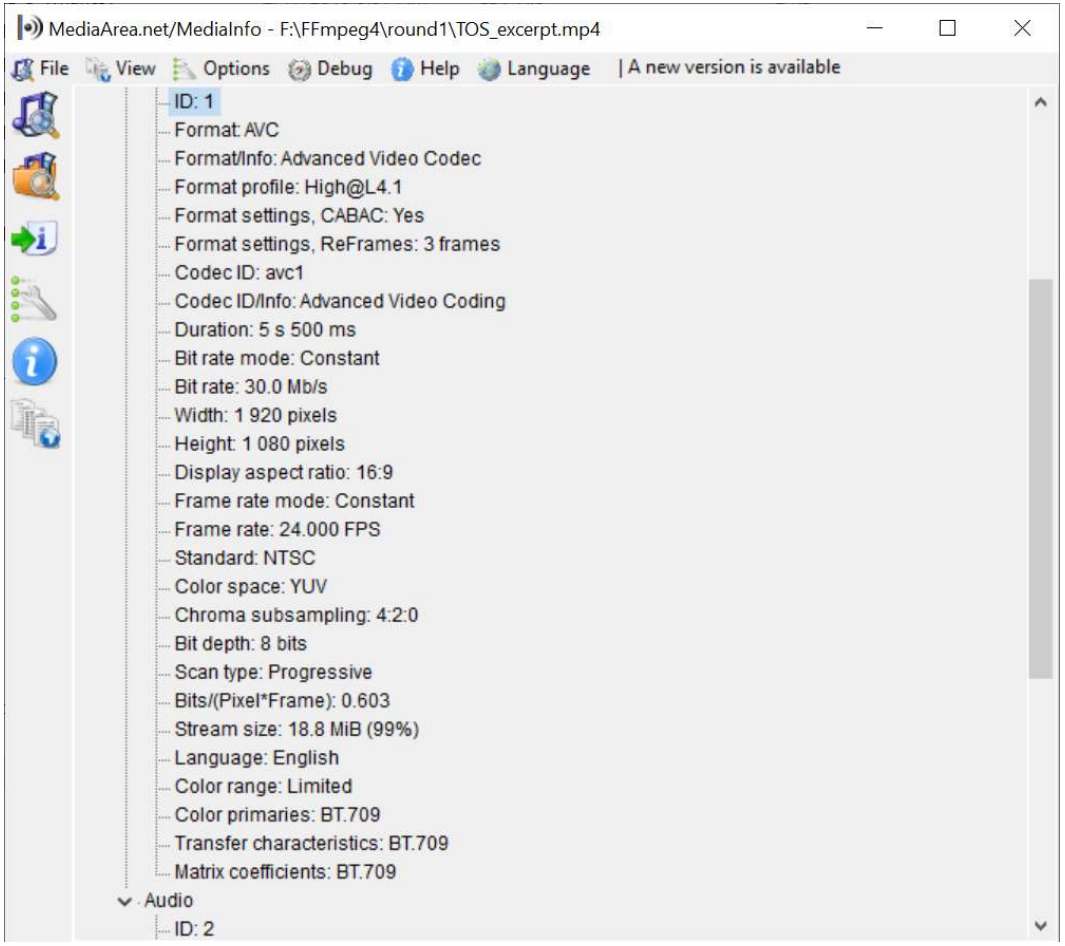
- Who uses
  - Most premium content
  - Most social for long form content

Lesson 6: Essential Tools

- Freebies
  - Bitrate Viewer
  - MediaInfo
  - FFBitrateViewer
- Premium
  - Switch
  - Zond 265

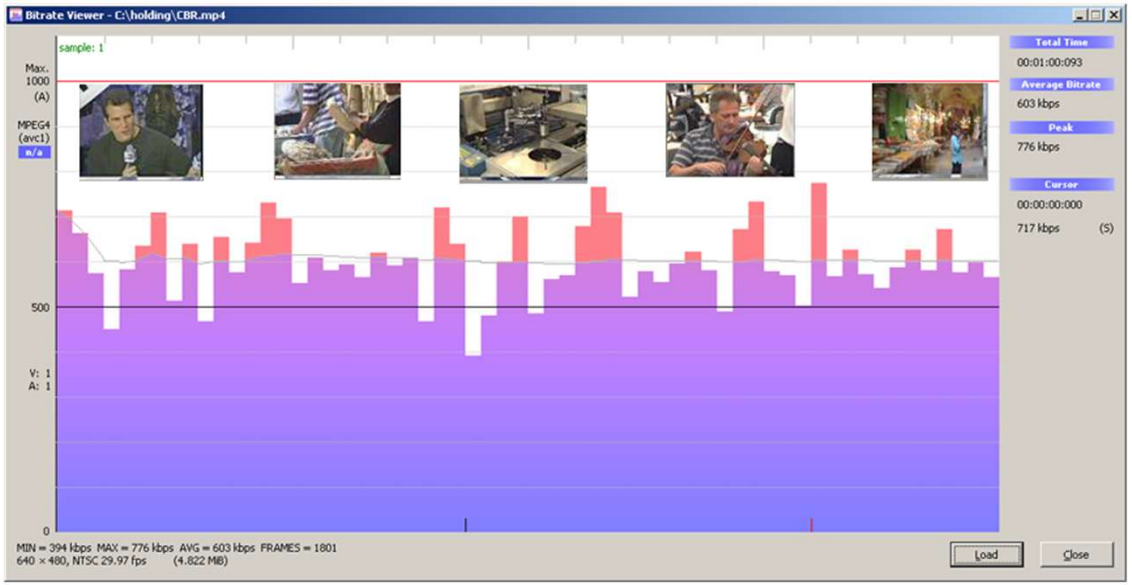
Key Tool - MediaInfo

- **OS:** Win/Mac/Linux/other
- **Function:** Identifies audio/video characteristics like data rate, codec, frame rate, and color space
- **Cost:** Free (Windows/$0.99 Mac)
- **Download:** bit.ly/MediaInfo_BRViewer
- **Buzz kill:** None – you need this on all your computers



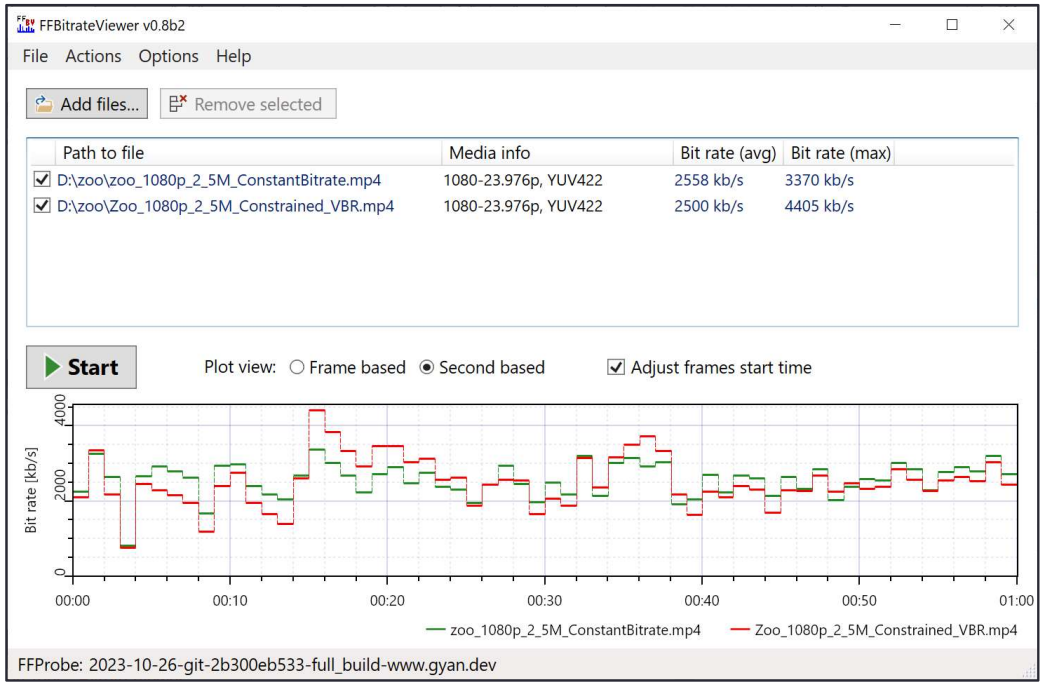
Key Tool – Bitrate Viewer

- **OS:** Windows only
- **Function:** Shows data rate and some file parameters
- **Cost:** Free
- **Download:** bit.ly/MediaInfo_BRViewer
- **Buzz kill:** MPEG-2/H.264 only, no HEVC, VP9, AV1



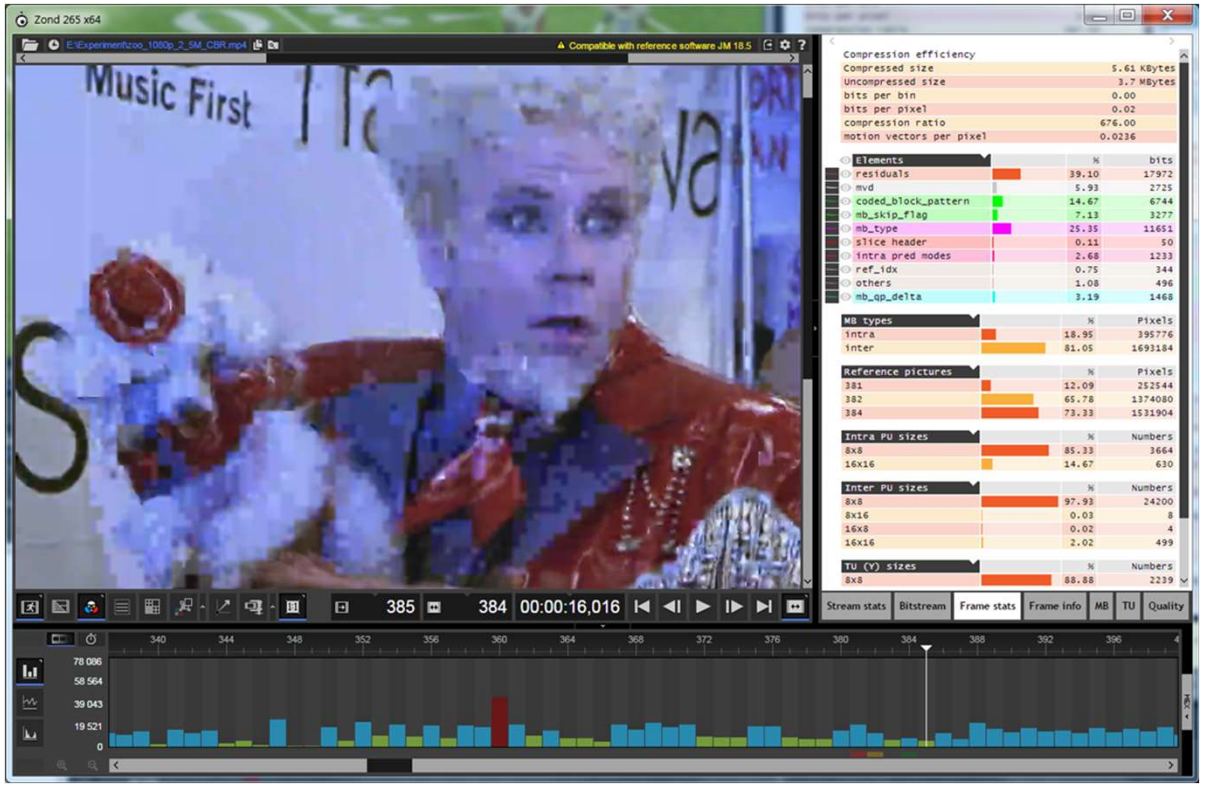
Key Tool – FFBitrateViewer

- **OS:** Windows only
- **Function:** Shows data rate and some file parameters for all FFmpeg compatible codecs
- **Cost:** Free
- **More info:** bit.ly/SLC_FBV
- **Buzz kill:** Graphic could be better; useless for more than 2 files



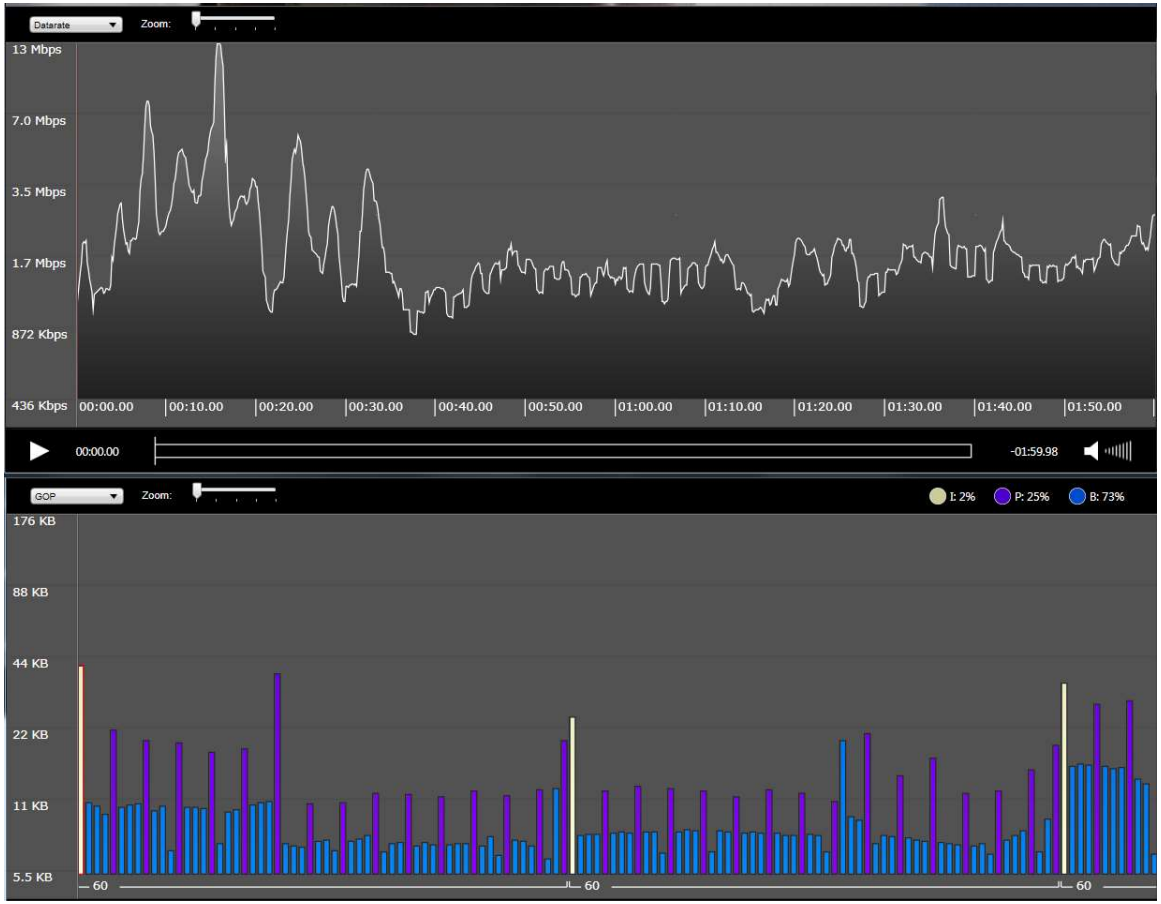
Key Tool – Zond 265

- **OS:** Windows only
- **Function:** Deep encoding parameters, data rate, frame visualization
- **Cost:** $1,390, limited function free version)
- **Info:** https://www.solveigmm.com/en/products/zond/
- **Buzz kill:** Price, though you can't test what you can't measure



Key Tool – Telestream Switch

- **OS:** Windows/Mac
- **Function:** File visualization (VP9/HEVC/H.264)
- **Cost:** $499 for version with these views
- **Info:** http://www.telestream.net/switch/overview.htm
- **Buzz kill:** price



Lesson 7: Introduction to Objective Quality Metrics

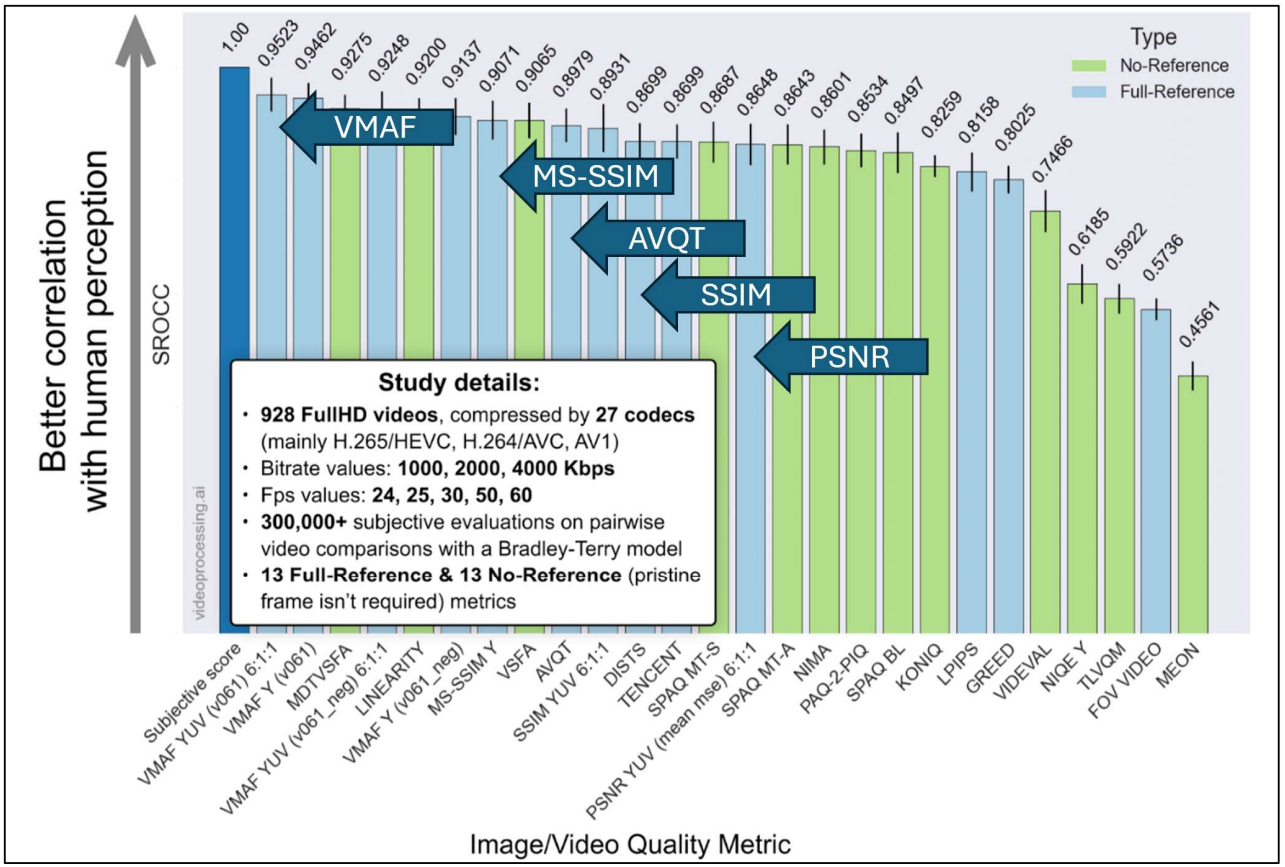
- What they are
- Why we need them
- Getting to know VMAF

What Are Objective Quality Metrics

- Mathematical formulas that (attempt to) predict how human eyes would rate the videos
  - Faster and less expensive
  - Automatable
- Examples
  - Peak Signal to Noise Ratio (PSNR)
  - Structural Similarity Index (SSIM)
  - SSIMPLUS
  - VMAF (Video Multimethod Assessment Fusion)

Which is Most Accurate?

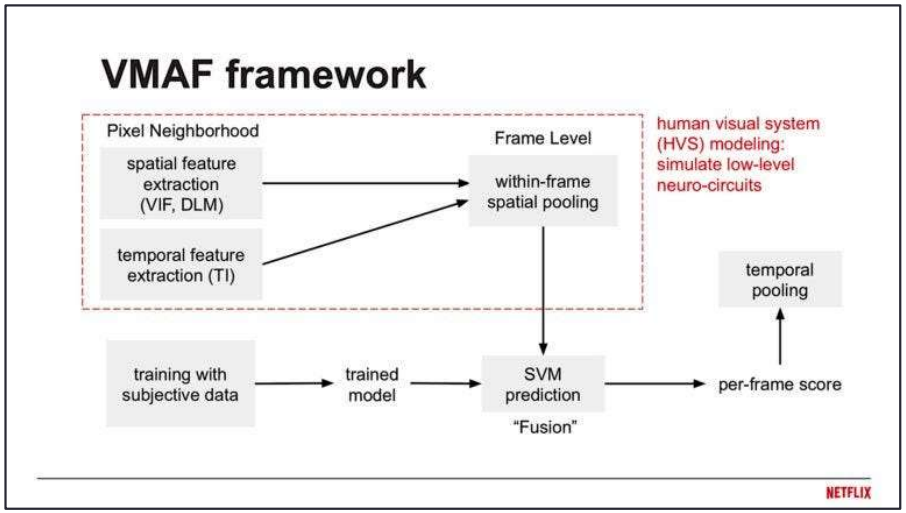
- Moscow State University Ranking
  - Measured correlation with subjective scores
  - See ranking
  - Still, many respected video engineers don't trust VMAF
- VMAF is hackable
  - Can use VMAF NEG
  - Presumably, you won't hack your own tests
- Bottom line:
  - VMAF is primary metric used in book



https://bit.ly/MSU_Dr_V

What is VMAF?

- Combines three existing metrics
  - Visual Information Fidelity (VIF)
  - Detail Loss Metric (DLM)
  - Motion
- Fused using a Support Vector Machine (SVM)-based regression to a single output score ranging from 0–100 per video frame
  - Frame values are averaged to compute a single score
  - 100 is identical to the reference video

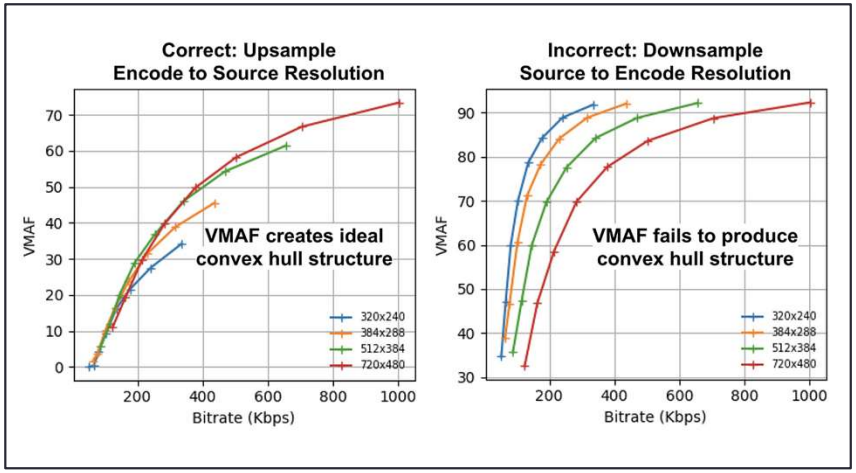


- Developed by Netflix and open-sourced
- Trainable:
  - Improves over time
  - Can be customized for specific video types

Interpreting VMAF Scores

VMAF Score	Human Opinion Scale	Description
0-20	Bad	Lowest quality, highly noticeable issues
21-40	Poor	Subpar quality, noticeable artifacts
41-60	Fair	Acceptable quality, some artifacts
61-80	Good	Good quality, minor artifacts
81-100	Excellent	Highest quality, almost no visible issues

https://bit.ly/VMAF_bestpractices



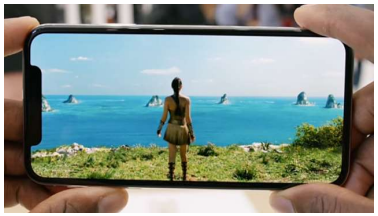
- Top rung target https://bit.ly/VMAF_toprung
  - 93-95 - higher scores not perceivable by viewers (95 is target for most premium content services)
  - Higher scores don't increase QoE so typically represents wasted bandwidth
- Just noticeable difference
  - What scoring delta will 50% or more viewers notice?
    - Netflix – 6 points
    - Researchers – 2 points (seems closer to me)

- Working with lower-resolution videos
  - VMAF can only compute scores for videos with the same resolution
  - So, 640x360 video from 1080p source. Do you:
    - Upscale 360p to 1080p and measure?
    - Downscale source to 360p and measure
  - Upscale to 1080p and measure
    - Most tools know this
    - Important if you're using Ffmpeg or VMAF

VMAF Models

- Original (Default) model
  - Watching 1080p display with the viewing distance of 3x the screen height (3H).
- Phone model
  - Assume viewers watch on a mobile phone
- 4K Model
  - Video displayed on a 4K TV and viewed from a distance of 1.5H
- VMAF NEG (No Enhancement Gain)
  - Disregard image enhancement gain that is not part of the codec (anti-hacking)

1080p display

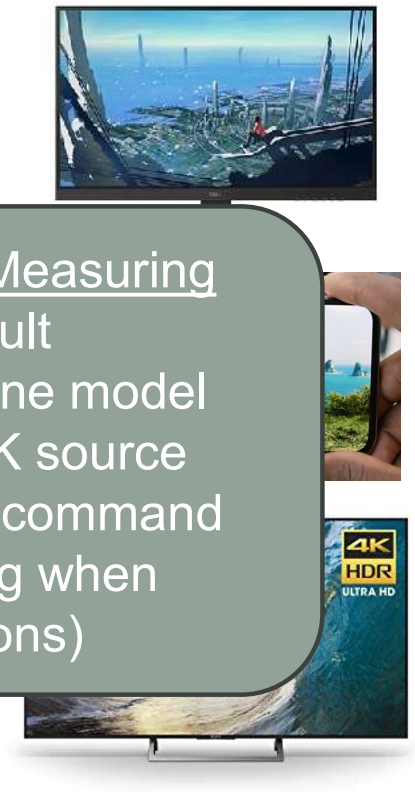


Smartphone

4K display

VMAF Models

- Original (Default) model
  - Watching 1080p display with the viewing distance of 3x the screen height (3H).
- Phone model
  - Assume viewers wa
- 4K Model
  - Video displayed on
    from a distance of 1.
- VMAF NEG (No Enhancement Gain)
  - Disregard image enhancement gain that is not part of the codec (anti-hacking)



1080p display

Smartphone

4K display

Choose Model Before Measuring

- VQMT –Default by default
  - Option to select phone model
- 4K automatically with 4K source
- FFmpeg – set model in command string (easy to get wrong when testing multiple resolutions)

Things VMAF Can’t DO

- High Dynamic Range
  - Netflix has internal HDR version, but hasn’t ported to open-source
  - Shouldn’t use VMAF to measure HDR content
- Videos with different frame rates (30p from 60p source)
  - Can create 30p source and measure VMAF
  - That ignores the additional smoothness of the 60 fps source
- Device specific ratings
  - None beyond phone model
  - IMAX ViewerScore has models for many Smart TVs and mobile devices

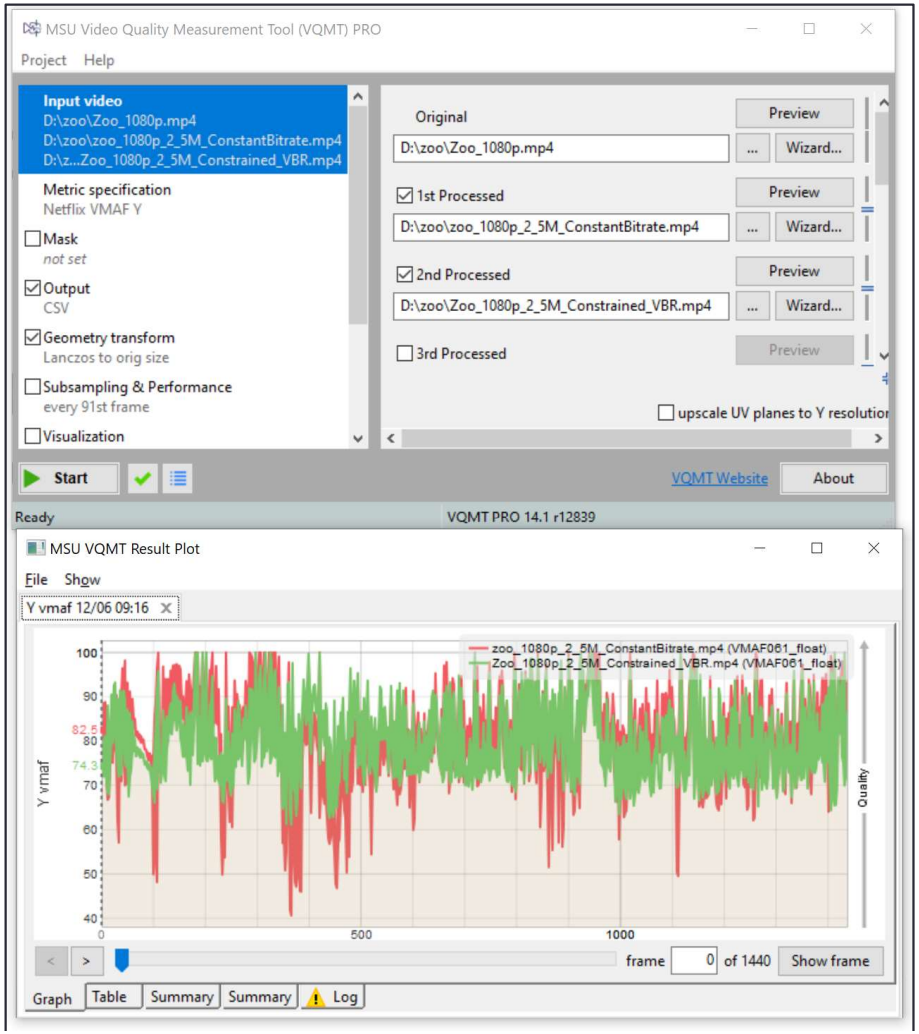
Key Tools for Computing Metrics

- Testing and evaluating
  - MSU VQMT
  - FF Metrics
- Features
  - Compute metrics
  - View scoring over time
  - View frames (VQMT)

- Production encodes
  - FFmpeg
  - Netflix open-source vmaf command line tool
- Features
  - Compute metrics
  - Easy integration into production workflows

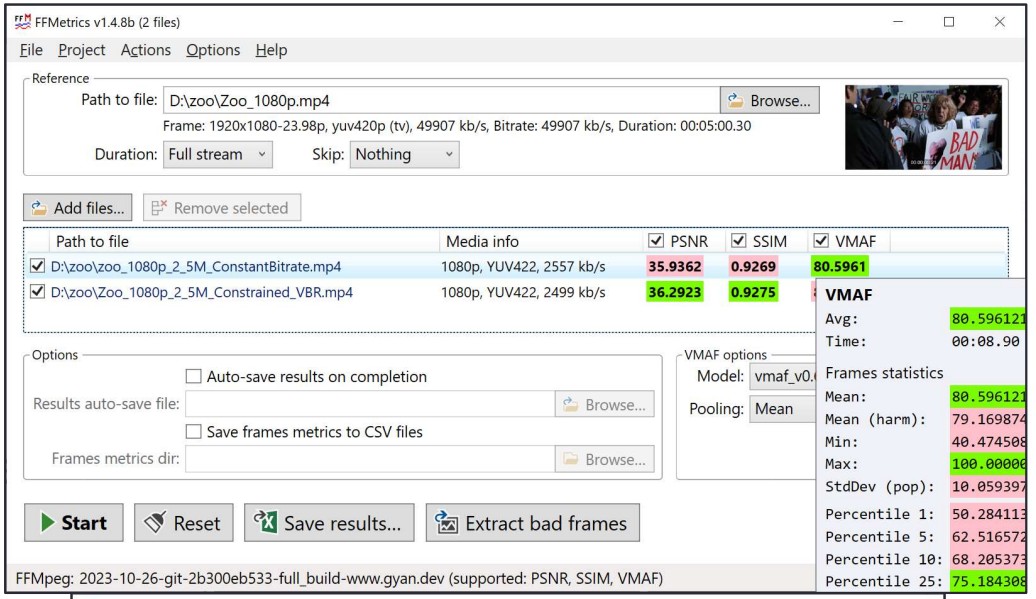
Key Tool – MSU - VQMT

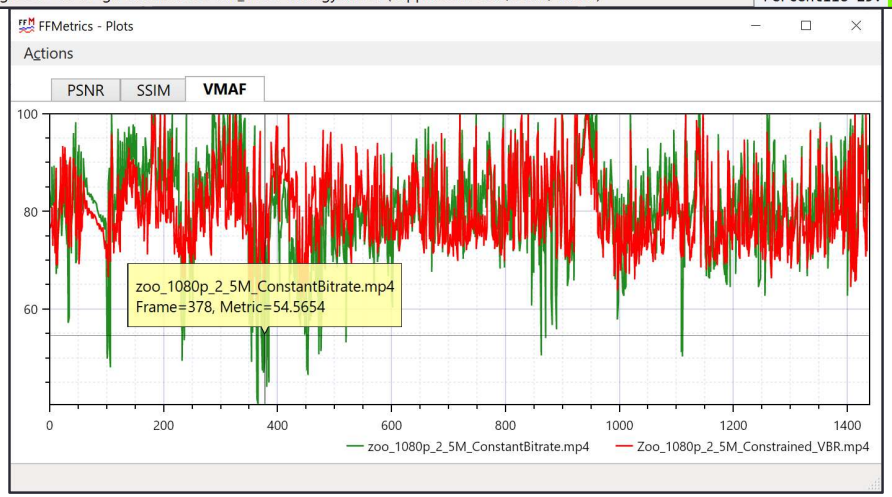
- **OS:** Windows-GUI
- **Function:** Metric calculation and visualization
- **Cost:** $999; limited function free version
- **Info:** https://bit.ly/vqmt_DL
- **Buzz kill:** None – fabulous tool. Free version is a must have. Full version with command line is essential for high-volume work



Key Tool – FFMetrics

- **OS:** Windows-GUI
- **Function:** Metric calculation and visualization
- **Cost:** free
- **Info:** bit.ly/ffmetrix_howto
- **Buzz kill:** can't visualize frames



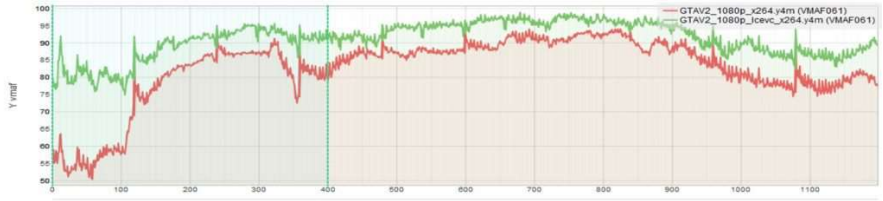


Common Errors Obscured by Automated VQ Assessment

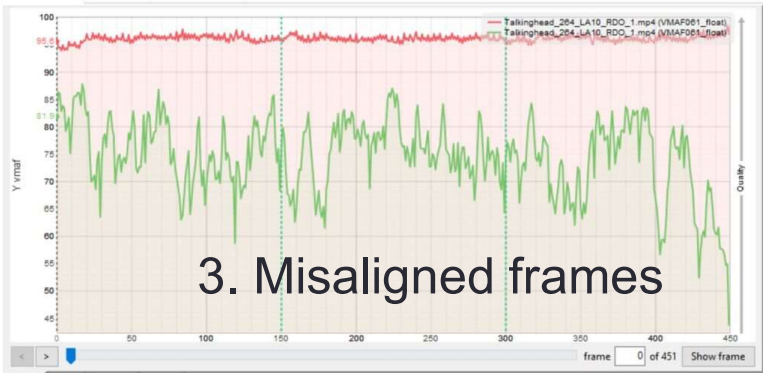
Home » Encoding » Common Errors Obscured by Automated Video Quality Assessment

Figure 3. Low-frame scores indicate a significant differential between the three encoding technologies.

COMMON ERRORS OBSCURED BY AUTOMATED VIDEO QUALITY ASSESSMENT



2. Start up issues that degrade score on short test files



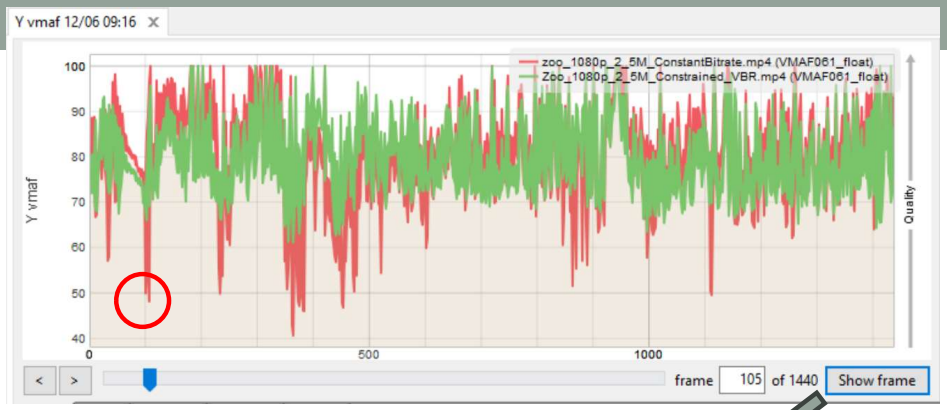
4. Low-frame scores that don't matter

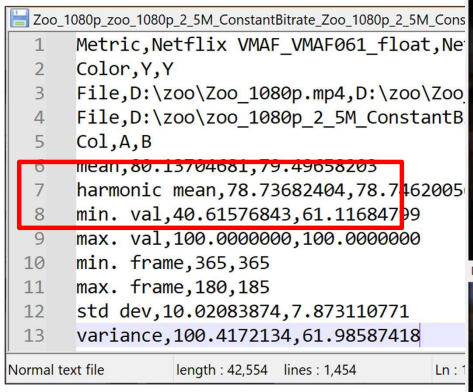
- fade to black transitions

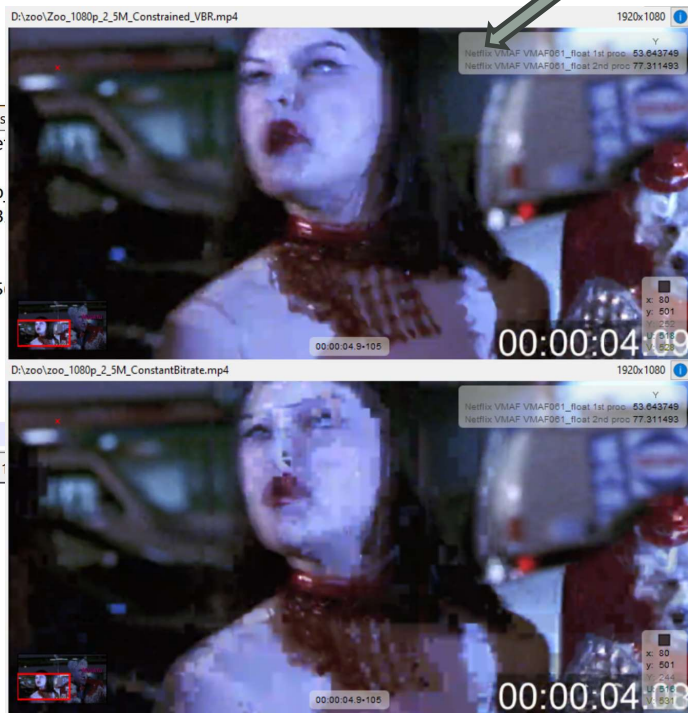
5. Apply the wrong model (default, not 4K)

Bottom Line Best Practices

- Encode file
  - Verify key parameters
    - Data rate
    - Other tested parameters
- Compute metric; consider
  - Harmonic mean average score
  - Low-frame score
- View results
  - Check results plot
  - Check frames







How Metrics Used in Production

- Metrics integrated with production
  - Netflix – VMAF helps create encoding ladders for all videos
  - Beamr – Internal metric controls encoding quality
  - Codec Market – VMAF directs per-title encoding quality
  - IMAX – IMAX ViewerScore directs per-title encoding quality

How Used in the Encoding by the Numbers

- Choose target bitrates for test files

Adjust data rate for each file

CRF23 - 1080p	FPS	Description	Data Rate	VMAF
Tears of Steel	24	Real world/CG movie	4,747	96.45
Sintel	24	Complex animation	5,168	96.96
Big Buck Bunny	30	Simple animatio	3,657	96.88
Screencam	30		1,625	96.59
Tutorial	30		1,001	96.68
Talking Head	30	Simple talking he	2,706	95.47
Freedom	30	Concert footag	5,527	95.90
Haunted	30	DSLR movie-like production	6,111	92.74
Average			**3,818**	**95.96**
Standard deviation				**1.39**

83% lower than top bitrate

VMAF target is 93-95

How Used in the Encoding by the Numbers

- Choose target bitrates for test files
- Compare codecs

x264/x265

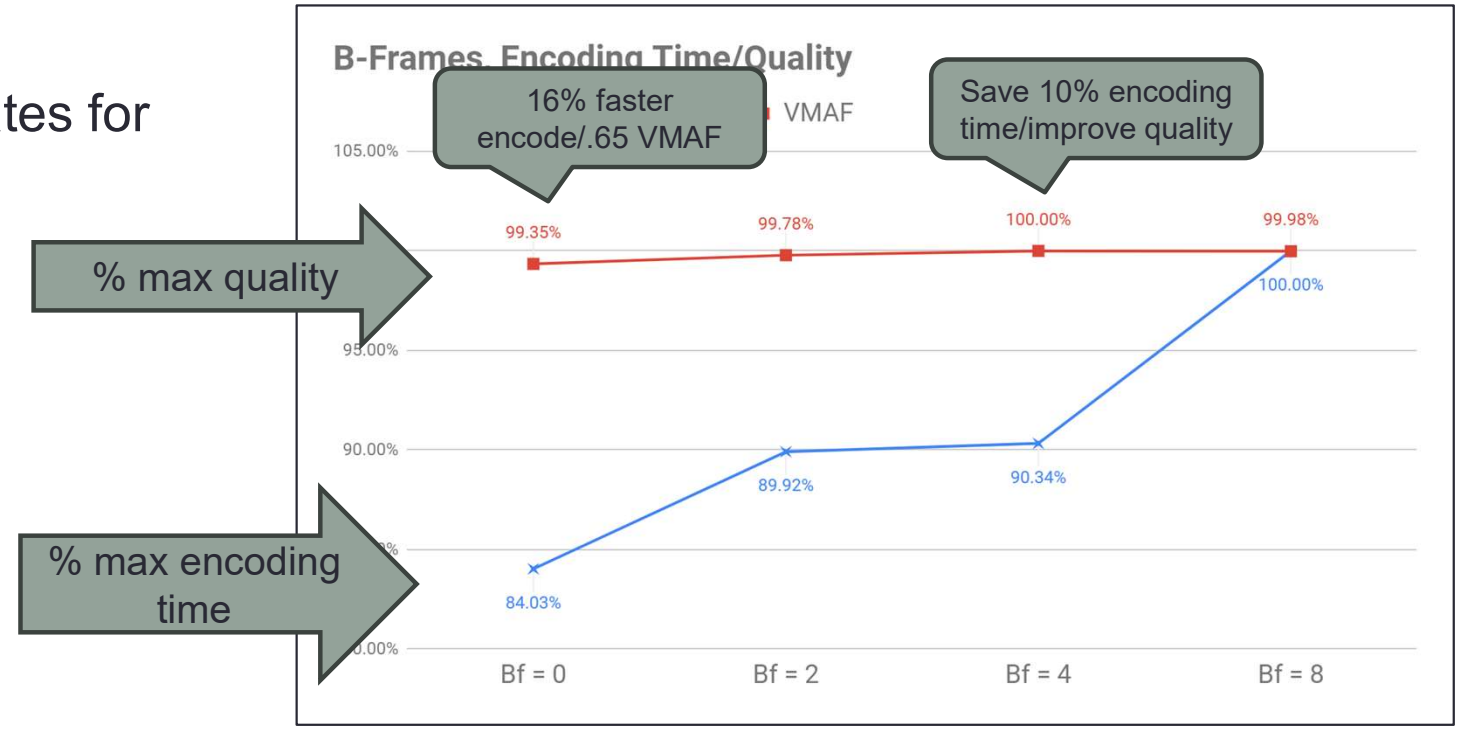
		x265		x264		Analysis	
CRF23 - 1080p	**FPS**	**Data Rate**	**VMAF**	**Data Rate**	**VMAF**	**Data Rate**	**VMAF**
Tears of Steel	24	3,335	96.83	4,747	96.45	29.75%	0.39%
Sintel	24	3,869	97.39	5,168	96.96	25.14%	0.44%
Big Buck Bunny	30	2,815	96.90	3,657	96.88	23.02%	0.02%
Screencam	30	1,056	96.49	1,625	96.59	35.02%	-0.10%
Tutorial	30	816	96.92	1,001	96.68	18.48%	0.24%
Talking Head	30	2,004	95.52	2,706	95.47	25.94%	0.05%
Freedom	30	4,759	96.21	5,527	95.90	13.90%	0.32%
Haunted	30	4,566	93.21	6,111	92.74	25.28%	0.51%
Average		**2,903**	**96.18**	**3,818**	**95.96**	**24.57%**	**0.23%**

~ Same VMAF Quality

Bitrate savings (old numbers)

How Used in the Encoding by the Numbers

- Choose target bitrates for test files
- Compare codecs
- Compare encoding parameters
  - B-frames



Test different B-frame configs

Metrics make you informed, rather than simply opinionated

Metrics make you informed, rather than simply opinionated

They’re not perfect, but they are better than nothing

Questions?