

Contents

Acknowledgments	4
Introduction	14
About Objective Quality Benchmarks	15
Overview of Objective Benchmarks and Tools	16
<i>Our Test Case</i>	18
<i>Peak Signal-to-Noise Ratio (PSNR)</i>	18
<i>Video Quality Metric (VQM)</i>	19
<i>Multi-scale Structural Similarity Metric (MS SSIM)</i>	20
<i>SSIMplus</i>	20
<i>Picture Quality Rating</i>	21
<i>Attention Weighted Difference Mean Opinion Score (AW DMOS)</i>	22
<i>Netflix VMAF</i>	23
How to Use Objective Metrics	24
How to Use this Book	25
<i>What's in this Book?</i>	26
Chapter 1: Technology Fundamentals	28
Compression and Codecs	28
<i>What's a Codec?</i>	29
<i>Choosing a Codec</i>	31
Choosing the Container Format	32
Distribution Alternatives	34
<i>Progressive Download</i>	34
<i>Streaming</i>	35
<i>Adaptive Bitrate (ABR) Streaming</i>	36
Chapter 2: Basic File Parameters	38
Overview	39
Video Resolution	40
<i>A Brief Word About Mod-16</i>	41
Frame Rate	42
Bitrate (or Data Rate)	42
<i>Bandwidth</i>	43
<i>Compression and Ben and Jerry's Ice Cream</i>	44
Bits Per Pixel	44
<i>Applying Bits per Pixel</i>	47
Encoding in FFmpeg	49
<i>FFmpeg Basics</i>	49

<i>Computing PSNR with FFmpeg</i>	50
Chapter 3: Essential Tools	51
MedialInfo	52
Bitrate Viewer	54
QuickTime Player 7	54
Telestream Switch	55
VLC Media Player	56
Beamr Video Comparison Tool (VCT)	56
HandBrake	57
FFmpeg	58
Charles Web Debugging Proxy	58
Zond 265	59
Chapter 4: Testing Overview	61
Creating Your Test Clips	61
<i>Selecting Your Test Clips</i>	62
<i>Producing the Test Clips</i>	63
Encode Your Clips	64
Verify Encodes	65
<i>Data Rate</i>	65
<i>Bitrate Control</i>	66
<i>Choose Test Program and Algorithm</i>	68
<i>Collect and Present the Results</i>	69
<i>Check the Actual Video Files</i>	71
<i>Retest As Needed</i>	72
<i>Get a Hefty Workstation</i>	72
Chapter 5: Working with MSU VQMT	74
Driving the GUI	75
<i>Loading Files</i>	75
<i>Choosing the Metric and Test Options</i>	78
<i>The Results Visualization Screen</i>	79
<i>Viewing the Frames</i>	80
<i>Viewing the Scores</i>	81
Working the Command Line	82
<i>Introduction to Batch File Creation and Operation</i>	84
<i>Essential Command Line Commands</i>	85
<i>Running VQMT from the Command Line</i>	86
<i>Working with YUV and Y4M Files</i>	87
<i>Working with YUV Files</i>	88

Converting with FFmpeg	88
<i>Scaling in FFmpeg</i>	89
Eliminating Excess Frames	90
Low Frame Quality	92
Chapter 6: Working with SQM	94
SQM's Unique Features	95
Driving the GUI	95
<i>Loading Files</i>	95
<i>Viewing the Results</i>	98
Running SQM in Batch Mode	99
<i>Creating the Batch File</i>	99
<i>Loading Batch File</i>	100
Running SQM in Command Line Interface Mode	102
<i>Creating Batch Files</i>	102
Visualizing Your Results	103
<i>Opening Visualizer and Loading Files</i>	103
Chapter 7: Choosing Data Rate	106
Finding the Appropriate Data Rate	106
<i>Netflix Per-title Encode Optimization</i>	107
Constant Rate Factor (CRF) Encoding	108
<i>About CRF Encoding</i>	109
<i>Using CRF</i>	110
<i>My Test Clips</i>	110
<i>Encoding with CRF</i>	111
1080p Results	112
<i>Hollywood Confirmation</i>	113
<i>How Low Should You Go?</i>	115
<i>Finding the Number</i>	117
720p Results	119
<i>How Does Hollywood Encode 720p Files?</i>	121
360p Results	122
CRF Encoding in FFmpeg	124
<i>Applying These Findings</i>	125
Two Other Applications	126
<i>Uploading Mezzanine Clips</i>	126
<i>Optimal Data Rate for Live Events</i>	127
Summary and Conclusion	128
Chapter 8: Bitrate Control	129

Techniques Defined	130
<i>CBR Defined</i>	131
<i>VBR and Constrained VBR</i>	132
<i>CBR Versus VBR Quality</i>	133
<i>Overall Results</i>	133
<i>Lowest -quality Frame Analysis</i>	135
<i>200 Percent Constrained VBR to the Rescue?</i>	138
Other Factors in Bitrate Control Selection	139
<i>VBR and CBR Deliverability</i>	142
<i>Balancing Quality and Deliverability</i>	143
Producing CBR	144
Producing VBR	145
Working with VBV	146
<i>Bitrate Control with the VBV Settings</i>	147
<i>VBV, Quality, and Stream Variability</i>	148
<i>Maximum Buffer in Practice</i>	150
<i>Applying These Findings</i>	151
Bitrate Control and Buffer Size in FFmpeg	152
<i>Two-Pass Encoding in FFmpeg</i>	153
<i>200 Percent Constrained VBR Encoding in FFmpeg</i>	154
<i>110 Percent Constrained VBR Encoding in FFmpeg</i>	155
Summary and Conclusion	156
Chapter 9: I-, B-, P-, and Reference Frames	157
Frame Overview	157
<i>The Hunt for Redundant Blocks</i>	158
Working with I-frames	159
<i>I-frames and Single Files</i>	159
<i>I-frames and Scene Change Detection</i>	160
<i>I-frames and Adaptive Streaming</i>	161
<i>Instantaneous Decode Refresh (IDR) Frames</i>	162
Working with B-frames	163
<i>B-Frames and Compatibility</i>	167
Reference Frames	168
<i>Reference Frames and Transient Quality</i>	170
<i>Reference Frames and Encoding Time</i>	170
Encoding Slices	171
Applying These Findings	173
I-, B-, and Reference Frames in FFmpeg	173

<i>I-frame Controls in FFmpeg</i>	173
<i>I-frames at Specified Interval and Scene Changes</i>	174
<i>B-frames in FFmpeg</i>	175
<i>Reference Frames in FFmpeg</i>	176
Chapter 10: Encoding H.264	177
What Is H.264?	178
<i>Container Formats</i>	180
<i>Other H.264 Details</i>	180
<i>H.264 Royalties</i>	181
<i>Comparing H.264 with Other Codecs</i>	182
Basic H.264 Encoding Parameters	183
<i>Profiles and Levels</i>	183
<i>Comparative Quality—Baseline, Main and High Profiles</i>	185
<i>CPU Required for Playback—Baseline, Main, and High Profiles</i>	186
H.264 Levels	188
<i>Levels and Computers/OTT</i>	189
<i>Levels and Encoding Tools</i>	189
<i>Entropy Coding</i>	190
All H.264 Encoders are Not Created Equal	193
<i>x264 Presets and Tuning</i>	193
<i>x264 Presets</i>	194
Tuning Mechanisms	199
<i>Animation Tuning</i>	199
<i>Film and Grain Tuning</i>	200
Working in FFmpeg	200
<i>Choosing Profiles in FFmpeg</i>	200
<i>Setting Levels in FFmpeg</i>	201
<i>Setting Entropy Encoding (CABAC versus CAVLC)</i>	202
<i>Choosing an x264 Preset</i>	202
<i>Choosing an x264 Tuning Mechanism</i>	202
Chapter 11: Encoding HEVC	203
Technology Background	203
<i>How HEVC Works</i>	204
<i>Standard versus Codec</i>	206
<i>Packaging HEVC</i>	207
<i>How Much Does HEVC Cost?</i>	207
<i>Where Will HEVC Play?</i>	209
<i>Comparing HEVC and VP9</i>	211
<i>Comparing HEVC and H.264</i>	212
<i>4K and 2K Results</i>	214
<i>Encoding Time</i>	214
Basic HEVC Encoding Parameters	216
<i>HEVC Profiles</i>	217
<i>About High Dynamic Range (HDR)</i>	218

<i>x265 Presets</i>	220
<i>Adobe Media Encoder Presets</i>	221
Applying These Findings	222
Encoding x265 in FFMpeg	222
<i>HEVC Profiles</i>	222
<i>x265 Presets</i>	223
<i>Other Commands</i>	223
<i>x265 Sample Scripts</i>	223
Chap 12: Working With VP9	224
Technology Background	224
<i>Packaging VP9</i>	225
<i>VP9 Intellectual Property Status</i>	225
<i>Where Does VP9 Play?</i>	226
IPTV	229
<i>Comparing VP9 to H.264</i>	230
<i>Comparing VP9 to HEVC</i>	230
<i>4K and 2K Results</i>	231
Basic VP9 Encoding Parameters	232
<i>Bitrate Control</i>	233
<i>Other Configuration Options</i>	235
<i>Threads</i>	236
<i>Speed</i>	237
<i>Frame Parallel</i>	238
<i>Tiles/Columns</i>	239
<i>AUTO-ALT-REF</i>	239
<i>Lag-In-Frames</i>	240
<i>Advice from the Stars</i>	240
<i>Sample Scripts</i>	241
Chapter 13: Choosing an ABR Technology	243
<i>Delivering to Computers via HTML5</i>	243
<i>What is HTML5?</i>	244
<i>HTML5 Generation 1</i>	245
<i>HTML5 Generation 2</i>	246
<i>Pulling It All Together</i>	249
<i>MSE/EME: Where Do We Stand?</i>	250
<i>Working with EME and Multiple DRMs</i>	250
Going Forward with HTML5	251
<i>Choosing a Codec for Browser-based Delivery</i>	252
<i>Encoding for Browser-based Playback</i>	253
Distributing to Mobile	254
<i>Common Media Application Format (CMAF)</i>	255
Adaptive Streaming to OTT Devices	256
Adaptive Streaming to Smart TVs	257
<i>Summary</i>	258

Chapter 14: Configuring Your Encoding Ladder	259
<i>From Segments to Byte-range Requests</i>	261
Building Your Encoding Ladder	262
<i>Per-title, Per-category, or One-size-fits-all?</i>	262
<i>One Ladder for All, or Target-specific Ladders?</i>	263
<i>Choose Mobile First</i>	267
<i>Then Browser-based Streams</i>	267
<i>OTT and Full-screen Playback Last</i>	269
<i>Other Considerations</i>	269
<i>More on Choosing Data Rate</i>	273
Other Configuration Items	273
<i>Choosing the H.264 Profile</i>	274
<i>CBR or VBR</i>	274
<i>Key Frame Interval and Segment Size</i>	275
<i>Audio Parameters</i>	278
HLS Specific Recommendations	279
Chapter 15: Encoding and Packaging ABR Streams	280
Encoding and Packaging	281
<i>Implementing Two-step Encoding/Packaging</i>	283
<i>Static Packaging</i>	283
<i>Dynamic Packaging</i>	283
<i>Dynamic Packaging with Wowza</i>	285
<i>Enterprise Encoders</i>	286
Multiple-file Encoding in FFmpeg	287
1. <i>When can you use the first pass more than once?</i>	288
2. <i>Which parameters need to be in the first and second pass?</i>	289
3. <i>Which parameters do you include in the first pass?</i>	289
<i>Extracting Audio or Video</i>	290
<i>Putting it All Together</i>	290
<i>Packaging HLS Files</i>	291
<i>Packaging Existing MP4 Files</i>	291
<i>Creating HLS Output from Scratch</i>	292
<i>Creating the Master Playlist File</i>	293
Working With Apple Tools	296
<i>Media File Segmenter</i>	296
<i>Variant Playlist Creator</i>	298
<i>Media Stream Validator</i>	299
<i>Packaging for DASH with MP4Box</i>	301
Chapter 16: Per-title Encoding	304
Netflix and Per-title Encoding	304
<i>Creating the Encoding Ladder</i>	305
<i>Applying the Netflix Technique</i>	306

YouTube and Per-title Encoding	308
Per-title Encoding with Capella Systems Cambria	309
<i>How Did SABL Perform?</i>	311
Category-specific Encoding	312
Ad Hoc Per-title Encoding	313
Capped CRF Encoding	314