

 John Watkinson

# THE **MPEG** HANDBOOK

Second Edition

The MPEG Handbook includes:

- The MPEG-4 standard fully revised to include MPEG-4 Part 10/H.264/AVC
- MPEG and networks
- Extensive examples of applications.

Review of previous edition:  
...provides everything you need to know about compression.'

Digital Technology



# Contents

---

<i>Preface</i>	xi
<i>Acknowledgements</i>	xii
<b>Chapter 1 Introduction to compression</b>	<b>1</b>
1.1 What is MPEG?	1
1.2 Why compression is necessary	3
1.3 MPEG-1, 2, 4 and H.264 contrasted	4
1.4 Some applications of compression	5
1.5 Lossless and perceptive coding	7
1.6 Compression principles	9
1.7 Video compression	14
1.7.1 Intra-coded compression	16
1.7.2 Inter-coded compression	16
1.7.3 Introduction to motion compensation	18
1.7.4 Film-originated video compression	19
1.8 Introduction to MPEG-1	21
1.9 MPEG-2: Profiles and Levels	21
1.10 Introduction to MPEG-4	24
1.11 Introduction to H.264 (AVC)	26
1.12 Audio compression	28
1.12.1 Sub-band coding	28
1.12.2 Transform coding	28
1.12.3 Predictive coding	29
1.13 MPEG bitstreams	29
1.14 Drawbacks of compression	30
1.15 Compression pre-processing	32
1.16 Some guidelines	32
References	33

## **Chapter 2 Fundamentals**

35

2.1	What is an audio signal?	35
2.2	What is a video signal?	35
2.3	Types of video	36
2.4	What is a digital signal?	38
2.5	Sampling	41
2.6	Reconstruction	46
2.7	Aperture effect	50
2.8	Choice of audio sampling rate	52
2.9	Video sampling structures	56
2.10	The phase-locked loop	58
2.11	Quantizing	60
2.12	Quantizing error	61
2.13	Dither	65
2.14	Introduction to digital processing	67
2.15	Logic elements	69
2.16	Storage elements	71
2.17	Binary coding	73
2.18	Gain control	84
2.19	Floating-point coding	85
2.20	Multiplexing principles	87
2.21	Packets	88
2.22	Statistical multiplexing	88
2.23	Timebase correction	89
	References	91

## **Chapter 3 Processing for compression**

92

3.1	Introduction	92
3.2	Transforms	95
3.3	Convolution	97
3.4	FIR and IIR filters	97
3.5	FIR filters	100
3.6	Interpolation	107
3.7	Downsampling filters	116
3.8	The quadrature mirror filter	117
3.9	Filtering for video noise reduction	121
3.10	Warping	123
3.11	Transforms and duality	129
3.12	The Fourier transform	132
3.13	The discrete cosine transform (DCT)	138
3.14	The wavelet transform	140
3.15	The importance of motion compensation	147

3.16	Motion-estimation techniques	150
3.16.1	Block matching	150
3.16.2	Gradient matching	152
3.16.3	Phase correlation	153
3.17	Motion-compensated displays	158
3.18	Camera-shake compensation	159
3.19	Motion-compensated de-interlacing	161
3.20	Compression and requantizing	162
	References	167

## Chapter 4 Audio compression

4.1	Introduction	169
4.2	The deciBel	170
4.3	Audio level metering	175
4.4	The ear	177
4.5	The cochlea	180
4.6	Level and loudness	182
4.7	Frequency discrimination	183
4.8	Critical bands	184
4.9	Beats	187
4.10	Codec level calibration	188
4.11	Quality measurement	189
4.12	The limits	191
4.13	Compression applications	192
4.14	Audio compression tools	192
4.15	Sub-band coding	197
4.16	Audio compression formats	198
4.17	MPEG audio compression	199
4.18	MPEG Layer I audio coding	201
4.19	MPEG Layer II audio coding	206
4.20	MPEG Layer III audio coding	208
4.21	MPEG-2 AAC – advanced audio coding	212
4.22	Dolby AC-3	218
4.23	MPEG-4 audio	219
4.24	MPEG-4 AAC	220
4.25	Compression in stereo and surround sound	221
	References	227

## Chapter 5 MPEG video compression

5.1	The eye	230
5.2	Dynamic resolution	234
5.3	Contrast	238
5.4	Colour vision	240
5.5	Colour difference signals	240
5.6	Progressive or interlaced scan?	245

5.7	Spatial and temporal redundancy in MPEG	250
5.8	<i>I</i> and <i>P</i> coding	255
5.9	Bidirectional coding	256
5.10	Coding applications	259
5.11	Intra-coding	260
5.12	Intra-coding in MPEG-1 and MPEG-2	265
5.13	A bidirectional coder	270
5.14	Slices	274
5.15	Handling interlaced pictures	275
5.16	MPEG-1 and MPEG-2 coders	281
5.17	The elementary stream	282
5.18	An MPEG-2 decoder	283
5.19	MPEG-4 and AVC	286
5.20	Video objects	288
5.21	Texture coding	291
5.22	Shape coding	297
5.23	Padding	299
5.24	Video object coding	301
5.25	Two-dimensional mesh coding	303
5.26	Sprites	308
5.27	Wavelet-based compression	310
5.28	Three-dimensional mesh coding	315
5.29	Animation	324
5.30	Scalability	326
5.31	Advanced Video Coding (AVC)	328
5.32	Motion compensation in AVC	335
5.33	An AVC codec	337
5.34	AVC profiles and levels	340
5.35	Coding artifacts	340
5.36	MPEG and concatenation	346
	References	352

<b>Chapter 6</b>	<b>MPEG bitstreams</b>	<b>353</b>
------------------	------------------------	------------

6.1	Introduction	353
6.2	Packets and time stamps	355
6.3	Transport streams	357
6.4	Clock references	359
6.5	Program Specific Information (PSI)	361
6.6	Multiplexing	362
6.7	Remultiplexing	364
	Reference	365

<b>Chapter 7</b>	<b>MPEG applications</b>	<b>366</b>
------------------	--------------------------	------------

7.1	Introduction	366
7.2	Telephones	367

7.3	Digital television broadcasting	368
7.4	The DVB receiver	381
7.5	ATSC	383
7.6	CD-Video and DVD	389
7.7	Personal video recorders	394
7.8	Networks	397
7.9	FireWire	405
7.10	Broadband networks and ATM	407
7.11	ATM AALs	411
	References	414

<i>Index</i>	415
--------------	-----