

# Contents

## **Analysis and Synthesis of Auditory Scenes**

<i>Jens Blauert</i> . . . . .	1
1 Introduction . . . . .	1
1.1 Some Reminiscing . . . . .	1
1.2 The Classical Paradigm of Communication Technology . . . . .	3
1.3 Splitting Up the Classical Transmission Chain . . . . .	4
2 Analysis of Auditory Scenes . . . . .	5
2.1 Quality Recognition and Assessment . . . . .	7
2.2 “Cocktail-Party Processing” . . . . .	8
2.3 Paradigmatic Consequences . . . . .	11
3 Synthesis of Auditory Scenes . . . . .	12
3.1 Binaural Room Simulation . . . . .	14
3.2 Virtual-Environment Generation . . . . .	15
4 Discussion and Conclusions . . . . .	18
References . . . . .	20

## **Evolutionary Adaptations for Auditory Communication**

<i>Georg Klump</i> . . . . .	27
1 Introduction . . . . .	27
2 Sender Adaptations . . . . .	28
3 Coping with the Properties of the Transmission Channel . . . . .	29
4 Receiver Adaptations . . . . .	30
4.1 Auditory Non-Linearities and Gain-Control Mechanisms . . . . .	30
4.2 Frequency Selectivity . . . . .	33
4.3 Sound Localization . . . . .	35
5 Auditory Scene Analysis . . . . .	37
6 Concluding Remarks . . . . .	40
References . . . . .	41

## **A Functional View on the Peripheral Human Hearing Organ**

<i>Herbert Hudde</i> . . . . .	47
1 Introduction . . . . .	47
2 Cochlea . . . . .	51
3 Ear Canal and Middle Ear . . . . .	56
4 Direct Bone Conduction to the Cochlea . . . . .	68

VIII Contents

5 Conclusions . . . . . 72  
References . . . . . 73

**Modelling of Binaural Hearing**

*Jonas Braasch* . . . . . 75  
1 Introduction . . . . . 75  
2 Analysis of Binaural Cues by Humans . . . . . 76  
3 Computational Analysis of Binaural Cues . . . . . 80  
  3.1 Simulation of the Peripheral Auditory System . . . . . 80  
  3.2 Inter-Aural Time Differences . . . . . 83  
  3.3 Inter-Aural Level Differences . . . . . 87  
  3.4 Monaural Cues . . . . . 88  
4 Decision Process . . . . . 89  
  4.1 Lateralization Models . . . . . 89  
  4.2 Weighting Functions . . . . . 91  
  4.3 Localization Models . . . . . 94  
5 Detection Algorithms . . . . . 97  
6 Localization in Multiple-Sound-Source Scenarios . . . . . 100  
References . . . . . 103

**Audio-Visual Interaction in the Context  
of Multi-Media Applications**

*Armin Kohlrausch, Steven van de Par* . . . . . 109  
1 Introduction . . . . . 109  
2 Basic Observations of Spatio-Temporal Interaction  
  in Audio-Visual Stimuli . . . . . 111  
  2.1 Interaction Between Stimuli Allowing  
    an Ambiguous Interpretation . . . . . 111  
  2.2 Illusory Interaction Effects . . . . . 113  
  2.3 Temporal-Rate Disparities . . . . . 114  
  2.4 Spatial Disparities . . . . . 115  
3 Cross-Modal Effects in Auditory-Visual Attention . . . . . 118  
4 Auditory and Visual Speech Perception . . . . . 120  
5 Perceived Quality of Auditory-Visual Stimuli . . . . . 121  
6 Sensitivity to Temporal Asynchrony in AV Stimuli . . . . . 125  
  6.1 Perceived Temporal Relations in Simple Stimuli . . . . . 125  
  6.2 Asynchrony Detection and Quality Degradation  
    for Video Reproduction . . . . . 130  
  6.3 An Explanation for the Asymmetric Sensitivity  
    to AV Delays? . . . . . 132  
7 Concluding Remarks . . . . . 133  
References . . . . . 134

**Psycho-Acoustics and Sound Quality**

<i>Hugo Fastl</i> .....	139
1 Introduction .....	139
2 Methods .....	140
2.1 The Ranking Procedure “Random Access” .....	140
2.2 The Semantic Differential .....	141
2.3 Category Scaling .....	141
2.4 Magnitude Estimation .....	142
3 Modelling of Psycho-Acoustic Quantities .....	143
3.1 Loudness .....	143
3.2 Sharpness .....	147
3.3 Roughness .....	148
3.4 Fluctuation Strength .....	148
3.5 Composed Metrics .....	149
4 Sound Quality .....	150
5 The Meaning of Sounds .....	153
6 Image of Brand Names .....	155
7 Audio–Visual Interactions .....	157
8 Outlook .....	159
References .....	160

**Quality of Transmitted Speech  
for Humans and Machines**

<i>Sebastian Möller</i> .....	163
1 Introduction .....	163
1.1 Speech Transmission in Telephone Networks .....	165
1.2 Quality and Quality of Service .....	167
2 Quality Aspects of Human-Human Interaction over the Phone ...	169
2.1 Taxonomy of Quality Aspects in Human-Human Interaction ..	170
2.2 Transmission Channel Impact in Human-Human Interaction .	172
2.3 Influence of Service and Contextual Factors in Human-Human Interaction .....	172
3 Quality Aspects of Human-Machine Interaction over the Phone ...	174
3.1 Taxonomy of Quality Aspects in Human-Machine Interaction .	175
3.2 Application Examples .....	179
4 Quality Assessment and Prediction .....	179
4.1 Assessment Methods for Human-Human Interaction .....	180
4.2 Assessment Methods for Human-Machine Interaction .....	181
4.3 Quality Prediction for Human-Human Interaction .....	182
4.4 Quality Prediction for Human-Machine Interaction .....	185
5 Conclusions and Outlook .....	188
References .....	190

**Assigning Meaning to Sounds – Semiotics in the Context of Product-Sound Design**

*Ute Jekosch* . . . . . 193

1 Introduction . . . . . 193

2 Product Sound and Semiotics . . . . . 194

3 The Sound as a Sign . . . . . 194

4 What is Semiotics? . . . . . 195

5 What is a Sign? . . . . . 197

6 What is Semiosis and How Does Semiosis Take Place? . . . . . 198

    6.1 Rules of Semiosis . . . . . 200

    6.2 Types of Schemas . . . . . 203

7 What are the Functions of Signs? . . . . . 204

8 Links Between Semiotics and Product-Sound Design . . . . . 205

9 Semiosis of Product Sounds . . . . . 208

    9.1 Ruling Schemas and Gestalt Perception . . . . . 208

    9.2 Patterns of Semiosis that Create Context . . . . . 210

10 Conclusions to be Drawn for Product-Sound Design . . . . . 213

11 Acoustic Design Between Innovation and Convention . . . . . 215

12 Conclusions . . . . . 218

References . . . . . 219

**Binaural Technique – Basic Methods for Recording, Synthesis, and Reproduction**

*Dorte Hammershøi, Henrik Møller* . . . . . 223

1 Introduction . . . . . 223

    1.1 Structure . . . . . 224

2 Theory . . . . . 225

    2.1 Sound-Transmission Model . . . . . 225

    2.2 Calibration of the Complete Recording and Play-Back Chain . 227

    2.3 Inter-Individual Variation . . . . . 228

3 Headphone Reproduction . . . . . 231

    3.1 Headphone Transfer Functions . . . . . 231

    3.2 Pressure Division . . . . . 232

    3.3 Headphone Equalization . . . . . 233

    3.4 Pre-Equalization of Binaural Recordings . . . . . 234

4 Performance with Binaural Recordings . . . . . 234

    4.1 Localization Experiments . . . . . 234

    4.2 Non-Individual Human Recordings . . . . . 236

    4.3 Artificial Heads . . . . . 237

5 Binaural Synthesis . . . . . 239

    5.1 Measurement . . . . . 240

    5.2 Low-Frequency Control . . . . . 242

    5.3 Filter Length and Order . . . . . 243

    5.4 Performance of Binaural Synthesis . . . . . 244

6 Applications ..... 245  
 References ..... 248

**Hearing-Aid Technology**

*Inga Holube, Volkmar Hamacher* ..... 255  
 1 Hearing-Instrument Design ..... 255  
 2 Chip Technologies ..... 257  
 3 Advantages of Digital Signal Processing ..... 259  
 4 Technological Restrictions ..... 259  
 5 Digital Hearing Instruments ..... 260  
 6 Directional Microphone Systems ..... 261  
 7 Frequency-Dependent Filtering ..... 265  
 8 Noise Reduction ..... 267  
 9 Dynamic Compression ..... 269  
 10 Feedback Reduction ..... 269  
 11 Classification of Listening Situations ..... 271  
 12 Hearing-Instrument Components ..... 273  
 13 Hearing-Instrument Fitting ..... 274  
 14 Summary and Outlook ..... 274  
 References ..... 274

**Auditory Virtual Environments**

*Pedro Novo* ..... 277  
 1 Introduction ..... 277  
 2 Auditory-Virtual-Environment Components ..... 278  
   2.1 Introduction ..... 278  
   2.2 Sound Sources ..... 279  
   2.3 Environment Models ..... 280  
   2.4 Reproduction Formats ..... 283  
   2.5 Signal Processing ..... 285  
 3 Current Systems and Research Issues ..... 287  
   3.1 Introduction ..... 287  
   3.2 Systems ..... 288  
   3.3 Current Issues in AVEs ..... 290  
 4 Conclusions ..... 291  
 References ..... 292

**The Evolution of Digital Audio Technology**

*John N. Mourjopoulos* ..... 299  
 1 Introduction ..... 299  
   1.1 Overview ..... 299  
   1.2 Systems, Formats and Market Trends ..... 300  
 2 Technology Evolution ..... 303  
   2.1 A Brief History ..... 303  
   2.2 Evolutionary Mechanisms ..... 304

XII Contents

3 Emerging Technologies ..... 312  
3.1 The All-Digital Audio Chain ..... 313  
3.2 Sound-Field Control ..... 313  
3.3 Portable, Networked and Wireless Devices ..... 314  
4 Conclusions ..... 314  
References ..... 315

**Speech Production – Acoustics, Models, and Applications**

*Arild Lacroix* ..... 321  
1 Introduction ..... 321  
2 Mechanism of Speech Production ..... 321  
3 The Acoustics of Speech Production ..... 324  
4 Speech-Production Models Based  
on Discrete-Time Acoustic Tubes ..... 324  
5 Parameter Estimation ..... 329  
6 Applications ..... 334  
References ..... 335

**Speech and Audio Coding – Aiming at High Quality  
and Low Data Rates**

*Ulrich Heute* ..... 339  
1 Introduction and Fundamentals ..... 339  
1.1 Signal Digitization – A Very Brief Summary ..... 339  
1.2 Coding Efficiency ..... 341  
1.3 Speech Production – Another Brief Review ..... 341  
1.4 Sound Perception – Again a Brief Summary ..... 343  
1.5 Speech Coding and the “Coding Gap” ..... 345  
1.6 Higher Bandwidth – Wide-Band Speech and Audio Coding .. 346  
2 Speech Coding ..... 346  
2.1 The Origin of the Gap ..... 346  
2.2 Approaches to Close the Gap ..... 348  
2.3 Closing the Gap ..... 351  
2.4 The Basis of the Break-Through ..... 352  
2.5 CELP Coders ..... 355  
2.6 Frequency-Domain Coding ..... 357  
2.7 Wide-Band-Speech Coding ..... 359  
3 Audio Coding – An Even Shorter Overview ..... 359  
4 Further Work and Results ..... 361  
4.1 Audio Coding ..... 361  
4.2 Speech Coding ..... 361  
5 Further Reading ..... 362  
References ..... 364

**Index** ..... 367