

DSP

DIGITAL SIGNAL AND IMAGE PROCESSING SERIES

Compression of Biomedical Images and Signals

Edited by
Amine Naït-Ali and Christine Cavarro-Ménard

ISTE

 **WILEY**

Table of Contents

Preface	xiii
Chapter 1. Relevance of Biomedical Data Compression	1
Jean-Yves TANGUY, Pierre JALLET, Christel LE BOZEC and Guy FRIJA	
1.1. Introduction	1
1.2. The management of digital data using PACS	2
1.2.1. Usefulness of PACS	2
1.2.2. The limitations of installing a PACS	3
1.3. The increasing quantities of digital data	4
1.3.1. An example from radiology	4
1.3.2. An example from anatomic pathology	6
1.3.3. An example from cardiology with ECG	7
1.3.4. Increases in the number of explorative examinations	8
1.4. Legal and practical matters	8
1.5. The role of data compression.	9
1.6. Diagnostic quality	10
1.6.1. Evaluation	10
1.6.2. Reticence	11
1.7. Conclusion.	12
1.8. Bibliography	12
Chapter 2. State of the Art of Compression Methods	15
Atila BASKURT	
2.1. Introduction	15
2.2. Outline of a generic compression technique	16
2.2.1. Reducing redundancy	17
2.2.2. Quantizing the decorrelated information	18
2.2.3. Coding the quantized values	18
2.2.4. Compression ratio, quality evaluation	20

2.3. Compression of still images	21
2.3.1. JPEG standard	22
2.3.1.1. Why use DCT?	22
2.3.1.2. Quantization.	24
2.3.1.3. Coding	24
2.3.1.4. Compression of still color images with JPEG	25
2.3.1.5. JPEG standard: conclusion	26
2.3.2. JPEG 2000 standard	27
2.3.2.1. Wavelet transform	27
2.3.2.2. Decomposition of images with the wavelet transform	27
2.3.2.3. Quantization and coding of subbands	29
2.3.2.4. Wavelet-based compression methods, serving as references	30
2.3.2.5. JPEG 2000 standard	31
2.4. The compression of image sequences.	33
2.4.1. DCT-based video compression scheme.	34
2.4.2. A history of and comparison between video standards.	36
2.4.3. Recent developments in video compression	38
2.5. Compressing 1D signals.	38
2.6. The compression of 3D objects	39
2.7. Conclusion and future developments	39
2.8. Bibliography	40
 Chapter 3. Specificities of Physiological Signals and Medical Images	 43
Christine CAVARO-MÉNARD, Amine NAÏT-ALI, Jean-Yves TANGUY, Elsa ANGELINI, Christel LE BOZEC and Jean-Jacques LE JEUNE	
3.1. Introduction	43
3.2. Characteristics of physiological signals	44
3.2.1. Main physiological signals	44
3.2.1.1. Electroencephalogram (EEG)	44
3.2.1.2. Evoked potential (EP)	45
3.2.1.3. Electromyogram (EMG)	45
3.2.1.4. Electrocardiogram (ECG).	46
3.2.2. Physiological signal acquisition	46
3.2.3. Properties of physiological signals	46
3.2.3.1. Properties of EEG signals.	46
3.2.3.2. Properties of ECG signals.	48
3.3. Specificities of medical images	50
3.3.1. The different features of medical imaging formation processes	50
3.3.1.1. Radiology	51
3.3.1.2. Magnetic resonance imaging (MRI).	54
3.3.1.3. Ultrasound.	58
3.3.1.4. Nuclear medicine.	62

3.3.1.5. Anatomopathological imaging	66
3.3.1.6. Conclusion.	68
3.3.2. Properties of medical images	69
3.3.2.1. The size of images	70
3.3.2.2. Spatial and temporal resolution	71
3.3.2.3. Noise in medical images	72
3.4. Conclusion.	73
3.5. Bibliography	74
Chapter 4. Standards in Medical Image Compression	77
Bernard GIBAUD and Joël CHABRIAIS	
4.1. Introduction	77
4.2. Standards for communicating medical data	79
4.2.1. Who creates the standards, and how?	79
4.2.2. Standards in the healthcare sector	80
4.2.2.1. Technical committee 251 of CEN	80
4.2.2.2. Technical committee 215 of the ISO	80
4.2.2.3. DICOM Committee	80
4.2.2.4. Health Level Seven (HL7)	85
4.2.2.5. Synergy between the standards bodies	86
4.3. Existing standards for image compression	87
4.3.1. Image compression.	87
4.3.2. Image compression in the DICOM standard.	89
4.3.2.1. The coding of compressed images in DICOM.	89
4.3.2.2. The types of compression available	92
4.3.2.3. Modes of access to compressed data	95
4.4. Conclusion.	99
4.5. Bibliography	99
Chapter 5. Quality Assessment of Lossy Compressed Medical Images	101
Christine CAVARO-MÉNARD, Patrick LE CALLET, Dominique BARBA and Jean-Yves TANGUY	
5.1. Introduction	101
5.2. Degradations generated by compression norms and their consequences in medical imaging	102
5.2.1. The block effect	102
5.2.2. Fading contrast in high spatial frequencies.	103
5.3. Subjective quality assessment	105
5.3.1. Protocol evaluation.	105
5.3.2. Analyzing the diagnosis reliability	106
5.3.2.1. ROC analysis	108
5.3.2.2. Analyses that are not based on the ROC method	111

- 5.3.3. Analyzing the quality of diagnostic criteria 111
- 5.3.4. Conclusion. 114
- 5.4. Objective quality assessment 114
 - 5.4.1. Simple signal-based metrics 115
 - 5.4.2. Metrics based on texture analysis 115
 - 5.4.3. Metrics based on a model version of the HVS. 117
 - 5.4.3.1. Luminance adaptation 117
 - 5.4.3.2. Contrast sensitivity. 118
 - 5.4.3.3. Spatio-frequency decomposition. 118
 - 5.4.3.4. Masking effect 119
 - 5.4.3.5. Visual distortion measures 120
 - 5.4.4. Analysis of the modification of quantitative clinical parameters . . . 123
- 5.5. Conclusion. 125
- 5.6. Bibliography 125

Chapter 6. Compression of Physiological Signals 129
Amine NAÏT-ALI

- 6.1. Introduction 129
- 6.2. Standards for coding physiological signals 130
 - 6.2.1. CEN/ENV 1064 Norm 130
 - 6.2.2. ASTM 1467 Norm 130
 - 6.2.3. EDF norm 130
 - 6.2.4. Other norms 131
- 6.3. EEG compression 131
 - 6.3.1. Time-domain EEG compression. 131
 - 6.3.2. Frequency-domain EEG compression 132
 - 6.3.3. Time-frequency EEG compression 132
 - 6.3.4. Spatio-temporal compression of the EEG 132
 - 6.3.5. Compression of the EEG by parameter extraction 132
- 6.4. ECG compression 133
 - 6.4.1. State of the art. 133
 - 6.4.2. Evaluation of the performances of ECG compression methods. . . 134
 - 6.4.3. ECG pre-processing 135
 - 6.4.4. ECG compression for real-time transmission 136
 - 6.4.4.1. Time domain ECG compression 136
 - 6.4.4.2. Compression of the ECG in the frequency domain 141
 - 6.4.5. ECG compression for storage 144
 - 6.4.5.1. Synchronization and polynomial modeling 145
 - 6.4.5.2. Synchronization and interleaving 149
 - 6.4.5.3. Compression of the ECG signal using the JPEG 2000 standard 150
- 6.5. Conclusion. 150
- 6.6. Bibliography 151

Chapter 7. Compression of 2D Biomedical Images 155

Christine CAVARO-MÉNARD, Amine NAÏT-ALI, Olivier DEFORGES and Marie BABEL

7.1. Introduction	155
7.2. Reversible compression of medical images	156
7.2.1. Lossless compression by standard methods	156
7.2.2. Specific methods of lossless compression	157
7.2.3. Compression based on the region of interest.	158
7.2.4. Conclusion.	160
7.3. Lossy compression of medical images	160
7.3.1. Quantization of medical images	160
7.3.1.1. Principles of vector quantization.	161
7.3.1.2. A few illustrations	161
7.3.1.3. Balanced tree-structured vector quantization	163
7.3.1.4. Pruned tree-structured vector quantization.	163
7.3.1.5. Other vector quantization methods applied to medical images	163
7.3.2. DCT-based compression of medical images.	164
7.3.3. JPEG 2000 lossy compression of medical images	167
7.3.3.1. Optimizing the JPEG 2000 parameters for the compression of medical images	167
7.3.4. Fractal compression	170
7.3.5. Some specific compression methods	171
7.3.5.1. Compression of mammography images	171
7.3.5.2. Compression of ultrasound images	172
7.4. Progressive compression of medical images.	173
7.4.1. State-of-the-art progressive medical image compression techniques	173
7.4.2. LAR progressive compression of medical images	174
7.4.2.1. Characteristics of the LAR encoding method	174
7.4.2.2. Progressive LAR encoding	176
7.4.2.3. Hierarchical region encoding.	178
7.5. Conclusion.	181
7.6. Bibliography	182

Chapter 8. Compression of Dynamic and Volumetric Medical Sequences . . 187

Azza OULED ZAID, Christian OLIVIER and Amine NAÏT-ALI

8.1. Introduction	187
8.2. Reversible compression of (2D+t) and 3D medical data sets	190
8.3. Irreversible compression of (2D+t) medical sequences	192
8.3.1. Intra-frame lossy coding	192
8.3.2. Inter-frame lossy coding	194
8.3.2.1. Conventional video coding techniques	194
8.3.2.2. Modified video coders.	195

8.3.2.3. 2D+t wavelet-based coding systems limits.	195
8.4. Irreversible compression of volumetric medical data sets	196
8.4.1. Wavelet-based intra coding.	196
8.4.2. Extension of 2D transform-based coders to 3D data	197
8.4.2.1. 3D DCT coding.	197
8.4.2.2. 3D wavelet-based coding based on scalar or vector quantization	198
8.4.2.3. Embedded 3D wavelet-based coding	199
8.4.2.4. Object-based 3D embedded coding	204
8.4.2.5. Performance assessment of 3D embedded coders.	205
8.5. Conclusion.	207
8.6. Bibliography	208

Chapter 9. Compression of Static and Dynamic 3D Surface Meshes 211

Khaled MAMOU, Françoise PRÊTEUX, Rémy PROST and
Sébastien VALETTE

9.1. Introduction	211
9.2. Definitions and properties of triangular meshes.	213
9.3. Compression of static meshes	216
9.3.1. Single resolution mesh compression	217
9.3.1.1. Connectivity coding	217
9.3.1.2. Geometry coding	218
9.3.2. Multi-resolution compression	219
9.3.2.1. Mesh simplification methods.	219
9.3.2.2. Spectral methods	219
9.3.2.3. Wavelet-based approaches	220
9.4. Compression of dynamic meshes	229
9.4.1. State of the art.	230
9.4.1.1. Prediction-based techniques	230
9.4.1.2. Wavelet-based techniques.	231
9.4.1.3. Clustering-based techniques	233
9.4.1.4. PCA-based techniques.	234
9.4.1.5. Discussion	234
9.4.2. Application to dynamic 3D pulmonary data in computed tomography	236
9.4.2.1. Data.	236
9.4.2.2. Proposed approach	237
9.4.2.3. Results	238
9.5. Conclusion.	239
9.6. Appendices	240
9.6.1. Appendix A: mesh via the MC algorithm	240
9.7. Bibliography	241

Chapter 10. Hybrid Coding: Encryption-Watermarking-Compression for Medical Information Security. 247

William PUECH and Gouenou COATRIEUX

10.1. Introduction	247
10.2. Protection of medical imagery and data.	248
10.2.1. Legislation and patient rights	248
10.2.2. A wide range of protection measures	249
10.3. Basics of encryption algorithms	251
10.3.1. Encryption algorithm classification	251
10.3.2. The DES encryption algorithm	252
10.3.3. The AES encryption algorithm	253
10.3.4. Asymmetric block system: RSA	254
10.3.5. Algorithms for stream ciphering	255
10.4. Medical image encryption.	257
10.4.1. Image block encryption	258
10.4.2. Coding images by asynchronous stream cipher	258
10.4.3. Applying encryption to medical images.	259
10.4.4. Selective encryption of medical images.	261
10.5. Medical image watermarking and encryption	265
10.5.1. Image watermarking and health uses	265
10.5.2. Watermarking techniques and medical imagery	266
10.5.2.1. Characteristics	266
10.5.2.2. The methods	267
10.5.3. Confidentiality and integrity of medical images by data encryption and data hiding	269
10.6. Conclusion	272
10.7. Bibliography.	273

Chapter 11. Transmission of Compressed Medical Data on Fixed and Mobile Networks. 277

Christian OLIVIER, Benoît PARREIN and Rodolphe VAUZELLE

11.1. Introduction	277
11.2. Brief overview of the existing applications.	278
11.3. The fixed and mobile networks.	279
11.3.1. The network principles.	279
11.3.1.1. Presentation, definitions and characteristics	279
11.3.1.2. The different structures and protocols	281
11.3.1.3. Improving the Quality of Service	281
11.3.2. Wireless communication systems	282
11.3.2.1. Presentation of these systems	282
11.3.2.2. Wireless specificities	284
11.4. Transmission of medical images	287

11.4.1. Contexts	287
11.4.1.1. Transmission inside a hospital	287
11.4.1.2. Transmission outside hospital on fixed networks	287
11.4.1.3. Transmission outside hospital on mobile networks	288
11.4.2. Encountered problems	288
11.4.2.1. Inside fixed networks.	288
11.4.2.2. Inside mobile networks	289
11.4.3. Presentation of some solutions and directions	293
11.4.3.1. Use of error correcting codes	294
11.4.3.2. Unequal protection using the Mojette transform.	297
11.5. Conclusion.	299
11.6. Bibliography.	300
Conclusion.	303
List of Authors	305
Index	309