

Table of Contents

Preface	vii
1 Multimedia Services, 5G Technology, and XR: An In-depth Exploration of Technologies, Standards, and Challenges	1
<i>Tiziana Cattai, Stefania Colonnese</i>	
1.1 Introduction	1
1.2 Conversational services	2
1.3 Streaming services	7
1.4 5G networks provisioning for multimedia services	8
1.5 Extended reality services in 5G networks	12
1.6 Unmanned vehicles for XR	16
References	18
2 Visual Compression: New Paradigms?	21
<i>Nicola Adami, Marco Dalai, Alessandro Gnutti, Fabrizio Guerrini, Riccardo Leonardi, Pierangelo Migliorati, Alberto Signoroni</i>	
2.1 Introduction	21
2.2 Background	23
2.2.1 General concepts	23
2.2.2 Principles of image compression	24
2.2.3 Principles of video compression	27
2.3 History of Image and Video Compression	29
2.3.1 Evolution of Image and Video Compression Standards	29
2.3.2 Distributed Video Coding	30
2.3.3 Wavelet-based (scalable) video coding	33
2.4 Traditional methods: novel investigative approaches	38
2.4.1 Multiple transforms	38
2.4.2 Graph domain	40
2.4.3 SBGFT	41
2.5 Artificial Intelligence (AI) methods: new paradigms	42
2.5.1 General principles	42
2.5.2 Image compression: seminal works	43
2.5.3 Video compression: seminal works	44
2.5.4 Conditional Augmented Normalizing Flows for Video Compression	45
2.6 Conclusions	46
References	46

3	Gaussian Class-Conditional Training for Secure and Robust Deep Neural Networks	55
	<i>Tiziano Bianchi, Andrea Migliorati, Enrico Magli</i>	
3.1	Introduction	55
3.1.1	Related works	56
3.2	Gaussian Class-Conditional training	58
3.3	Multiclass classification	59
3.3.1	Target Distributions Parameters	60
3.3.2	Adversarial Robustness Evaluation	62
3.4	Metric learning	68
3.4.1	Network design	68
3.4.2	Face verification	70
3.5	Conclusions	71
	References	71
4	Graph Neural Networks for Inverse Problems in Multimedia	79
	<i>Diego Valsesia, Emanuele Aiello</i>	
4.1	Introduction	79
4.2	Graph neural networks and Transformers	80
4.3	Point Cloud Generation	82
4.4	Point Cloud Denoising	84
4.5	Point Cloud Completion	86
4.5.1	Local and Global Pretraining of GNNs for Point Cloud Completion	87
4.5.2	Point Cloud and RGB image fusion	90
4.6	Image Denoising	93
4.7	Image Restoration with Transformers	94
4.8	Conclusions	96
	References	96
5	Distributed Learning for Adaptive Multimedia Processing	101
	<i>Marco Carpentiero, Vincenzo Matta, Ali H. Sayed</i>	
5.1	Introduction	101
5.1.1	Adaptation and Communication Constraints	102
5.1.2	Network Learning Architectures	103
5.2	Related Work	106
5.3	Background	107
5.3.1	Network	107
5.3.2	Optimization Problem	108
5.3.3	Classical ATC Diffusion Strategy	109
5.4	Adaptive Compressed Learning	110
5.4.1	Performance	112
5.5	Distributed Image Classification Example	115
5.6	Conclusion	117
	References	117
6	Multimodal Deepfake Detection Using Audio-Visual Cues	121
	<i>Davide Salvi, Sara Mandelli, Honggu Liu, Paolo Bestagini, Stefano Tubaro</i>	

6.1	Introduction	121
6.2	Deepfake Detection	123
6.2.1	Visual-only deepfake detection	123
6.2.2	Audio-only deepfake detection	124
6.2.3	Audio-visual deepfake detection	125
6.3	Problem Formulation and Proposed Methodology	125
6.3.1	Problem Formulation	126
6.3.2	Proposed Methodology	126
6.4	Experimental Setup	129
6.4.1	Considered datasets	130
6.4.2	Processing pipeline	132
6.4.3	Training Strategy	132
6.5	Results	133
6.5.1	Evaluation metrics	133
6.5.2	Monomodal results	133
6.5.3	Multimodal results	133
6.6	Conclusions and Future Works	138
	References	139
7	Uncertainty-driven detection and localization of image forgeries	145
	<i>Fabrizio Guillaro, Davide Cozzolino, Giovanni Poggi, Luisa Verdoliva</i>	
7.1	Introduction	145
7.2	Proposed uncertainty-driven approach	148
7.2.1	Noiseprint++	149
7.2.2	Anomaly localization map	150
7.2.3	Confidence map and integrity score	151
7.3	Datasets and metrics	152
7.3.1	Noiseprint++ training	153
7.3.2	Localization and detection training	153
7.3.3	Testing	154
7.3.4	Performance evaluation	154
7.4	Results	154
7.4.1	Ablation study	154
7.4.2	State-of-the-art comparison	155
7.4.3	Robustness analysis	158
7.4.4	Qualitative comparisons	159
7.5	Conclusions	160
	References	161
8	On-the-move Multimodal Biometric Recognition	165
	<i>Emanuele Maiorana, Lorenzo Giusti, Patrizio Campisi</i>	
8.1	Introduction	165
8.2	State of the art	167
8.3	Design of the Proposed Device	170
8.4	Data Processing	173
8.4.1	Face Processing	174
8.4.2	Vein Pattern Processing	176

8.5	Experimental Tests	179
8.6	Conclusions	180
8.7	Acknowledgements	180
	References	181
9	Digital Twins for Data Generation and Crowd Understanding	185
	<i>Nicola Conci, Niccolò Bisagno, Nicola Garau, Antonio Luigi Stefani</i>	
9.1	Introduction	185
9.2	Related Work	187
9.3	Synthetic Data and Visual Fidelity	189
	9.3.1 People Segmentation	190
	9.3.2 Crowd counting	192
9.4	Synthetic Data and Behavioral Fidelity	195
9.5	Conclusions	199
9.6	Acknowledgement	201
	References	201
10	Affective-based Modelling Approaches for Quality of Experience-based Management Systems	207
	<i>Alessandro Floris, Simone Porcu, Matteo Anedda, Daniele Giusto</i>	
10.1	Introduction	207
10.2	QoE estimation based on facial expression and gaze direction for video streaming services	209
	10.2.1 Framework	209
	10.2.2 Data Collection	209
	10.2.3 Data Preprocessing	212
	10.2.4 QoE Estimation Model and Performance Results	214
10.3	QoE estimation based on facial expressions for WebRTC services	215
	10.3.1 Methodology	215
	10.3.2 Data collection	216
	10.3.3 Data Preprocessing	217
	10.3.4 QoE Estimation Model and Performance Results	219
10.4	Conclusions	221
	References	221