Editor
Roumen Kountchev

New Approaches in Intelligent Image Processing

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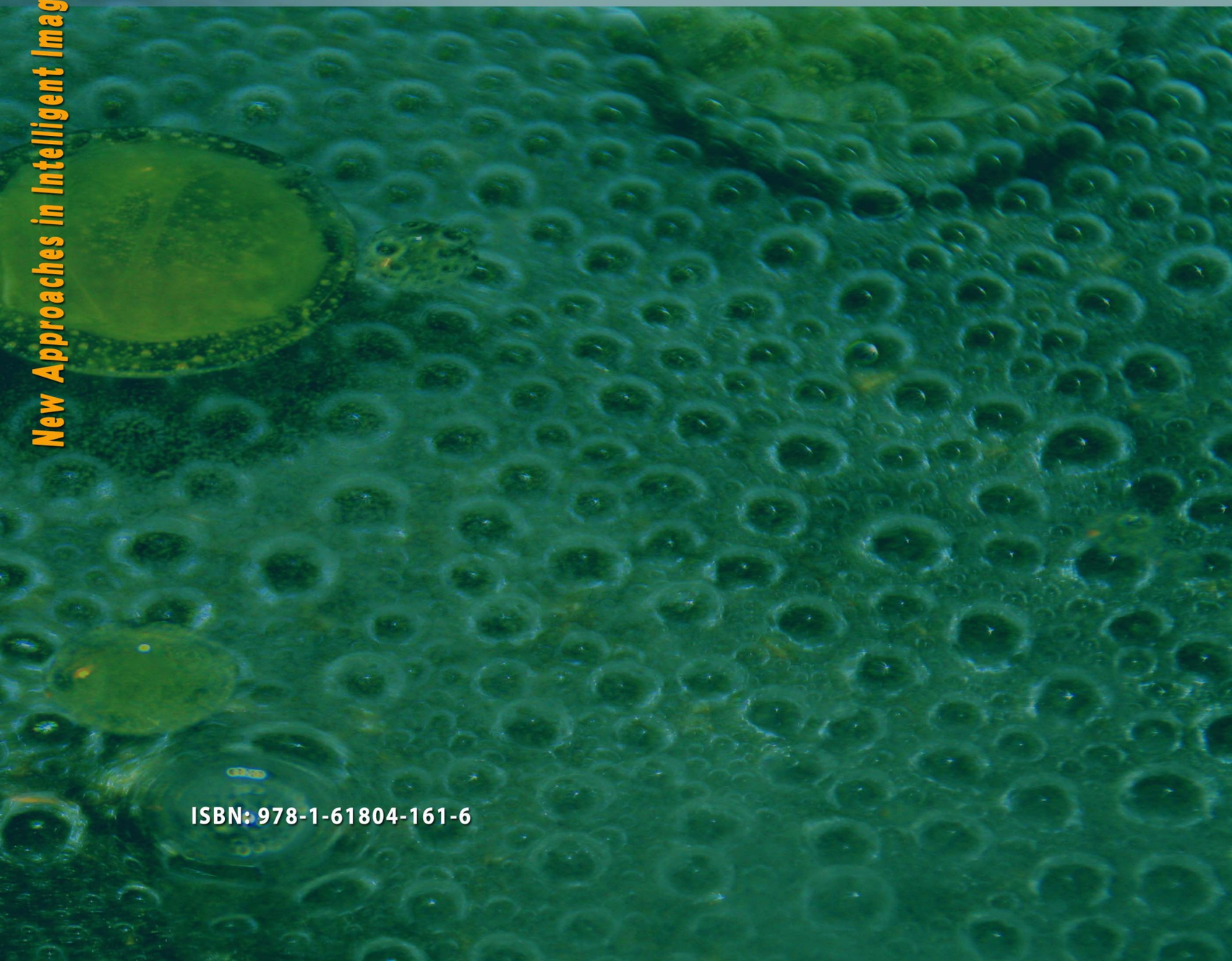

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Preface

During the past years huge investigation work was performed in the area of the intelligent image processing, mainly adapted to image basic parameters and contents. It actuality grew up together with the fast development of the information and communication theories all over the world. In a short time period were created, developed and perfected wide variety of algorithms for compression, processing and analysis of images of different kind: natural, multispectral, multi-view, medical, satellite photos of very high resolution, etc. The image processing application areas were also widened in mobile video communications, e-trade, e-services, geographic information systems and systems for visual control of mobile robots, visually controlled computer interfaces, biometric systems, electronic art, computer games, etc.

The present book is devoted to some new approaches in the intelligent image processing, making up for deficiencies in theory and practice and further developing some of the famous methods and algorithms in the area. The original methods and algorithms, introduced in the book, represent the research activity of the editor during the past years, as well as these of his co-authors from the Technical University of Sofia and colleagues, with whom he worked on various related research projects. Significant part of the chapters is based on the method for Inverse Pyramid Decomposition of still images. Nevertheless, each chapter could be read independently.

The book is aimed at specialists, interested in new and non-conventional approaches in the contemporary image processing and also at BSc, MSc, PhD and post-graduate students, who study methods and algorithms for digital image processing, search by content in image databases and visual control of mobile robots.

Book arrangement

The book consists of 2 parts and comprises 18 chapters.
Part 1: "Techniques and methodologies" has 10 chapters, in which are presented new methods and algorithms, considering various aspects of the intelligent image processing.
Part 2: "Applications of the Intelligent Image Processing" has 8 chapters, devoted to various application problems of the image processing, solved on the basis of the new algorithms modeling.
Each chapter is arranged so, that to be individually read and understood, which makes the book easily used. There is also given information for the chapter authors, which permits direct contacts with them, when needed. Each chapter has vast contemporary references on the themes.
Significant part of the chapters is based on the Inverse Pyramid Decomposition of still images, developed initially by the Editor in 2001, and later developed together with some of his co-authors. This basic decomposition was used for the development of various application algorithms mainly in the areas of image processing and analysis.

Brief presentation of the book chapters' contents is given below:
1. Pyramidal image representation in the spectrum space domain: in the chapter is presented one new approach for still image processing, based on the Inverse Pyramid Decomposition (IPD). The basic principles of the decomposition are given, and in particular - the implementation with orthogonal linear transforms. The chapter also contains comparison of the Inverse and the Laplacian pyramidal decompositions, and outlines the advantages of the new decomposition. Here is given also in detail the Reduced IPD, which is not overcomplete, and is presented one new method for image compression enhancement, based on the spectrum pyramid.
2. IPD with adaptive non-linear transforms based on neural networks: one new method for non-linear still image representation based on the Inverse Pyramidal Decomposition with a neural network is proposed in this chapter. This approach is developed by analogy with the human way for image recognition, based on consecutive approximations with increasing similarity. The corresponding approximations in the decomposition layers are represented by the neurons in the hidden layers of the neural networks. This approach ensures efficient description of the processed images and as a result - a higher compression ratio. The new image representation is suitable for various applications.

3. Image color representation with adaptive KLT: the use of the Karhunen-Loève Transform (KLT) for the processing of the image primary color components gives as a result their decorrelation, which ensures the enhancement of some other operations: compression, color-based segmentation, etc. The basic problem is the high computational complexity of the KLT. In this chapter is offered a simplified algorithm for the calculation of the KLT color space transform matrix, which is based on the analytic detection of the color covariance matrix eigenvectors. The new algorithm surpasses the existing similar algorithms in its lower computational complexity, which is a prerequisite for fast color segmentation or for adaptive coding of color images aimed at real time applications.

4. Multi-view and multispectral image representation by IPD: one new approach for compression of multi-view and multispectral images, based on the Inverse Pyramid Decomposition (IPD) is presented. This approach is applicable to large number of spectral images or views of same object, processed as a common group. For this, their histograms are calculated and compared. The image, whose histogram is most similar with these of the remaining ones in the group, is used as a reference. The image decomposition starts with the reference image, which is processed with some kind of orthogonal transform, using limited number of transform coefficients only; after inverse transform is obtained the coarse approximation of the image. The IPD then branches out into several parts, corresponding to number of images in the group. The first approximation used in the group is that, calculated for the reference image. In result is obtained high compression and very good visual quality of the restored images.

5. Lossless data compression based on adaptive run-length coding: the method for adaptive lossless image coding is aimed at the efficient compression of grayscale or color digital still images. The method is based on the analysis of the processed images histograms, followed by modified Huffman and run-length coding. The coding is performed in two consecutive stages: at first, the original data (i.e., the digital information about the image brightness and color components) is transformed without affecting their volume in such a way, that to obtain sequences of same values (in particular, zeros) of maximum length; in the second stage of the processing the transformed data is analyzed and sequences of same numbers are detected. Every such sequence is substituted by a shorter one, corresponding to number of same values which it contains. The method is extremely suitable for images of graphics or texts (for example: fingerprints, contour images, cartoons, medical signals, etc.). The method has low computational complexity and is suitable for real-time applications.

6. Multi-layer image watermarking based on the IPD with Complex Hadamard Transform: one new method for digital content protection based on watermark data insertion in the image transform domain is introduced. For this, the still digital image is transformed using Complex Hadamard Transform (CHT), and the watermark data is then inserted in the imaginary part of the transform coefficients. The selection of transform coefficients, suitable for the watermarking, is done in accordance with pre-defined rules. The inserted watermark is perceptually invisible. The method permits insertion of relatively large amount of data, retaining the high quality of the protected image. Main advantages of the algorithm for digital watermarking, based on the CHT are that it is resistant against attacks, based on high-frequency filtration (JPEG compression); it permits the insertion of significant amount of data, and the watermark detection could be done without using the original image.

7. Invariant object description with inverse pyramid based on the truncated modified Mellin-Fourier Transform: one new method for invariant 2D object representation based on the Mellin-Fourier Transform, modified for the application is presented. The so obtained image representation is invariant against 2D rotation, scaling, and translation changes. The representation is additionally made invariant to significant contrast and illumination changes. The method is aimed at content-based object retrieval in large image databases. The experimental results obtained using the software implementation of the method proved its efficiency. The method is suitable for various applications, such as detection of children sexual abuse in multimedia files, search of handwritten and printed documents, etc.

8. Multi-layer search in image database using inverse pyramidal representation: one of the most important problems concerning the efficient management of large image databases is the creation of algorithms for efficient content-based image retrieval. In Section 1 of this chapter is presented one new approach for fast search of 2D objects in image databases, generalized for 3D objects in Section 2. Both approaches are based on the pyramid image decomposition in the spectrum domain, called Inverse Pyramid Decomposition. The image retrieval is performed by evaluation of the multi-layer distance between compared images. The method permits to perform the search through recursive algorithm of relatively low computational complexity. The approach for fast search of 3D objects in image databases, presented in Section 2, requires preliminary introduction of specially selected multi-view images for each object. These

images are used for the creation of the cognitive multi-layer model for 3D object representation, whose basic parameters in the learning procedure are set by neural networks.

9. Object segmentation based on the adaptive color Principal Component Analysis: one new application of the adaptive color Principal Component Analysis, PCA (also known as the adaptive color Karhunen-Loève Transform - ACKLT) for objects segmentation on the basis of their dominant color is presented. In the case, when color vectors of the objects have Gaussian distribution, for their segmentation is used the famous elliptic boundary color model. In result of the use of the PCA, this model is represented by the canonic equation of an ellipsoid. As a result is simplified the calculation of the Mahalanobis distance between the color vector of each pixel and the centroid of the color vectors for a given cluster. The segmentation accuracy is higher also. In the case, when the color vectors of the objects do not have Gaussian distribution, is used the non-linear transform based on the Kernel PCA, which permits in this case also to achieve higher color segmentation accuracy. In the chapter are given some experimental results of the algorithms modeling, and in particular - the application for human skin detection of people from various ethnic groups.

10. Contrast enhancement with histogram-adaptive image segmentation: a specific approach aimed at the improvement of the visual quality of underexposed or low-contrast images is presented. For this is developed new algorithm for contrast-enhancement, based on the segmentation of the image area with relatively high density of dark elements. The problem is solved changing the brightness intervals of the selected segments followed by adaptive equalization of the corresponding parts of the histogram. The software implementation of the method is relatively simple and permits easy adaptation of the contrasting algorithm in accordance with the image contents, requiring the setting of small number of parameters only. The obtained results prove the efficiency of the new method on the processed image quality.

11. Archiving and protection of documents images: a new approach for efficient archiving and content protection of scanned documents, comprising texts and pictures, is presented. It presumes to compress pictures and texts in different way: the pictures - with lossy coding based on decomposition, called Inverse Pyramid Decomposition (IPD), and the parts, containing text (graphics) - with lossless coding. For the reliable image content protection is offered new method for digital watermarking based on the IPD, which permits the insertion of multi-layer watermarks.

12. New format for coding of still images based on the inverse pyramid decomposition: the recent development and use of huge image databases creates various problems related to their efficient archiving and content protection. A wide variety of standards, methods and formats have been created, most of them aimed at the efficient compression of still images. Each standard and method has its specific advantages and demerits, and the best image compression solution is still to come. This chapter presents new format for archiving of still images and sequences of similar images (multispectral, medical, etc.), based on the Inverse Pyramid Decomposition (IPD). In a special annex is given the set of coefficients, which permit image archiving with consecutive quality improvement in 100 consecutive steps.

13. Local adaptive interpolation of halftone images: a new method for local adaptive two-dimensional interpolation of halftone images is presented. The adaptation is based on the local information from the four neighboring pixels of processed image and the interpolation type is changed to zero or bilinear one. An analysis of local image characteristics in small areas is performed and optimal selection of thresholds for dividing into homogeneous and contour blocks is made which results in adaptive change of the interpolation type. The analysis of the interpolated halftone image quality is made and the methods for zero, bilinear and cubic image interpolation are compared on the basis of the calculated PSNR, SNR, MSE and subjective observation. Experimental results are given from the simulation in MATLAB environment. The average signal to noise ratio enhancement is about 1.5 dB.

14. Enhancement and efficient storage of signatures and fingerprint images: a new approach for processing the images of fingerprints, signatures, and handwritten texts, based on histogram modification and on adaptive filtration followed by image segmentation is presented. The visual quality of images obtained in result of the processing is significantly enhanced. The archiving is based on the method for adaptive lossless data compression, which suits the statistics of the processed images very well and ensures high compression ratio. The comparison with JPEG 2000 LS proves the method efficiency.

15. Defects detection in X-ray images and photos: a new approach for defects detection in low contrast digital images (X-ray or photos) and images with uneven background illumination is presented. The specially developed algorithm comprises two main stages: image pre-processing (noise suppression and correction of the uneven illumination) and adaptive defects segmentation. This approach permits detection of different kinds of defects and irregularities and ensures high accuracy. It is suitable for the analysis of X-

ray images of welds, or photos of pipes, plates, etc. The experimental results obtained with the software implementation of the described algorithm prove its efficiency. The chapter also points up the advantages of the presented algorithm in comparison with some well-known methods for non-destructive control.

16. Visual observation, motion control and tracking for intelligent mobile robots. Visual observation is a part of the image processing methods applied in visual systems of the intelligent robots. Visual robot systems acquire information from the area of observation capturing images and using visual sensors or video cameras as visual perception devices. Visual observation methods depend on the intelligent robot application or executed tasks. In this chapter are considered applications for intelligent mobile robots only, especially - the tasks of motion control - and are proposed image processing methods for visual observation of objects or people in the mobile robot area. From the review and analysis of existing similarity between the intelligent mobile robot visual observation and the human visual perception are determined some useful conclusions for the development of two algorithms for learning and testing the intelligent mobile robot observation system.

17. Age-group classification with dissimilarity representation and subspace projection: a framework for age-group classification in two classes is presented. An investigation of the framework performance, based on two configurations, is performed. The configurations consist of dimensionality reduction and classification steps. The first configuration reduces the input space dimensionality using combination of Principal Component Analysis (PCA) and spectral regression algorithms. Classification with Support Vector Machines (SVM) is used following the dimensionality reduction step. The second configuration of the framework consists of PCA and classification over dissimilarity representation steps. The classification problem is solved by the proximity index"shape coefficient" with SVM decision rules. In order to work with real life images with complicated background, both configurations are extended with face detection and face normalization algorithms. The results from experiments with real images are encouraging enough to propose this framework as good alternative to other algorithms for age-group classification.

18. Robust eye tracking with active camera control: two different algorithms for eye tracking based on artificial infra-red lightning are described. The first one uses a particle filter to locate and track the eye pupil and an optimization with Expectation-Maximization algorithm for better pupil contour approximation. The second one relies on synchronized switching infrared lightning and deformable template of the eye lids. Finally a gaze direction is calculated by using a geometrical model of the human eye-ball. An algorithm for face pose estimation is also introduced which helps to compensate the user's head rotations, which in combination with the gaze direction estimation make the system much more robust and independent of the user's head movements.

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Prof. D.Sc. Roumen Kountchev

Table of Contents

Preface iii

Acknowledgements vii

Part I Techniques and Methodologies

1 Pyramidal Image Representation in the Spectrum Space 1
Roumen Kountchev
1.1 Basic Methods for Pyramidal Image Decomposition 1
1.2 Basic Principles of the Inverse Pyramid Decomposition 5
1.2.1 Inverse Pyramid Decomposition with Orthogonal Transforms 5
1.2.2 Comparison of the Inverse and the Laplacian Pyramidal Decompositions 9
1.2.3 Reduced Inverse Pyramid Decomposition 14
1.2.4 Enhancement of the Image Compression Based on Spectrum Pyramid 20
1.3 Experimental Results 21
1.4 Conclusions 26
References 26

2 Inverse Pyramid Decomposition with Adaptive Non-linear Transforms Based on Neural Networks 31
Roumen Kountchev
2.1 Introduction 31
2.2 Image Representation with Adaptive Inverse Pyramidal Decomposition 31
2.3 Experimental results 35
2.4 Conclusions 41
References 42

3 Image Color Representation with Adaptive Karhunen-Loève Transform 45
Roumen Kountchev
3.1 Introduction 45
3.2 Direct Calculation of the Matrix for Adaptive Color KLT 46
3.3 Estimation of Computational Complexity for Covariance Matrix Eigenvalues Calculation 50
3.4 Algorithm for Adaptive Color KLT 50
3.5 Improved Adaptive Color KLT Based on Non-linear Pre- and Post-Processing 52
3.6 Comparative Analysis of Adaptive Color KLT and YCrCb 54
3.7 Image Compression Based on IPD-WHT and Adaptive Color KLT 57
3.8 Conclusions 61
References 61

4 Multi-view and Multispectral Image Representation by Inverse Pyramidal Decomposition 63
Roumen Kountchev
4.1 Multi-view Object Representation Based on the Inverse Pyramidal Decomposition 63
4.1.1 Multi-view 3D Object Representation with Modified IPD 63
4.1.2 Experimental Results for the Multi-view Information Coding 67
4.2 Multispectral Image Representation by Inverse Pyramidal Decomposition 71
4.2.1 Reference Image Selection in the Multispectral Sequence 72
4.2.2 Representation of Multispectral Images with 2-level Modified IPD 73
4.2.3 Experimental Results for the Multispectral Image Representation 73
4.3 Multispectral Image Compression by Branched Inverse Pyramidal Decomposition with Non-linear Pre- and Post-processing 74
4.3.1 Branched IPD with Non-linear Pre- and Post-processing 74
4.3.2 Experimental Results for the Branched Inverse Pyramidal Decomposition 78
4.4 Conclusions 81
References 81

5 Lossless Data Compression Based on Adaptive Run-length Coding 83
Vladimir Todorov, Roumen Kountchev, Roumiana Kountcheva
5.1 Introduction 83
5.2 Basic Principles 84
5.2.1 Data Coding 85
5.2.2 Data Decoding 87
5.3 Evaluation of the Lossless Coding Method Efficiency 88
5.4 Experimental Results 88
5.5 Conclusions 90
Appendix: numerical examples for data compression with the ARLE method 91
References 96

6 Multi-layer Image Watermarking Based on the Inverse Pyramidal Decomposition with Complex Hadamard Transform 97
Roumen Kountchev
6.1 Introduction 97
6.2 Algorithm for Multilayer Watermarking 98
6.2.1 Multilayer Image Watermarking 98
6.2.2 Detection of Multi-level Watermarks 104
6.2.3 Evaluation of the Multi-level Watermarking Efficiency 107
6.2.4 Experimental Results 108
6.3 Conclusions 112
References 112

7 Invariant Object Description with Inverse Pyramid Based on the Truncated Modified Mellin-Fourier Transform 113
Roumen Kountchev
7.1 Introduction 113
7.2 Invariant Object Representation with Pyramid of Coefficients Based on the Truncated Modified Mellin-Fourier Transform 114
7.3 Search by Content of Closest Objects in Image Databases 119
7.4 Fast Search of Closest Vector in the Image Database 120
7.5 Experimental Results 122
7.6 Conclusions 126
References 127

8 Multi-layer Search in Image Database Using Inverse Pyramidal Representation 129
Roumen Kountchev
Section 1: Search of 2D Objects in Image Databases 129
8.1 Introduction - Section 1 129
8.2 Image Decomposition with Inverse Pyramid 129
8.3 Multi-layer Search in Image Database 131
8.4 Evaluation of the Multi-layer Search Algorithm Efficiency 133
8.5 Experimental Results - Section 1 133
8.6 Conclusions for Section 1 136
Section 2: Fast Search of 3D Objects in Image Databases 136
8.7 Introduction - Section 2 136
8.8 Basic Principles of the Cognitive Image Representation 137
8.9 Creation of the Cognitive 3D Object Model 138
8.10 Experimental Results for Section 2 140
8.11 Conclusions - Section 2 141
References 142

9 Object Segmentation Based on the Adaptive Color PCA 145
Roumen Kountchev
9.1 Introduction 145
9.2 Space Color Presentation by Adaptive Color PCA 145
9.3 Modification of the Elliptic Boundary Color Model by Adaptive Color PCA 147
9.4 Algorithm for Object Color Segmentation Based on ACPCA and MEBM 149
9.5 Object Color Segmentation Based on the Color Kernel PCA 150

9.6 Evaluation of the Color Vectors Distribution in the Transformed Space 154
9.7 Experimental Results 154
9.8 Conclusions 156
References 156

10 Contrast Enhancement with Histogram-Adaptive Image Segmentation 159
Roumen Kountchev
10.1 Introduction 159
10.2 Method for Histogram-Adaptive Image Segmentation 160
10.3 Experimental results 161
10.4 Conclusions 165
References 165

Part II Applications of the Intelligent Image Processing

11 Archiving and Protection of Documents Images 167
Roumen Kountchev
11.1 Introduction 169
11.2 Image Histogram Modification 170
11.3 Inverse Pyramidal Image Decomposition 173
11.4 Algorithm for Lossless Data Coding 174
11.5 Adaptive Compression of Compound Images 175
11.6 Contents Protection with Fragile Digital Watermarking 176
11.7 Experimental Results 179
11.8 Conclusions 180
References 181

12 New Format for Coding of Still Images Based on the IPD 181
Vladimir Todorov, Roumiana Kountcheva
12.1 Introduction 183
12.2 Brief Representation of the Methods, Used as a Basis for the Creation of the New Format 185
12.2.1 Basic Principles of the IPD Decomposition 185
12.2.2 Description of the ARL Coding Method 186
12.3 New Format Description 186
12.3.1 General Header 186
12.3.2 Coding of Group of Images: Additional Header 188
12.3.3 Coding of Compound Images: Additional Header 187
12.3.4 Additional Information 189
12.4 Application areas 189
12.5 Conclusions 189
Annex: Basic IPD parameters for the 100-step IPD compression 190
References 193

13 Local Adaptive Interpolation of Halftone Images 193
Roumen Mironov
13.1 Introduction 195
13.2 Mathematical Description of the Method for Two-Dimensional Adaptive Image 195
13.3 Analysis of the Characteristics of the Filter for Two-Dimensional Adaptive Interpolation 197
13.3.1 Characteristics of the Bilinear Interpolation 200
13.3.2 Characteristics of the Zero Interpolation 200
13.4 Evaluation of the Adaptive 2D Interpolation Error 202
13.5 Block Scheme of the 2D Adaptive Interpolator 206
13.6 Experimental Results 207
13.6.1 Digital Scaling of Halftone Images 207
13.6.2 Optimal Thresholds Selection for Adaptive Image Interpolation 208
13.7 Conclusions 212
References 212

14 Enhancement and Efficient Storage of Signatures and Fingerprint Images 213
Roumen Kountchev
14.1 Introduction 213
14.2 Image Histogram Modification 214
14.3 Image Filtration and Segmentation 218
14.3.1 Adaptive Noise Filtration 219
14.3.2 Equalization of the Image Background Illumination 220
14.3.3 Image Segmentation 221
14.4 Experimental Results 220
14.4.1 Histogram modification and segmentation 222
14.4.2 Comparison to Other Similar Techniques 225
14.4.3 Content-based Run-length Encoding 226
14.5 Conclusions 229
References 230

15 Defects Detection in X-ray Images and Photos 231
Roumen Kountchev
15.1 Introduction 231
15.2 Image Preprocessing 232
15.3 Correction of the Background Uneven Illumination 233
15.4 Image Segmentation 234
15.5 Experimental Results 236
15.6 Conclusions 241
References 241

16 Visual Observation, Motion Control and Tracking for Intelligent Mobile Robots 243
Alexander Bekiarski
16.1 Visual Observation Model of Intelligent Mobile Robots Position Localization, Motion Control, Objects and People Tracking 243
16.2 Methods for Mobile Robots Position Localization, Motion Control, Objects and People Tracking 246
16.3 Algorithm for Mobile Robots Position Localization, Motion Control, Objects and People Tracking 250
16.4 Algorithms for Motion Detection and Object Tracking Used in the Testing of the Developed Algorithms for Simultaneous Localization with Visual Observation Information 254
16.5 Experimental Results of the Developed Algorithms 258
16.6 Conclusions 264
References 264

17 Age-Group Classification with Dissimilarity Representation and Subspace Projection 269
Krasimir Tonchev, Agata Manolova, Ognian Boumbarov
17.1 Introduction 269
17.2 Framework for Age-Group Classification 270
17.2.1 Framework Description 270
17.2.2 Face Detection 270
17.2.3 Face Normalization 272
17.2.4 Facial Features Extraction with Subspace Projection 272
17.2.5 Classification into Age-Groups 275
17.3 Experimental Testing and Results 277
17.4 Conclusion 278
References 278

18 Robust Eye Tracking with Active Camera Control 281
Ognian Boumbarov, Stanislav Panev, Ihor Paliy, Plamen Petrov
18.1 Introduction 281
18.2 Eye Tracking Based on Particle Filter 282
18.2.1 Assumptions 282
18.2.2 Pupil Model 282

18.2.3 Estimating the Hypotheses for Contour Presence 283
18.2.4 Particle Filtering 283
18.2.5 Constraining the Hypothesis 284
18.2.6 Optimization 284
18.3 Eye Tracking Based on Frame Rate Synchronized Switching IR Lightning 286
18.3.1 Assumptions 286
18.3.2 Pupil Segmentation 286
18.3.3 Eye Corners Detection 287
18.3.4 Gaze Estimation Geometric Model 288
18.4 Homography-Based Face Orientation Determination from a Fixed Monocular Camera 289
18.4.1 Neural Network-Based Face Detection Algorithm 289
18.4.2 Face Feature Detection Algorithm 290
18.4.3 Homography Using Characteristic Points for Face Orientation Estimation 290
18.5 Pan-Tilt Camera Motion Algorithm Description 293
18.6 Experimental Results 292
18.6.1 Particle Filter Algorithm Results 294
18.6.2 Synced Lightning Algorithm Results 294
18.6.3 Homography-based Algorithm Results 295
18.7 Conclusions 297
References 298
Subject Index 301

SUBJECT INDEX

A
Active Appearance Model (AAM) 267
Active Camera Control 279, 296
Active Shape Model (ASM) 267
ACT-HT Algorithm 53, 56, 57
AdaBoost Algorithm 269, 287
Adaptive Color PCA (ACPCA) 145, 147
Adaptive Color KLT (ACT) 50, 52, 54, 55, 57
Adaptive Interpolation (AD) 207
Adaptive Dictionary Algorithms 182
Adaptive Two-Dimensional Interpolation 193
Adaptive 2D Interpolation Error 200
Adaptive Defects Segmentation 229
Adaptive Inverse Pyramid Decomposition (AIPD) 31
Adaptive IPD by Back Propagation NN (AIPD-BPNN) 33, 35-38, 41
Adaptive Noise Filtration 217, 230
Adaptive Run-Length (ARL) Coding 83, 84, 184
Adaptive Resonance Theory (ART) 31
Adaptive Scalar Quantization (ASQ) 50, 52
Adaptive Vector Quantization (AVQ) 31
Advanced Wavelet Pyramid (WP) 4
Additive Gaussian Noise 217, 230, 234
Affine Moment Invariants 137, 143
Affine Transform 113, 137, 168
Age-Group Classification (AGC) 268, 270, 275
Aging Manifold Analysis 267
Aging Pattern Subspace 267
Algorithm for Object Color Segmentation 145, 149
Algorithm for Phase Watermarking 110
Algorithm for Background Illumination Correction 235
Algorithm for calculation of the R-dimensional RSTC-invatiant vector 117
Algorithm for 2D Object Representation 114
Algorithm for Eye Tracking 280, 296
Algorithm for Fragile Watermark Insertion 174
Algorithm for Histogram Modification 220
Algorithm for IPD 129
Algorithm for Lossless Data Coding 172
Algorithm for Mobile Robots Position Localization 248
Algorithm for Multilayer Watermarking 98
Algorithms for Relative Location Determination of Object 246
Algorithm for Welding Defects Detection 239
Aliasing Effect 4
Angles of Rotation 291
Anthropometric Model 267
Arithmetic Coding (AC) 78, 91, 167
Artificial Neural Networks (ANN) 4
Attention Model 4, 137
AT&T (Test Set) 293
Azimuth Angle 292

B
Background Equalization 217-219, 221, 229
Background Uneven Illumination, 219, 231,
Back Propagation NN (BPNN) 31-38, 41-43
Basic Functions for 2D-CHT 99
Bicubic (BC) Interpolation 207, 210
Bi-Histogram Transform 159, 212
Bilinear (BL) Interpolation 194-198, 202-204, 207, 210, 270
Bilinear Model 255
Binary Arithmetic Coding (BAC) 83
Binary Matrix-Mask 6, 75, 100, 103
Binary Morphological Opening 284/5
Bipolar Sigmoid Transfer Function 269, 287
BIPD Algorithm, based on HM 74
Bit Rate (BR) 19
Blocking Atrifacts Reduction 19
BMP 21, 54, 58, 108, 135, 167, 181, 182, 234
Bomblebee Stereo Camera 252, 253
Branched Inverse Pyramidal Decomposition (BIPD) 74, 77, 78, 81
Brightness Transform 160, 161, 169-171, 215, 216
Brownian Motion 280
Burrows-Wheeler Transform (BWT) 83

C
Canonic Color Ellipsoid 145
Cartesian Position and Orientation 280
Centered Pyramid (CP) 2
Chain Code 113, 182
Classification over Dissimilarity 267, 268, 273, 276
Coding of Group of Images 186
Cognitive 3D Object Model 138
Cognitive Image Retrieval 139
Cognitive Multi-Layer Model 129
Colors Covariance Matrix 147
Color Features Extraction 45
Color Models 45, 145, 149, 157
Computational Complexity 5, 9, 11-14, 19, 20, 23, 26, 31, 37, 45, 47, 50, 61, 67, 70, 71, 74, 83, 97, 109, 113, 121, 126, 129, 136, 137, 141, 146, 149, 154, 156, 165, 168, 178, 182 -184, 187, 188, 193, 227, 229, 230, 239, 245, 248
Complex Hadamard Transform (CHT) 5, 8, 97-104, 110, 112

Component Progressive Scalability 183
Compression Ratio (CR) 38, 58, 69, 140, 225
Compression with Reversible Embedded Wavelets (CREW) 4, 28
Content-Based Image Retrieval (CBIR) 129,137
Content-Based Run-Length Encoding (CBRLE) 224
Content Driven Laplacian Pyramid (CDLP) 2
Contours Extraction 104, 165, 234, 238, 239
Contrast Enhancement 159-162, 164-166, 168, 171,178, 211, 212, 215, 218, 223, 224, 227, 231
Contrast Pyramid 2.
Contrast Response Neurons Function 224
Contourlet Function 136
Convolutional Neural Network (CNN) 268, 269, 287, 288
Convolutional Kernel 269, 287
Co-occurrence Matrix 229, 230
Correction of the Uneven Background Illumination 229-231, 234
Cost Function for Least Square Optimization 255
Cosine Similarity (CSim) 122
Covariance Matrix 45, 47, 48, 50, 146-149, 151, 153, 247-249, 254, 270, 281
Cross-Covariance Matrix 249

D

Database (DB) 21, 26, 31, 37, 41, 54, 57-59, 71, 74, 88, 91, 97, 112-114, 116, 119, 120, 123-127, 129-134, 136-141, 154, 156, 161, 178, 211, 220
Deblocking by Iterative Projections on to Convex Set (POCS) 20
Deflation 182
Defects Detection 229, 230, 239
De-noising 270
Detection of Cracks 236, 239
Detection Rate (DR) 156
Depth Ratio 291
Differential Pulse Code Modulation (DPCM) 182
Digital Imaging and COmmunications in Medicine (DICOM), 181
Digital Watermarking (DW) 5, 97, 167, 168, 174
Discrete Angle 115
Dissimilarity-Based Classification (DBCs) 273
Discrete Cosine Transform (DCT) 1, 4, 6, 8, 12-14, 17-21, 25, 41, 61, 67, 71, 72, 75, 97, 130, 131, 133, 134, 137, 167, 183, 185, 186, 188
Discrete Fourier Transform (DFT) 1, 6, 8, 26, 97, 113, 114, 116, 118, 123, 126, 168
Discrete Wavelet Transform (DWT) 3, 4, 41, 113
Dissimilarity Matrix 275, 276
Dissimilarity Representation 267, 268, 273, 276

E

Edge Detection 20, 145, 165, 237, 249, 257
Edge Effect 4
Edge Improvement 270
Ego-Motion of the Camera 254, 255
Embedded Block Coding with Optimized Truncation (EBCOT) 4
Embedded Predictive Wavelet Image Coder (EBCOT) 4
Embedded Zero-tree of Wavelet Coefficients (EZW) 4
Elias Code 83
Elliptic Boundary Model (EBM) 145, 147-149
Entropy Coder/Decoder (EC/ED) 34
Error Covariance Matrix 249
Euclidean Homography Matrix 280
Euler Angle 49, 50
Euclidean Homography 280, 290
Euclidean Space 288
Exhaustive Search Algorithm (ESA) 133
Exponential-Golomb Code 83
Expectation-Maximization (EM) Algorithm 282
Exponential Polar Transform (EPT) 116, 126
Eye Corners Detection 285

F

Face Alignment Algorithm 276
Face Detection (FD) 268, 270, 275
Face Orientation Estimation Algorithm 280, 288, 293, 295
Face Normalization (FN) 268, 275
Facial Features Extraction 270
False Alarms (FA) Rate 268
False Positive Rate (FPR) 156
Fast Fourier Transform (FFT) 41, 114, 115, 239
Feature Selection Algorithm 254
Filter for Two-Dimensional Adaptive Interpolation 195
FG-NET dataset 276
First Order Autoregressive Process 282
Fitting Criterion 254
Fixed Monocular Camera 280, 287, 288
Fourier-Mellin Transform (MFT) 113, 114, 116, 117, 119, 126
Fractal Transform (FT) 167
Fragile Watermark 167, 168, 174, 178
Frame Rate 284, 295
Fusion 228-230, 284
Fuzzy Expert System 230
Fuzzy Histogram Hyperbolization 159, 212

Fuzzy Logic-based Occupancy Grid (FLOG), 254
Fuzzy k-Nearest Neighbor 230

G
Gabor Function 137, 229
Gaze Estimation Geometric Model 286
Gaze Tracking 279, 280, 284, 293, 295
Gaussian Deformation 281
Gaussian Mixture Model (GMM) 149
Gaussian Pyramid (GP) 2
Gauss Pyramid with DWT (GP-DWT) 4
Generalized Laplacian 281
Geometric Alignment 268, 270
Gibbs Effect 20
Global Positioning System (GPS) 248
Gram Matrix 152
Graphic DjVu 167
Graphic Interchange Format (GIF) 181-183, 191
Grey Level Differences (GLDs) 280

H
Haar-like Features Classifier 268
Hartley Transform 137
Hierarchical DCT Pyramid (DCT-H Pyramid) 4
Hierarchy-Embedded Differential Pyramid (HEDI) 2
Hierarchical Interpolation by Radial Basis Function Network (HI-RBFN) 2
Higher-Order SVD (HOSVD) 150.
Hilbert Space 272
Histogram Equalization 159-163, 171, 178, 211, 212, 215, 270
Histogram Matching (HM) 52-54, 57, 74
Histogram Modification 54, 63, 90, 165, 168, 169, 177, 178, 211, 212, 215, 220-224, 227
Homography-Based Algorithm 293
Homography Matrix 280, 291
Hough Transform (HT) 113
Householder Algorithm 45
Huffman Coding (HC) 8, 33, 78, 91, 167, 172, 173
Human Age Estimation (AE) 267
Human and Animal Visual Perception 244
Human-Computer Interaction (HCI) 267, 279
Human Facial Image Analysis 267
Human Visual System (HVS) 1, 137

I
Incremental Navigation Map 245
Independent Component Analysis (ICA) 150
Industrial Radiographic Image 229
Infra-Red Camera 279, 297
Infra-Red Filter 284
Integer Interpolation 205
Intelligent Robots 241
Interpolation Algorithms 193
Invertible Intrinsic Camera Calibration Matrix 290
Inverse Pyramid Decomposition (IPD) 5, 7-26, 31, 41, 57, 58, 60, 61-67, 69-77, 81, 97, 98, 100-105, 107-110, 112, 114, 117-119, 126, 129, 131-134, 137-140, 167, 168, 171-179, 181-188, 190, 192
Inverse Pyramid Decomposition with Modified MFT (IPD-MMFT) 119
Inverse Pyramid Decomposition with Discrete Cosine Transform (IPD-DCT) 8, 17-19, 61
Inverse Pyramid Decomposition with Karhunen-Loeve Transform (IPD-KLT) 58, 60, 61
Inverse Pyramid Decomposition with Walsh - Hadamard Transform (IPD-WHT) 15, 16, 18,19, 57, 77

J
Joint Picture Experts Group (JPEG) 24, 25, 26, 31, 36-38, 41, 61-74, 81-83, 97, 109-111, 167, 168, 176, 178, 181, 183, 187, 211, 225
Joint Picture Experts Group 2000 (JPEG2000) 12, 14, 24, 26, 31, 36-38, 41, 70, 72, 74, 80, 81, 89, 90, 96, 167, 177, 179, 187, 211, 224-226

K
Kalman Filter 224, 245, 247
Karhunen-Loeve Transform (KLT) 1, 6, 8, 26, 45-52, 54, 57-61, 66, 72, 167
Kernel PCA (KPCA) 145, 150
Kernel Spectral Regression Algorithm 276
Kinematics Model 245

L
Lagrangian Function 272
Lagrange Multipliers 272, 274
Lapped Orthogonal Transform (LOT) 137
Laplacian Pyramid (LP) 1, 2, 9, 12, 136
Layered Image Representation 1
Least-Square Laplacian Pyramid (LS-LP) 2
Learning and Testing Algorithms 241, 251, 260, 262
Learning Visual Observation Algorithm 251
Learning Algorithm for Simultaneous Localization with Visual Observation 250
Leave One Person Out (LOPO) Evaluation Method 275
Lee Algorithm 12
Lempel-Ziv Coding (LZ77, LZ78) 83
Lempel-Ziv-Welch Coding (LZW) 83, 167, 182

Levenberg-Marquardt (LM) Algorithm 32
Lighting Normalization 270
Lloyd-Max Algorithm 50
Locally-Adaptive Filtration 230
Locally Adaptive Resolution (LAR) 4
Local Adaptive Interpolation 193
Local Image Processing Algorithm 249, 257
Localization with Visual Observation 249-253, 256
Log-Polar Transform (LPT) 113, 115, 122
Lorentz Cost Function 254
LOw COmplexity LOssless COmpression for Images (LOCO-I) 83
Low Pass Filter (LPF) 255, 256

M
Majority Vote Algorithm 120
Manifold Learning Algorithm 267
Map Covariance Matrix 249
Markov Process 45
Markov's Chain 281
Matching Pursuit Technique 137
M-band Perfect Reconstruction FB 3
Mean Absolute Error 294, 295
Mean Pyramid (MP) 2
Mean-Shift Algorithm 282
Mean Square Error (MSE) 34, 50, 108, 200, 207, 210
Measurement Line (ML) 280-282
Medial Axis Transform 113
Membership Functions 159, 212, 254
Mercer Kernel Function 272
Mobile Robots Motion Control 241
Mobile Robot Platform 241, 242, 249, 256, 257, 258
Mobile Robot Position Localization 241, 244, 248
Mobile Robot Visual Area 241, 244
Mobile Robot Visual Attention 243, 249, 257
Mobile Robot Visual Perception 244, 246
Mobile Robot Visual Sensors 242, 246, 249, 252, 256, 257
Mobile Robot Visual System 241, 249, 251
Model Predicts an S-Shaped 243
Modified Elliptic Boundary Model (MEBM) 148
Modified IPD 63, 64, 66, 67, 69-74
Modified MFT 114, 116, 126
Modified Squared Cosine Similarity (MSCSim) 122
Morphological Image Pyramid (MIP) 2
Morphological Subband Decomposition (MSD) 4
Morphological Subband Pyramid (MSP) 4
Motion Detection and Object Tracking 252
Moving Picture Experts Group 2 (MPEG 2) 90
Multi-Layer Distance (MLD) 129. 131, 132
Multi-Layer Search (MLS) 31, 114, 129, 130-134, 136, 138
Multi-Spectral (MS) Image 61,71-75, 78, 79, 81
Multi-layer Neural Networks 230
Multilayer Perceptron 145, 287
Multi-level Watermark Detection 104
Multi-level Watermark Insertion 104, 106
Multilayer Watermarking 98
Multi-Sigmoid Activation Function 145
Multi-Task Gaussian Wrapped Process 267
Multi-View Image 63-66, 71, 73, 125, 129, 141, 187

N
Non-Destructive Control 229
Non-Linear Image Representation 31, 41
Non-Orthogonal Pyramid 1, 2
Normalized Cartesian Coordinates 290
Neural Network Classifier 269, 287, 288, 293
Neural Network-Based Face Detection 287
Neurobiology 243
Noise Suppression 170, 221, 229, 230, 234

O
Objects and People Tracking 241, 242, 244, 248
Orthogonal Locality Preserving Projections 267
Orthogonal Pyramid 3, 136
Orthogonal Rotation Matrix 289, 290
Orthogonal Transform (OT) 1, 5, 6, 8, 18-20, 26, 31, 47, 61, 63-67, 130-132, 137, 167, 171, 172, 175, 179, 183, 184, 188
Otsu Algorithm 284

P
Pan Angle 253, 293, 294
Pan-Tilt Camera Motion Algorithm 291
Pan-Tilt Unit (PTU) 280, 293
Particle Filter 279-282, 292, 295-297
Particle Filter Tracker 292
Peak Signal to Noise Ratio (PSNR) 8, 19, 21-23, 35-38, 40, 41, 51-53, 55, 56, 59, 61, 69, 70, 74, 80, 89, 90, 108, 109-111, 140, 178, 193, 207-209, 217, 220
Penetrating Electromagnetic Radiation 229
Phase Angle 109
Personal Computer eXchange (PCX) 182
Polynomial Approximation Pyramid (PAP) 2
Polynomial Spline Pyramid (PSP) 2
Portable Network Graphics (PNG) 181, 182
Post-Filter 8
Predictive Coding 83, 182

Pre-Processing 75, 84, 90, 229, 270
Principal Color 145
Principal Component Analysis (PCA) 145, 153, 154, 156, 267, 268, 270, 275, 276
Probability Density Function (pdf) 281
Probabilistic PCA (PPCA) 150
Profile 230, 282-284, 293
Progressive Image Transfer (PIT) 4
Proportional, Integral, Derivative (PID) Controller 280, 291
Pupil Glint Vector 279
Pupil Model 280
Pyramidal Image Decomposition (PID) 1, 41, 171
Pyramid based on Hierarchical Interpolation by Radial Basis Function Networks (HI-RBFN) 2

Q
QM-Coder 83
QR Factorization 45
Quadrature Complex Conjugated FB 3
Quadrature Mirror FB 3
Quadtree Division 6
Quality Factor (QF) 21-23, 109
Quality Progressive Scalability 183
Quantization/Dequantization (Q/Q^{-1}) 8

R
Radial Basis Function Network (RBFN) 2
Radon Transform (RT) 168
Recognition of Welding Defects 229
Recursive Hilbert Scan 6, 7
Reduced Inverse Pyramid Decomposition (RIPD), 14, 15, 18-20
Reduced Inverse Pyramid Decomposition with Discrete Cosine Transform (RIPD-DCT) 18, 19
Regional Force 285
Reduced Laplacian Pyramid/Enhanced Laplacian Pyramid (RLP/ELP) 2
Reduced-Sum Pyramid/Reduced-Difference Pyramid (RSP/RDP) 2, 12
Region of Interest (ROI) 236, 270
Regional Torque 285, 286
Regularized Least Squares 271
Resistant Watermark 97, 112, 168
Resolution Progressive Scalability 183
Responses Generation 271
Ridgelet Transform 4
Ringing Effect 4
Robust Eye Tracking 279
Robust Regression with Local Adjustments 267
Root Mean Square Error (RMSE) 36, 40, 41
Rounding Transform Pyramid (RTP) 2
Run-Length Coding (RLC) 33, 35, 78, 167
Run-Length Encoding (RLE) 93, 95, 172, 182, 185
RSTC Description 114
RST-invariant Object Representation 113
RSTC Invariant Object Representation 116
RSTC Invariant Vector 117, 119

S
Salient Features Extraction 63
Scaling Algorithm 205
Segmentation 20, 45, 119, 124, 145, 146, 148-150, 152, 154-156, 159, 160, 162, 164, 169, 170, 174, 177, 187, 211-213, 216, 217, 219-222, 227, 229, 230-233, 237, 284
Self-Organizing Kohonen (SOK) 31
Separating Hyperplane 271, 272
Shape Coefficient (Cs) 273
Shannon-Fano 83
Shiftable Complex Directional Pyramid Decomposition (SCD-PD) 4
Sign Language (SL) Interpreter 164
Simultaneous Localization and Map (SLAM) 245, 248, 252, 253
Single Gaussian Model (SGM) 149
Singular Value Decomposition (SVD) 1, 137
Skin-Color Detection 145
Skin Color Models 145
Sliding Window 20, 217, 230
SOM Algorithm 31
Space-Frequency Quantization (SFQ) 4
Sparse, Semi-Supervised Gaussian Process (S3GP) 279
Spatial Partitioning of Images into Hierarchical Trees (SPIHT) 4, 31, 72
Spectral Regression (SR) 267, 268, 270, 276
Speed up Ratio (SR) 133
Squared Euclidean Distance (EUD) 119, 121
Statistical (Adaptive) Transforms, 159, 212
State Covariance Matrix 248, 249
Steerable Pyramid (ST) 4
Stimulus Component 243, 244
State Transition Model 246
Stochastic Pyramid (SP) 2
S-Transform Pyramid (STP) 2
Structural SIMilarity (SSIM) 40, 41, 80
Subspace Projection (SP) 268
Support Vector Machine (SVM) 4, 153, 267, 268, 271-276
Synced Lightning Algorithm 292

T
Tag Image File (TIF) 182
Template Fitting 285

Testing Algorithm 241, 249, 250, 251, 259-261, 262
Tilt Angle 270, 294, 295
Time Dependent Covariance Matrix 281
Tracking Algorithm 242, 252, 280, 285, 295
Tracking Optimization 283
Transform Coefficients Quantization 186
Transformation of 2D-Data into 1D-Sequence (2D-1D) 8
Transformation of 1D-Sequence into 2D-Data (2D-1D) 8
Transformation Model 255
Trellis Coded Quantization (TCQ) 4
Triangle Algorithm 219, 230, 232
Two-Dimensional Adaptive Fuzzy Filter (2DAFF) 217, 221, 230, 234, 236, 237
Two-Dimensional Interpolation 193, 195
Two-Dimensional Z Transform 197
Tree Structured FB 3, 4
True Positives Rate (TPR) 156

U
Ultrasound (US) Image 174
Unibrain Fire-I Firewire Camera 293

V
Variable Block Subband DCT Decomposition (VB-SBDCT) 4
Variable Length Huffman Coding 33
View Angle 124, 127, 139
Vision Algorithm 254
Visual Attention Model 137
Visual Features Extraction 253
Visual Mobile Robot Observation 248, 251
Visual Observation Learning Algorithm 249, 257
Visual Observation Model 241, 242, 244, 246, 247
Virtual Reality 267, 280, 296
Visual Tracking 241
Volumetric Inspection 229

W
Walsh-Hadamard Transform (WHT) 1, 13, 20, 130, 137, 167, 177
Watermarking Algorithms 97
Wavelet Decomposition by Tree Structured FB4
Wavelet Pyramid (WP) 4, 14
Wavelet Packet Transform (WPT) 4
Wavelet Scalar Quantization (WSQ) 211, 224, 225
Wavelet Transform (WT) 4, 72, 167, 168, 183
Weighted Covariance Matrix 148
Weights Matrix 270
Weld District Extraction 230
Wide Angle Camera 280
Wide Angle Lenses 293

X
X-ray Image 159, 229, 230, 235

Y
Yale Test Set 293

Z
Zernike Polynomial 113
Zero (ZR) Interpolation 118, 195, 198, 200, 201, 202, 204, 205

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