<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3.2</td>
<td>Line Sources</td>
<td>26</td>
</tr>
<tr>
<td>2.3.3</td>
<td>Area Sources</td>
<td>27</td>
</tr>
<tr>
<td>2.4</td>
<td>Local Shading Models</td>
<td>28</td>
</tr>
<tr>
<td>2.4.1</td>
<td>Local Shading Models for Point Sources</td>
<td>28</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Area Sources and their Shadows</td>
<td>31</td>
</tr>
<tr>
<td>2.4.3</td>
<td>Ambient Illumination</td>
<td>31</td>
</tr>
<tr>
<td>2.5</td>
<td>Application: Photometric Stereo</td>
<td>33</td>
</tr>
<tr>
<td>2.5.1</td>
<td>Normal and Albedo from Many Views</td>
<td>36</td>
</tr>
<tr>
<td>2.5.2</td>
<td>Shape from Normals</td>
<td>37</td>
</tr>
<tr>
<td>2.6</td>
<td>Interreflections: Global Shading Models</td>
<td>40</td>
</tr>
<tr>
<td>2.6.1</td>
<td>An Interreflection Model</td>
<td>42</td>
</tr>
<tr>
<td>2.6.2</td>
<td>Solving for Radiosity</td>
<td>43</td>
</tr>
<tr>
<td>2.6.3</td>
<td>The qualitative effects of interreflections</td>
<td>45</td>
</tr>
<tr>
<td>2.7</td>
<td>Notes</td>
<td>47</td>
</tr>
<tr>
<td>2.8</td>
<td>Assignments</td>
<td>50</td>
</tr>
<tr>
<td>2.8.1</td>
<td>Exercises</td>
<td>50</td>
</tr>
<tr>
<td>2.8.2</td>
<td>Programming Assignments</td>
<td>51</td>
</tr>
<tr>
<td>3</td>
<td>COLOUR</td>
<td>53</td>
</tr>
<tr>
<td>3.1</td>
<td>The Physics of Colour</td>
<td>53</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Radiometry for Coloured Lights: Spectral Quantities</td>
<td>53</td>
</tr>
<tr>
<td>3.1.2</td>
<td>The Colour of Surfaces</td>
<td>54</td>
</tr>
<tr>
<td>3.1.3</td>
<td>The Colour of Sources</td>
<td>55</td>
</tr>
<tr>
<td>3.2</td>
<td>Human Colour Perception</td>
<td>58</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Colour Matching</td>
<td>58</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Colour Receptors</td>
<td>61</td>
</tr>
<tr>
<td>3.3</td>
<td>Representing Colour</td>
<td>63</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Linear Colour Spaces</td>
<td>63</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Non-linear Colour Spaces</td>
<td>68</td>
</tr>
<tr>
<td>3.3.3</td>
<td>Spatial and Temporal Effects</td>
<td>73</td>
</tr>
<tr>
<td>3.4</td>
<td>Application: Finding Specularities</td>
<td>73</td>
</tr>
<tr>
<td>3.5</td>
<td>Surface Colour from Image Colour</td>
<td>77</td>
</tr>
<tr>
<td>3.5.1</td>
<td>Surface Colour Perception in People</td>
<td>77</td>
</tr>
<tr>
<td>3.5.2</td>
<td>Inferring Lightness</td>
<td>80</td>
</tr>
<tr>
<td>3.5.3</td>
<td>A Model for Image Colour</td>
<td>83</td>
</tr>
<tr>
<td>3.5.4</td>
<td>Surface Colour from Finite Dimensional Linear Models</td>
<td>86</td>
</tr>
<tr>
<td>3.6</td>
<td>Notes</td>
<td>89</td>
</tr>
</tbody>
</table>
3.6.1 Trichromacy and Colour Spaces 89
3.6.2 Lightness and Colour Constancy 90
3.6.3 Colour in Recognition 91
3.7 Assignments 91

II IMAGE MODELS 94

4 GEOMETRIC IMAGE FEATURES 96
4.1 Elements of Differential Geometry 100
4.1.1 Curves 100
4.1.2 Surfaces 105
Application: The shape of specularities 109
4.2 Contour Geometry 112
4.2.1 The Occluding Contour and the Image Contour 113
4.2.2 The Cusps and Inflections of the Image Contour 114
4.2.3 Koenderink’s Theorem 115
4.3 Notes 117
4.4 Assignments 118

5 ANALYTICAL IMAGE FEATURES 120
5.1 Elements of Analytical Euclidean Geometry 120
5.1.1 Coordinate Systems and Homogeneous Coordinates 121
5.1.2 Coordinate System Changes and Rigid Transformations 124
5.2 Geometric Camera Parameters 129
5.2.1 Intrinsic Parameters 129
5.2.2 Extrinsic Parameters 132
5.2.3 A Characterization of Perspective Projection Matrices 132
5.3 Calibration Methods 133
5.3.1 A Linear Approach to Camera Calibration 134
Technique: Linear Least Squares Methods 135
5.3.2 Taking Radial Distortion into Account 139
5.3.3 Using Straight Lines for Calibration 140
5.3.4 Analytical Photogrammetry 143
Technique: Non-Linear Least Squares Methods 145
5.4 Notes 147
5.5 Assignments 147
6 AN INTRODUCTION TO PROBABILITY

6.1 Probability in Discrete Spaces
   6.1.1 Probability: the P-function
   6.1.2 Conditional Probability
   6.1.3 Choosing P

6.2 Probability in Continuous Spaces
   6.2.1 Event Structures for Continuous Spaces
   6.2.2 Representing a P-function for the Real Line
   6.2.3 Probability Densities

6.3 Random Variables
   6.3.1 Conditional Probability and Independence
   6.3.2 Expectations
   6.3.3 Joint Distributions and Marginalization

6.4 Standard Distributions and Densities
   6.4.1 The Normal Distribution

6.5 Probabilistic Inference
   6.5.1 The Maximum Likelihood Principle
   6.5.2 Priors, Posteriors and Bayes’ rule
   6.5.3 Bayesian Inference
   6.5.4 Open Issues

6.6 Discussion

III EARLY VISION: ONE IMAGE

7 LINEAR FILTERS

7.1 Linear Filters and Convolution
   7.1.1 Convolution
   7.1.2 Example: Smoothing by Averaging
   7.1.3 Example: Smoothing with a Gaussian

7.2 Shift invariant linear systems
   7.2.1 Discrete Convolution
   7.2.2 Continuous Convolution
   7.2.3 Edge Effects in Discrete Convolutions

7.3 Spatial Frequency and Fourier Transforms
   7.3.1 Fourier Transforms

7.4 Sampling and Aliasing
   7.4.1 Sampling
7.4.2 Aliasing 201
7.4.3 Smoothing and Resampling 202
7.5 Technique: Scale and Image Pyramids 204
  7.5.1 The Gaussian Pyramid 205
  7.5.2 Applications of Scaled Representations 206
  7.5.3 Scale Space 208
7.6 Discussion 211
  7.6.1 Real Imaging Systems vs Shift-Invariant Linear Systems 211
  7.6.2 Scale 212

8 EDGE DETECTION 214
  8.1 Estimating Derivatives with Finite Differences 214
    8.1.1 Differentiation and Noise 216
    8.1.2 Laplacians and edges 217
  8.2 Noise 217
    8.2.1 Additive Stationary Gaussian Noise 219
  8.3 Edges and Gradient-based Edge Detectors 224
    8.3.1 Estimating Gradients 224
    8.3.2 Choosing a Smoothing Filter 225
    8.3.3 Why Smooth with a Gaussian? 227
    8.3.4 Derivative of Gaussian Filters 229
    8.3.5 Identifying Edge Points from Filter Outputs 230
  8.4 Commentary 234

9 FILTERS AND FEATURES 237
  9.1 Filters as Templates 237
    9.1.1 Convolution as a Dot Product 237
    9.1.2 Changing Basis 238
  9.2 Human Vision: Filters and Primate Early Vision 239
    9.2.1 The Visual Pathway 239
    9.2.2 How the Visual Pathway is Studied 241
    9.2.3 The Response of Retinal Cells 241
    9.2.4 The Lateral Geniculate Nucleus 242
    9.2.5 The Visual Cortex 243
    9.2.6 A Model of Early Spatial Vision 246
  9.3 Technique: Normalised Correlation and Finding Patterns 248
    9.3.1 Controlling the Television by Finding Hands by Normalised Correlation 248
9.4 Corners and Orientation Representations 249
9.5 Advanced Smoothing Strategies and Non-linear Filters 252
  9.5.1 More Noise Models 252
  9.5.2 Robust Estimates 253
  9.5.3 Median Filters 254
  9.5.4 Mathematical morphology: erosion and dilation 257
  9.5.5 Anisotropic Scaling 258
9.6 Commentary 259

10 TEXTURE 261
  10.1 Representing Texture 263
    10.1.1 Extracting Image Structure with Filter Banks 263
  10.2 Analysis (and Synthesis) Using Oriented Pyramids 268
    10.2.1 The Laplacian Pyramid 269
    10.2.2 Oriented Pyramids 272
  10.3 Application: Synthesizing Textures for Rendering 272
    10.3.1 Homogeneity 274
    10.3.2 Synthesis by Matching Histograms of Filter Responses 275
    10.3.3 Synthesis by Sampling Conditional Densities of Filter Responses 280
    10.3.4 Synthesis by Sampling Local Models 284
  10.4 Shape from Texture: Planes and Isotropy 286
    10.4.1 Recovering the Orientation of a Plane from an Isotropic Texture 288
    10.4.2 Recovering the Orientation of a Plane from an Homogeneity Assumption 290
    10.4.3 Shape from Texture for Curved Surfaces 291
  10.5 Notes 292
    10.5.1 Shape from Texture 293

IV EARLY VISION: MULTIPLE IMAGES 295

11 THE GEOMETRY OF MULTIPLE VIEWS 297
  11.1 Two Views 298
    11.1.1 Epipolar Geometry 298
    11.1.2 The Calibrated Case 299
    11.1.3 Small Motions 300
    11.1.4 The Uncalibrated Case 301
    11.1.5 Weak Calibration 302
11.2 Three Views
  11.2.1 Trifocal Geometry 307
  11.2.2 The Calibrated Case 307
  11.2.3 The Uncalibrated Case 309
  11.2.4 Estimation of the Trifocal Tensor 310
11.3 More Views 311
11.4 Notes 317
11.5 Assignments 319

12 STEREOPSIS 321
  12.1 Reconstruction 323
    12.1.1 Camera Calibration 324
    12.1.2 Image Rectification 325
  Human Vision: Stereopsis 327
  12.2 Binocular Fusion 331
    12.2.1 Correlation 331
    12.2.2 Multi-Scale Edge Matching 333
    12.2.3 Dynamic Programming 336
  12.3 Using More Cameras 338
    12.3.1 Trinocular Stereo 338
    12.3.2 Multiple-Baseline Stereo 340
  12.4 Notes 341
  12.5 Assignments 343

13 AFFINE STRUCTURE FROM MOTION 345
  13.1 Elements of Affine Geometry 346
  13.2 Affine Structure from Two Images 349
    13.2.1 The Affine Structure-from-Motion Theorem 350
    13.2.2 Rigidity and Metric Constraints 351
  13.3 Affine Structure from Multiple Images 351
    13.3.1 The Affine Structure of Affine Image Sequences 352
    Technique: Singular Value Decomposition 353
    13.3.2 A Factorization Approach to Affine Motion Analysis 353
  13.4 From Affine to Euclidean Images 356
    13.4.1 Euclidean Projection Models 357
    13.4.2 From Affine to Euclidean Motion 358
  13.5 Affine Motion Segmentation 360
    13.5.1 The Reduced Echelon Form of the Data Matrix 360
13.5.2 The Shape Interaction Matrix 360
13.6 Notes 362
13.7 Assignments 363

14 PROJECTIVE STRUCTURE FROM MOTION 365
14.1 Elements of Projective Geometry 366
  14.1.1 Projective Bases and Projective Coordinates 366
  14.1.2 Projective Transformations 368
  14.1.3 Affine and Projective Spaces 370
  14.1.4 Hyperplanes and Duality 371
  14.1.5 Cross-Ratios 372
  14.1.6 Application: Parameterizing the Fundamental Matrix 375
14.2 Projective Scene Reconstruction from Two Views 376
  14.2.1 Analytical Scene Reconstruction 376
  14.2.2 Geometric Scene Reconstruction 378
14.3 Motion Estimation from Two or Three Views 379
  14.3.1 Motion Estimation from Fundamental Matrices 379
  14.3.2 Motion Estimation from Trifocal Tensors 381
14.4 Motion Estimation from Multiple Views 382
  14.4.1 A Factorization Approach to Projective Motion Analysis 383
  14.4.2 Bundle Adjustment 386
14.5 From Projective to Euclidean Structure and Motion 386
  14.5.1 Metric Upgrades from (Partial) Camera Calibration 387
  14.5.2 Metric Upgrades from Minimal Assumptions 389
14.6 Notes 392
14.7 Assignments 394

V MID-LEVEL VISION 399

15 SEGMENTATION USING CLUSTERING METHODS 401
15.1 Human vision: Grouping and Gestalt 403
15.2 Applications: Shot Boundary Detection, Background Subtraction and Skin Finding 407
  15.2.1 Background Subtraction 407
  15.2.2 Shot Boundary Detection 408
  15.2.3 Finding Skin Using Image Colour 410
15.3 Image Segmentation by Clustering Pixels 411
15.3.1 Simple Clustering Methods 411
15.3.2 Segmentation Using Simple Clustering Methods 413
15.3.3 Clustering and Segmentation by K-means 415
15.4 Segmentation by Graph-Theoretic Clustering 417
  15.4.1 Basic Graphs 418
  15.4.2 The Overall Approach 420
  15.4.3 Affinity Measures 420
  15.4.4 Eigenvectors and Segmentation 424
  15.4.5 Normalised Cuts 427
15.5 Discussion 430

16 FITTING 436
  16.1 The Hough Transform 437
    16.1.1 Fitting Lines with the Hough Transform 437
    16.1.2 Practical Problems with the Hough Transform 438
  16.2 Fitting Lines 440
    16.2.1 Least Squares, Maximum Likelihood and Parameter Estimation 441
    16.2.2 Which Point is on Which Line? 444
  16.3 Fitting Curves 445
    16.3.1 Implicit Curves 446
    16.3.2 Parametric Curves 449
  16.4 Fitting to the Outlines of Surfaces 450
    16.4.1 Some Relations Between Surfaces and Outlines 451
    16.4.2 Clustering to Form Symmetries 453
  16.5 Discussion 457

17 SEGMENTATION AND FITTING USING PROBABILISTIC METHODS 460
  17.1 Missing Data Problems, Fitting and Segmentation 461
    17.1.1 Missing Data Problems 461
    17.1.2 The EM Algorithm 463
    17.1.3 Colour and Texture Segmentation with EM 469
    17.1.4 Motion Segmentation and EM 470
    17.1.5 The Number of Components 474
    17.1.6 How Many Lines are There? 474
  17.2 Robustness 475
    17.2.1 Explicit Outliers 475
    17.2.2 M-estimators 477
17.2.3 RANSAC 480
17.3 How Many are There? 483
  17.3.1 Basic Ideas 484
  17.3.2 AIC — An Information Criterion 484
  17.3.3 Bayesian methods and Schwartz’ BIC 485
  17.3.4 Description Length 486
  17.3.5 Other Methods for Estimating Deviance 486
17.4 Discussion 487

18 TRACKING 489
  18.1 Tracking as an Abstract Inference Problem 490
    18.1.1 Independence Assumptions 490
    18.1.2 Tracking as Inference 491
    18.1.3 Overview 492
  18.2 Linear Dynamic Models and the Kalman Filter 492
    18.2.1 Linear Dynamic Models 492
    18.2.2 Kalman Filtering 497
    18.2.3 The Kalman Filter for a 1D State Vector 497
    18.2.4 The Kalman Update Equations for a General State Vector 499
    18.2.5 Forward-Backward Smoothing 500
  18.3 Non-Linear Dynamic Models 505
    18.3.1 Unpleasant Properties of Non-Linear Dynamics 508
    18.3.2 Difficulties with Likelihoods 509
  18.4 Particle Filtering 511
    18.4.1 Sampled Representations of Probability Distributions 511
    18.4.2 The Simplest Particle Filter 515
    18.4.3 A Workable Particle Filter 518
    18.4.4 If’s, And’s and But’s — Practical Issues in Building Particle Filters 519
  18.5 Data Association 523
    18.5.1 Choosing the Nearest — Global Nearest Neighbours 523
    18.5.2 Gating and Probabilistic Data Association 524
  18.6 Applications and Examples 527
    18.6.1 Vehicle Tracking 528
    18.6.2 Finding and Tracking People 532
  18.7 Discussion 538
II Appendix: The Extended Kalman Filter, or EKF 540
VI HIGH-LEVEL VISION

19 CORRESPONDENCE AND POSE CONSISTENCY

19.1 Initial Assumptions
19.1.1 Obtaining Hypotheses
19.2 Obtaining Hypotheses by Pose Consistency
19.2.1 Pose Consistency for Perspective Cameras
19.2.2 Affine and Projective Camera Models
19.2.3 Linear Combinations of Models
19.3 Obtaining Hypotheses by Pose Clustering
19.4 Obtaining Hypotheses Using Invariants
19.4.1 Invariants for Plane Figures
19.4.2 Geometric Hashing
19.4.3 Invariants and Indexing
19.5 Verification
19.5.1 Edge Proximity
19.5.2 Similarity in Texture, Pattern and Intensity
19.5.3 Example: Bayes Factors and Verification
19.6 Application: Registration in Medical Imaging Systems
19.6.1 Imaging Modes
19.6.2 Applications of Registration
19.6.3 Geometric Hashing Techniques in Medical Imaging
19.7 Curved Surfaces and Alignment
19.8 Discussion

20 FINDING TEMPLATES USING CLASSIFIERS

20.1 Classifiers
20.1.1 Using Loss to Determine Decisions
20.1.2 Overview: Methods for Building Classifiers
20.1.3 Example: A Plug-in Classifier for Normal Class-conditional Densities
20.1.4 Example: A Non-Parametric Classifier using Nearest Neighbours
20.1.5 Estimating and Improving Performance
20.2 Building Classifiers from Class Histograms
20.2.1 Finding Skin Pixels using a Classifier
20.2.2 Face Finding Assuming Independent Template Responses
20.3 Feature Selection
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.3.1</td>
<td>Principal Component Analysis</td>
<td>595</td>
</tr>
<tr>
<td>20.3.2</td>
<td>Canonical Variates</td>
<td>597</td>
</tr>
<tr>
<td>20.4</td>
<td>Neural Networks</td>
<td>601</td>
</tr>
<tr>
<td>20.4.1</td>
<td>Key Ideas</td>
<td>601</td>
</tr>
<tr>
<td>20.4.2</td>
<td>Minimizing the Error</td>
<td>606</td>
</tr>
<tr>
<td>20.4.3</td>
<td>When to Stop Training</td>
<td>610</td>
</tr>
<tr>
<td>20.4.4</td>
<td>Finding Faces using Neural Networks</td>
<td>610</td>
</tr>
<tr>
<td>20.4.5</td>
<td>Convolutional Neural Nets</td>
<td>612</td>
</tr>
<tr>
<td>20.5</td>
<td>The Support Vector Machine</td>
<td>615</td>
</tr>
<tr>
<td>20.5.1</td>
<td>Support Vector Machines for Linearly Separable Datasets</td>
<td>616</td>
</tr>
<tr>
<td>20.5.2</td>
<td>Finding Pedestrians using Support Vector Machines</td>
<td>618</td>
</tr>
<tr>
<td>20.6</td>
<td>Conclusions</td>
<td>622</td>
</tr>
<tr>
<td>II</td>
<td>Appendix: Support Vector Machines for Datasets that are not Linearly Separable</td>
<td>624</td>
</tr>
<tr>
<td>III</td>
<td>Appendix: Using Support Vector Machines with Non-Linear Kernels</td>
<td>625</td>
</tr>
<tr>
<td>21</td>
<td>RECOGNITION BY RELATIONS BETWEEN TEMPLATES</td>
<td>627</td>
</tr>
<tr>
<td>21.1</td>
<td>Finding Objects by Voting on Relations between Templates</td>
<td>628</td>
</tr>
<tr>
<td>21.1.1</td>
<td>Describing Image Patches</td>
<td>628</td>
</tr>
<tr>
<td>21.1.2</td>
<td>Voting and a Simple Generative Model</td>
<td>629</td>
</tr>
<tr>
<td>21.1.3</td>
<td>Probabilistic Models for Voting</td>
<td>630</td>
</tr>
<tr>
<td>21.1.4</td>
<td>Voting on Relations</td>
<td>632</td>
</tr>
<tr>
<td>21.1.5</td>
<td>Voting and 3D Objects</td>
<td>632</td>
</tr>
<tr>
<td>21.2</td>
<td>Relational Reasoning using Probabilistic Models and Search</td>
<td>633</td>
</tr>
<tr>
<td>21.2.1</td>
<td>Correspondence and Search</td>
<td>633</td>
</tr>
<tr>
<td>21.2.2</td>
<td>Example: Finding Faces</td>
<td>636</td>
</tr>
<tr>
<td>21.3</td>
<td>Using Classifiers to Prune Search</td>
<td>639</td>
</tr>
<tr>
<td>21.3.1</td>
<td>Identifying Acceptable Assemblies Using Projected Classifiers</td>
<td>640</td>
</tr>
<tr>
<td>21.3.2</td>
<td>Example: Finding People and Horses Using Spatial Relations</td>
<td>640</td>
</tr>
<tr>
<td>21.4</td>
<td>Technique: Hidden Markov Models</td>
<td>643</td>
</tr>
<tr>
<td>21.4.1</td>
<td>Formal Matters</td>
<td>644</td>
</tr>
<tr>
<td>21.4.2</td>
<td>Computing with Hidden Markov Models</td>
<td>645</td>
</tr>
<tr>
<td>21.4.3</td>
<td>Varieties of HMM’s</td>
<td>652</td>
</tr>
<tr>
<td>21.5</td>
<td>Application: Hidden Markov Models and Sign Language Understanding</td>
<td>654</td>
</tr>
<tr>
<td>21.6</td>
<td>Application: Finding People with Hidden Markov Models</td>
<td>659</td>
</tr>
<tr>
<td>21.7</td>
<td>Frames and Probability Models</td>
<td>662</td>
</tr>
<tr>
<td>21.7.1</td>
<td>Representing Coordinate Frames Explicitly in a Probability Model</td>
<td>664</td>
</tr>
</tbody>
</table>
21.7.2 Using a Probability Model to Predict Feature Positions 666
21.7.3 Building Probability Models that are Frame-Invariant 668
21.7.4 Example: Finding Faces Using Frame Invariance 669
21.8 Conclusions 669

22 ASPECT GRAPHS 672
22.1 Differential Geometry and Visual Events 677
  22.1.1 The Geometry of the Gauss Map 677
  22.1.2 Asymptotic Curves 679
  22.1.3 The Asymptotic Spherical Map 681
  22.1.4 Local Visual Events 682
  22.1.5 The Bitangent Ray Manifold 684
  22.1.6 Multilocal Visual Events 686
  22.1.7 Remarks 687
22.2 Computing the Aspect Graph 689
  22.2.1 Step 1: Tracing Visual Events 690
  22.2.2 Step 2: Constructing the Regions 691
  22.2.3 Remaining Steps of the Algorithm 692
  22.2.4 An Example 692
22.3 Aspect Graphs and Object Recognition 696
22.4 Notes 696
22.5 Assignments 697

VII APPLICATIONS AND TOPICS 699

23 RANGE DATA 701
  23.1 Active Range Sensors 701
  23.2 Range Data Segmentation 704
  Technique: Analytical Differential Geometry 705
    23.2.1 Finding Step and Roof Edges in Range Images 707
    23.2.2 Segmenting Range Images into Planar Regions 712
  23.3 Range Image Registration and Model Construction 714
  Technique: Quaternions 715
    23.3.1 Registering Range Images Using the Iterative Closest-Point Method 716
    23.3.2 Fusing Multiple Range Images 719
  23.4 Object Recognition 720
23.4.1 Matching Piecewise-Planar Surfaces Using Interpretation Trees 721
23.4.2 Matching Free-Form Surfaces Using Spin Images 724
23.5 Notes 729
23.6 Assignments 730

24 APPLICATION: FINDING IN DIGITAL LIBRARIES 732

24.1 Background 733
  24.1.1 What do users want? 733
  24.1.2 What can tools do? 735
24.2 Appearance 736
  24.2.1 Histograms and correlograms 737
  24.2.2 Textures and textures of textures 738
24.3 Finding 745
  24.3.1 Annotation and segmentation 748
  24.3.2 Template matching 749
  24.3.3 Shape and correspondence 751
24.4 Video 754
24.5 Discussion 756

25 APPLICATION: IMAGE-BASED RENDERING 758

25.1 Constructing 3D Models from Image Sequences 759
  25.1.1 Scene Modeling from Registered Images 759
  25.1.2 Scene Modeling from Unregistered Images 767
25.2 Transfer-Based Approaches to Image-Based Rendering 771
  25.2.1 Affine View Synthesis 772
  25.2.2 Euclidean View Synthesis 775
25.3 The Light Field 778
25.4 Notes 782
25.5 Assignments 784