Contents

1 Introduction 1
- 1.1 The Input . . . 2
- 1.2 Issues in Shape Description . . . 2
  - 1.2.1 Criteria for shape description . . . 2
  - 1.2.2 Choosing segmented surface descriptions . . . 4
- 1.3 Issues of Recognition . . . 5
  - 1.3.1 Description of models . . . 5
  - 1.3.2 Matching primitives and algorithms . . . 6
- 1.4 Questions for the Research . . . 7
- 1.5 The Contribution of the Research . . . 8
- 1.6 Organization of the Book . . . 8

2 Survey of Previous Work 11
- 2.1 Survey of Shape Descriptions . . . 11
  - 2.1.1 Volume descriptions . . . 12
  - 2.1.2 Curve/line descriptions . . . 13
  - 2.1.3 Surface descriptions . . . 14
  - 2.1.4 Summary . . . 17
- 2.2 Survey of Recognition Systems . . . 17
  - 2.2.1 3DPO . . . 18
  - 2.2.2 Nevatia and Binford . . . 18
  - 2.2.3 ACRONYM . . . 19
  - 2.2.4 Extended Gaussian Image (EGI) . . . 21
  - 2.2.5 Oshima and Shirai . . . 21
  - 2.2.6 Grimson and Lozano-Pérez . . . 22
  - 2.2.7 Faugeras and Hebert . . . 23
  - 2.2.8 Bhanu . . . 24
  - 2.2.9 Ikeuchi . . . 25
  - 2.2.10 Summary . . . 26

3 Surface Segmentation and Description 27
- 3.1 Curvature Properties and Surface Discontinuities . . . 27

3.2 Detecting Surface Features 30
3.2.1 Method 1: using directional curvatures and scale-space tracking 32
3.2.2 Method 2: using principal curvatures at a single scale 39
3.2.3 Method 3: using anisotropic filtering 40
3.3 Space Grouping 42
3.4 Spatial Linking 42
3.5 Segmentation into Surface Patches 43
3.6 Surface Fitting 45
3.7 Object Inference 47
3.7.1 Labeling boundaries 47
3.7.2 Occlusion and connectivity 50
3.7.3 Inferring and describing objects 50
3.8 Representing Objects by Attributed Graphs 52
3.8.1 Node attributes 53
3.8.2 Link attributes 53

4 Object Recognition **55**
4.1 Representation of Models 55
4.2 Overview of the Matching Process 55
4.3 Module 1: Screener 58
4.4 Module 2: Graph Matcher 59
4.4.1 Compatibility between nodes of the model view and scene graph 61
4.4.2 Compatibility between two pairs of matching nodes 62
4.4.3 Computing the geometric transform 64
4.4.4 Modifications based on the geometric transform . . . 66
4.4.5 Measuring the goodness of a match 67
4.5 Module 3: Analyzer 67
4.5.1 Splitting objects 68
4.5.2 Merging objects 69
4.6 Summary 71

5 Experimental Results **73**
5.1 The Models 73
5.2 A Detailed Case Study 82
5.2.1 Search nodes expanded in recognition 82
5.3 Results for Other Scenes 94
5.4 Parallel Versus Sequential Search 108
5.5 Unknown Objects 115
5.6 Occlusion 115

6 Discussion and Conclusion **121**
6.1 Discussion 121
6.1.1 Problems of segmentation 121
6.1.2 Problems of approximation 123
6.2 Contribution 123
6.3 Future Research 125
6.3.1 From surface to volume 125
6.3.2 Applications 126

A Directional Curvatures **127**

B Surface Curvature **131**

C Approximation by Quadric Surfaces **133**

Bibliography **135**