Contents

Preface xi

1. Thinking, Visual Thinking and Shape Understanding 1
1.1. Introduction 1
1.2. Shape and Form 4
1.3. Understanding 9
1.3.1. Cognition 13
1.3.2. Visual Perception 14
1.3.3. Visual Intelligence 16
1.3.4. Knowledge 17
1.3.5. Learning 22
1.3.6. Reasoning 24
1.3.7. Recognition 26
1.4. Thinking 26
1.5. Shape Understanding System 34

2. Shape Classes 47
2.1. Possible Classes of Shape 47
2.1.1. General Classes: A Priori Classes 48
2.1.1.1. Convex Classes 50
2.1.1.1.1. Convex Polygon Class and Its Subclasses 50
2.1.1.1.2. Convex Curve-Polygon Class and Its Subclasses 52
2.1.1.1.3. Convex Curve Class and Its Subclasses 54
2.1.1.2. Concave Classes 57
2.1.1.2.1. Levels of Iterations 58
2.1.1.2.2. Concave Polygon Class 61
2.1.1.2.3. Concave Curve-Polygon Class 64
2.1.1.3. Thin Classes 66
2.1.1.4. Cyclic Class 72
2.1.1.5. Complex Cyclic Class 74

2.1.1.6. Cyclic Thin Class: The G-Class 75
2.1.1.6.1. Convex Cyclic Thin G-Class 77
2.1.1.6.2. Concave Cyclic Thin G-Class 78
2.1.1.7. Colored Classes 79
2.1.2. The a Posteriori Classes 80
2.1.2.1. The Star Class 81
2.1.2.2. The Spade Class 84
2.1.2.3. The Letter Class 89
2.1.3. String Form: Type of the Class 93
2.1.4. Generalization 96

3. Digital Objects, Image Transformations, and Reasoning Process 101
3.1. Digital Image Representation 101
3.2. Processing Methods: Image Transformations 102
3.2.1. Image Transformation and the Visibility Measure 103
3.3. Reasoning Process 105
3.3.1. Convex Object: Reasoning Process 107
3.3.2. Concave Polygon Object: Reasoning Process 121
3.3.3. Thin Object: Reasoning Processes 125
3.3.4. Cyclic Object: Reasoning Process 132

4. Categories 135
4.1. Introduction 135
4.2. Category of Visual Objects 139
4.2.1. Perceptual Categories 141
4.2.2. Structural Categories 143
4.2.2.1. Element Category 143
4.2.2.2. Pattern Category 146
4.2.2.3. Picture Category 149
4.2.2.4. Category of Animation 153
4.2.3. Ontological Categories 153
4.2.3.1. Interpretation of the Visual Object 154
4.2.3.2. Dependence Among Ontological Categories 157
4.2.3.3. Figure Category 163
4.2.3.3.1. Polygon Category 164
4.2.3.3.2. Category of Curves 166
4.2.3.3.3. Category of Curve-Polygon Figures 168
4.2.3.3.4. Category of Mathematical Objects 168
Category of 2D Mathematical Objects 168
Category of 3D Figures 175
Category of Mathematical Coordinate Systems 175

4.2.3.3.5. Category of Statistical Objects 177
4.2.3.3.6. Category of Visual Physical Models 180
4.2.3.4. Category of Signs 182
4.2.3.4.1. Category of Visual Symbols 183
Category of Mathematical Symbols 184
Category of Musical Symbols 186
Category of Engineering Symbols 187
4.2.3.4.2. Category of Symbolic Signs 190
4.2.3.5. Category of Letters 193
4.2.3.6. Category of Real-World Objects 196
4.2.3.6.1. Categories of Macro- and Micro-Objects 204
4.2.3.6.2. Category of Earthy-World Objects 205
Category of Non-Living Objects 206
Category of Living Objects 213
Category of Animals 214
Category of Plants 217
4.2.3.7. Category of Imaginary Objects 223
4.2.3.8. Category of Real-World Processes 224
4.2.3.9. Category of Visual Tests 228
4.3. Categorical Learning 234

5. Visual Thinking: Understanding 241
5.1. Understanding in the Context of Shape Understanding System 241
5.2. Thinking and Visual Thinking 245
5.3. Visual Thinking as a Problem Solving Process 247
5.4. Problem Solving 251
5.4.1. Problems Given in the Form of the Symbolic Representations 255
5.4.2. Problem Given in the Form of Both Symbolic and Visual Representations 258
5.4.3. Problem Given in the Form of the Visual Representation 260
5.4.3.1. Performing Task Given by the User 260
5.5. Visual Thinking as a Problem Solving 267
5.5.1. Perception: Problem Solving 267
5.5.2. Naming and Recognition of the Different Categories of Objects 278
5.5.2.1. Figure Naming: Assigning the Name to the Figure 280
5.5.2.1.1. Naming of the Figure Without Name 281
5.5.2.1.2. Naming of the Figure with Name 282

5.5.2.2. Naming of the Sign 284
5.5.2.2.1. Naming of Mathematical Symbols..... 285
5.5.2.2.2. Naming of Symbolic Signs..... 287
5.5.2.3. Letter Naming 292
5.5.2.3.1. Naming of the Different Fonts of the Letter.. 292
5.5.2.3.2. Similarities of Different Letters 298
5.5.2.4. Naming and Recognition of Real-World Objects .. 304
5.5.2.5. Naming of the Mathematical Object 326
5.5.2.6. Identification of Statistical Visual Objects 329
5.5.2.6.1. Data Analysis..... 330
5.5.2.7. Category of Physical and Engineering Models..... 334
5.5.2.8. Visual Resemblance: Visual Analogy..... 336
5.5.2.9. Spatial Problems..... 342
5.5.2.10. Problem Solving – Categorical Knowledge..... 348
5.5.2.11. Visual Diagnosis 350
5.5.2.12. Assembling Tools 355
5.5.2.13. Moving Object Outside..... 371
5.5.2.14. Obstacle Detection and Motion Planning 372
5.5.2.15. Visual Intelligence Tests..... 375
5.5.2.15.1. Visual Discrimination Test..... 376
5.5.2.15.2. Visual Sequential Memory Test..... 378
5.5.2.15.3. Visual Form Constancy Test..... 379
5.5.2.15.4. Matrix Test..... 380
5.5.2.15.5. Category of Spatial Tests 394