Contents

1 Fundamentals of Intellectual Technologies 1
1.1 Fuzzy Sets 2
1.1.1 Fundamentals of Fuzzy Set Theory 2
1.1.2 Basic Properties of Fuzzy Sets 4
1.1.3 Basic Operations on Fuzzy Sets 4
1.1.4 Further Properties and Related Concepts 5
1.1.5 Fuzzy Relations 6
1.1.6 Fuzzy Numbers 7
1.1.7 Fuzziness and Probability 9
1.2 Genetic Algorithms 10
1.2.1 General Structure of Genetic Algorithms 11
1.2.2 Genetic Operators 13
1.2.3 Search Techniques 14
1.2.4 Comparison of Conventional and Genetic Approaches 15
1.2.5 Advantages of Genetic Algorithms 15
1.2.6 Genetic Algorithm Vocabulary 16
1.2.7 Examples with Genetic Algorithms 16
1.3 Neural Networks 27
1.3.1 Neural Net Basics 27
1.3.2 Mimic of Human Nerve Cells 28
1.3.3 Mathematical Model of a Neuron 29
1.3.4 Training Neural Nets 30
1.3.5 Error Back Propagation Algorithm 31
1.3.6 The Multilayer Neural Network Learning Algorithm 35
References 36

2 Direct Inference Based on Fuzzy Rules 39
2.1 Formalization of Source Information 40
2.1.1 Inputs and Outputs of an Object 40
2.1.2 Linguistic Variables 41
2.1.3 Fuzzy Knowledge Base 43
2.1.4 Membership Functions 45
2.2 Fuzzy Approximator for System with Discrete Output 46
2.2.1 Problem Statement 46
2.2.2 Fuzzy Logical Equations 47
2.2.3 Approximation Algorithm 48

Bibliografische Informationen
http://d-nb.info/1016844441

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

2.3 Fuzzy Approximator for System with Continuous Output 49
2.3.1 Problem Statement 50
2.3.2 Approximation Algorithm 51
References 53

3 Fuzzy Rules Tuning for Direct Inference 55
3.1 Problems of Fuzzy Rules Tuning 56
3.1.1 Object with Continuous Output 58
3.1.2 Object with Discrete Output 58
3.1.3 "Multiple Inputs – Multiple Outputs" Object 59
3.1.4 Criteria of Identification Quality 61
3.2 Genetic Tuning of Fuzzy Rules 63
3.2.1 Coding 63
3.2.2 Crossover 63
3.2.3 Mutation 65
3.2.4 Fitness Function 66
3.2.5 Choice of Parents 66
3.2.6 Population Initialization 67
3.2.7 Genetic Algorithm 68
3.3 Neural Tuning of Fuzzy Rules 69
3.3.1 Structure of the Network 69
3.3.2 Recursive Relations 71
3.4 Computer Simulations 73
3.4.1 Computer Experiment Methods 73
3.4.2 Objects with Continuous Output 73
3.4.3 Objects with Discrete Output 83
3.5 Example 1: Differential Diagnosis of Heart Disease 92
3.5.1 Diagnosis Types and Parameters of Patient's State 92
3.5.2 Fuzzy Rules 93
3.5.3 Fuzzy Logic Equations 96
3.5.4 Rough Membership Functions 97
3.5.5 Algorithm of Decision Making 98
3.5.6 Fine Tuning of the Fuzzy Rules 101
3.6 Example 2: Prediction of Disease Rate Evolution 105
3.6.1 Linguistic Model of Prediction 106
3.6.2 Neuro-fuzzy Model of Prediction 111
3.6.3 On-Line Training of the Neuro-fuzzy Model of Prediction 113
3.6.4 Results of Prediction 114
References 116

4 Fuzzy Rules Extraction from Experimental Data 119
4.1 Fuzzy Rules for "Multiple Inputs – Single Output" Object 120
4.2 Rules Extraction as Optimization Problem 121
4.3 Genetic Algorithm for Rules Extraction 123
4.4 Neuro-fuzzy Network for Rules Extraction from Data 124
4.5 Computer Simulations 126

4.6 Example 3: Rules Extraction for Differential Diagnosis of Heart Disease ... 134
4.6.1 Hierarchical System of IF-THEN Rules ... 134
4.6.2 Hierarchical System of Parameter Matrices ... 136
4.6.3 Computer Experiment ... 137
4.6.4 Comparison of the Expert and Extracted from Histories of Diseases IF-THEN Rules ... 142
4.6.5 Comparison of the Results of Medical Diagnosis ... 144
References ... 147

5 Inverse Inference Based on Fuzzy Relational Equations ... 149
5.1 Fuzzy Relational Equations in Diagnostic Problems ... 150
5.2 Solving Fuzzy Relational Equations as an Optimization Problem ... 151
5.3 Genetic Algorithm for Solving Fuzzy Relational Equations ... 152
5.4 Example 4: Car Engine Diagnosis ... 155
5.4.1 Genetic Search for the Null Solution ... 156
5.4.2 Genetic Search for the Complete Solution Set ... 158
5.4.3 Solution Interpretation and Model Testing ... 160
5.4.4 Assessment of Genetic Algorithm Effectiveness ... 161
References ... 161

6 Inverse Inference with Fuzzy Relations Tuning ... 163
6.1 Diagnostic Approximator Based on Fuzzy Relations ... 164
6.2 Optimization Problem for Fuzzy Relations Based Inverse Inference ... 167
6.3 Genetic Algorithm for Fuzzy Relations Based Inverse Inference ... 169
6.4 Neuro-fuzzy Network for Fuzzy Relations Based Inverse Inference ... 170
6.5 Expert Method of Fuzzy Relations Construction ... 171
6.6 Problem of Fuzzy Relations Tuning ... 173
6.7 Genetic Algorithm of Fuzzy Relations Tuning ... 174
6.8 Adaptive Tuning of Fuzzy Relations ... 175
6.9 Computer Simulations ... 176
6.10 Example 5: Oil Pump Diagnosis ... 184
References ... 191

7 Inverse Inference Based on Fuzzy Rules ... 193
7.1 Diagnostic Approximator Based on Fuzzy Rules ... 194
7.2 Interconnection of Fuzzy Rules and Relations ... 196
7.3 Optimization Problem for Fuzzy Rules Based Inverse Inference ... 198
7.4 Genetic Algorithm for Fuzzy Rules Based Inverse Inference ... 203
7.5 Neuro-fuzzy Network for Fuzzy Rules Based Inverse Inference ... 204
7.6 Problem of Fuzzy Rules Tuning ... 207
7.7 Genetic Algorithm for Fuzzy Rules Tuning ... 207
7.8 Adaptive Tuning of Fuzzy Rules ... 208
7.9 Computer Simulations ... 210
7.10 Example 6: Hydro Elevator Diagnosis ... 222
References ... 232

8 Fuzzy Relations Extraction from Experimental Data 235
8.1 "Multiple Inputs – Multiple Outputs" Object 236
8.2 Fuzzy Rules, Relations and Relational Equations 237
8.3 Optimization Problem for Fuzzy Relations Extraction 239
8.4 Genetic Algorithm for Fuzzy Relations Extraction 241
8.5 Neuro-fuzzy Network for Fuzzy Relations Extraction 243
8.6 Computer Simulations 245
8.7 Example 7: Fuzzy Relations Extraction for Heart Diseases Diagnosis 253
References 257

9 Applied Fuzzy Systems 259
9.1 Dynamic System Control 259
9.1.1 Control Object 260
9.1.2 Classical Control Model 261
9.1.3 Fuzzy Control Model 263
9.1.4 Connection with Lyapunov's Functions 264
9.2 Inventory Control 266
9.2.1 Analogy with Turned-Over Pendulum 267
9.2.2 Method of Identification 268
9.2.3 Fuzzy Model of Control 269
9.2.4 Fuzzy Model Tuning 272
9.2.5 Example of Fuzzy Model Tuning 273
9.3 Prediction of Football Games Results 277
9.3.1 The Structure of the Model 278
9.3.2 Fuzzy Model of Prediction 280
9.3.3 Genetic and Neuro Tuning 281
9.4 Identification of Car Wheels Adhesion Factor with a Road Surface 285
9.4.1 Technique of Identification 285
9.4.2 Structural Identification 285
9.4.3 Parametrical Identification 286
9.4.4 Example and Comparison with the Technique in Use Now 292
9.5 Innovative Projects Creditworthiness Evaluation 293
9.5.1 Types of Decisions and Partial Figures of Quality 293
9.5.2 Fuzzy Knowledge Bases 294
9.5.3 Evaluation Examples 296
9.6 System Reliability Analysis 298
9.6.1 Basic Principles 298
9.6.2 Fuzzy-Algorithmic Elements 300
9.6.3 Fuzzy-Algorithmic Structures 302
9.6.4 Example of Technological System Reliability Analysis 304
References 310