

Contents

1. Linguistic Information Granules	1
1.1 Mathematical Handling of Linguistic Terms	2
1.2 Linguistic Discretization of Continuous Attributes	4
2. Pattern Classification with Linguistic Rules	11
2.1 Problem Description	11
2.2 Linguistic Rule Extraction for Classification Problems	12
2.2.1 Specification of the Consequent Class	13
2.2.2 Specification of the Rule Weight	17
2.3 Classification of New Patterns by Linguistic Rules	20
2.3.1 Single Winner-Based Method	20
2.3.2 Voting-Based Method	22
2.4 Computer Simulations	25
2.4.1 Comparison of Four Definitions of Rule Weights	26
2.4.2 Simulation Results on Iris Data	29
2.4.3 Simulation Results on Wine Data	32
2.4.4 Discussions on Simulation Results	35
3. Learning of Linguistic Rules	39
3.1 Reward–Punishment Learning	39
3.1.1 Learning Algorithm	39
3.1.2 Illustration of the Learning Algorithm Using Artificial Test Problems	41
3.1.3 Computer Simulations on Iris Data	45
3.1.4 Computer Simulations on Wine Data	47
3.2 Analytical Learning	47
3.2.1 Learning Algorithm	48
3.2.2 Illustration of the Learning Algorithm Using Artificial Test Problems	50
3.2.3 Computer Simulations on Iris Data	54
3.2.4 Computer Simulations on Wine Data	56
3.3 Related Issues	57
3.3.1 Further Adjustment of Classification Boundaries	57
3.3.2 Adjustment of Membership Functions	62

4. Input Selection and Rule Selection	69
4.1 Curse of Dimensionality	69
4.2 Input Selection	70
4.2.1 Examination of Subsets of Attributes	70
4.2.2 Simulation Results	71
4.3 Genetic Algorithm-Based Rule Selection	75
4.3.1 Basic Idea	76
4.3.2 Generation of Candidate Rules	77
4.3.3 Genetic Algorithms for Rule Selection	80
4.3.4 Computer Simulations	87
4.4 Some Extensions to Rule Selection	89
4.4.1 Heuristics in Genetic Algorithms	90
4.4.2 Prescreening of Candidate Rules	93
4.4.3 Computer Simulations	96
5. Genetics-Based Machine Learning	103
5.1 Two Approaches in Genetics-Based Machine Learning	103
5.2 Michigan-Style Algorithm	105
5.2.1 Coding of Linguistic Rules	105
5.2.2 Genetic Operations	105
5.2.3 Algorithm	107
5.2.4 Computer Simulations	108
5.2.5 Extensions to the Michigan-Style Algorithm	111
5.3 Pittsburgh-Style Algorithm	116
5.3.1 Coding of Rule Sets	117
5.3.2 Genetic Operations	117
5.3.3 Algorithm	119
5.3.4 Computer Simulations	119
5.4 Hybridization of the Two Approaches	121
5.4.1 Advantages of Each Algorithm	121
5.4.2 Hybrid Algorithm	124
5.4.3 Computer Simulations	125
5.4.4 Minimization of the Number of Linguistic Rules	126
6. Multi-Objective Design of Linguistic Models	131
6.1 Formulation of Three-Objective Problem	131
6.2 Multi-Objective Genetic Algorithms	134
6.2.1 Fitness Function	134
6.2.2 Elitist Strategy	135
6.2.3 Basic Framework of Multi-Objective Genetic Algorithms	135
6.3 Multi-Objective Rule Selection	136
6.3.1 Algorithm	136
6.3.2 Computer Simulations	136
6.4 Multi-Objective Genetics-Based Machine Learning	139
6.4.1 Algorithm	139

6.4.2	Computer Simulations	139
7.	Comparison of Linguistic Discretization with Interval Discretization	143
7.1	Effects of Linguistic Discretization	144
7.1.1	Effect in the Rule Generation Phase	144
7.1.2	Effect in the Classification Phase	146
7.1.3	Summary of Effects of Linguistic Discretization	147
7.2	Specification of Linguistic Discretization from Interval Discretization	147
7.2.1	Specification of Fully Fuzzified Linguistic Discretization	147
7.2.2	Specification of Partially Fuzzified Linguistic Discretization	150
7.3	Comparison Using Homogeneous Discretization	151
7.3.1	Simulation Results on Iris Data	151
7.3.2	Simulation Results on Wine Data	154
7.4	Comparison Using Inhomogeneous Discretization	155
7.4.1	Entropy-Based Inhomogeneous Interval Discretization	156
7.4.2	Simulation Results on Iris Data	157
7.4.3	Simulation Results on Wine Data	158
8.	Modeling with Linguistic Rules	161
8.1	Problem Description	161
8.2	Linguistic Rule Extraction for Modeling Problems	162
8.2.1	Linguistic Association Rules for Modeling Problems ..	163
8.2.2	Specification of the Consequent Part	165
8.2.3	Other Approaches to Linguistic Rule Generations	166
8.2.4	Estimation of Output Values by Linguistic Rules	169
8.2.5	Standard Fuzzy Reasoning	169
8.2.6	Limitations and Extensions	172
8.2.7	Non-Standard Fuzzy Reasoning Based on the Specificity of Each Linguistic Rule	174
8.3	Modeling of Nonlinear Fuzzy Functions	177
9.	Design of Compact Linguistic Models	181
9.1	Single-Objective and Multi-Objective Formulations	181
9.1.1	Three Objectives in the Design of Linguistic Models ..	181
9.1.2	Handling as a Single-Objective Optimization Problem ..	182
9.1.3	Handling as a Three-Objective Optimization Problem ..	183
9.2	Multi-Objective Rule Selection	185
9.2.1	Candidate Rule Generation	185
9.2.2	Candidate Rule Prescreening	185
9.2.3	Three-Objective Genetic Algorithm for Rule Selection ..	187
9.2.4	Simple Numerical Example	189
9.3	Fuzzy Genetics-Based Machine Learning	190

9.3.1	Coding of Rule Sets	192
9.3.2	Three-Objective Fuzzy GBML Algorithm.....	192
9.3.3	Simple Numerical Example	194
9.3.4	Some Heuristic Procedures	194
9.4	Comparison of Two Schemes	196
10.	Linguistic Rules with Consequent Real Numbers	199
10.1	Consequent Real Numbers	199
10.2	Local Learning of Consequent Real Numbers.....	201
10.2.1	Heuristic Specification Method	201
10.2.2	Incremental Learning Algorithm.....	203
10.3	Global Learning	205
10.3.1	Incremental Learning Algorithm.....	206
10.3.2	Comparison Between Two Learning Schemes.....	207
10.4	Effect of the Use of Consequent Real Numbers	208
10.4.1	Resolution of Adjustment	208
10.4.2	Simulation Results	210
10.5	Twin-Table Approach.....	211
10.5.1	Basic Idea	212
10.5.2	Determination of Consequent Linguistic Terms	213
10.5.3	Numerical Example.....	215
11.	Handling of Linguistic Rules in Neural Networks	219
11.1	Problem Formulation	220
11.1.1	Approximation of Linguistic Rules.....	220
11.1.2	Multi-Layer Feedforward Neural Networks.....	221
11.2	Handling of Linguistic Rules Using Membership Values.....	222
11.2.1	Basic Idea	222
11.2.2	Network Architecture	223
11.2.3	Computer Simulation	223
11.3	Handling of Linguistic Rules Using Level Sets	225
11.3.1	Basic Idea	225
11.3.2	Network Architecture	226
11.3.3	Computer Simulation	226
11.4	Handling of Linguistic Rules Using Fuzzy Arithmetic	228
11.4.1	Basic Idea	228
11.4.2	Fuzzy Arithmetic.....	228
11.4.3	Network Architecture	230
11.4.4	Computer Simulation	233
12.	Learning of Neural Networks from Linguistic Rules	235
12.1	Back-Propagation Algorithm.....	235
12.2	Learning from Linguistic Rules for Classification Problems...	237
12.2.1	Linguistic Training Data	237
12.2.2	Cost Function.....	237

12.2.3	Extended Back-Propagation Algorithm	238
12.2.4	Learning from Linguistic Rules and Numerical Data . .	241
12.3	Learning from Linguistic Rules for Modeling Problems	245
12.3.1	Linguistic Data	245
12.3.2	Cost Function	245
12.3.3	Extended Back-Propagation Algorithm	246
12.3.4	Learning from Linguistic Rules and Numerical Data . .	247
13.	Linguistic Rule Extraction from Neural Networks	251
13.1	Neural Networks and Linguistic Rules	252
13.2	Linguistic Rule Extraction for Modeling Problems	252
13.2.1	Basic Idea	253
13.2.2	Extraction of Linguistic Rules	253
13.2.3	Computer Simulations	254
13.3	Linguistic Rule Extraction for Classification Problems	258
13.3.1	Basic Idea	259
13.3.2	Extraction of Linguistic Rules	259
13.3.3	Computer Simulations	263
13.3.4	Rule Extraction Algorithm	265
13.3.5	Decreasing the Measurement Cost	267
13.4	Difficulties and Extensions	270
13.4.1	Scalability to High-Dimensional Problems	271
13.4.2	Increase of Excess Fuzziness in Fuzzy Outputs	271
14.	Modeling of Fuzzy Input–Output Relations	277
14.1	Modeling of Fuzzy Number-Valued Functions	277
14.1.1	Linear Fuzzy Regression Models	278
14.1.2	Fuzzy Rule-Based Systems	280
14.1.3	Fuzzified Takagi–Sugeno Models	281
14.1.4	Fuzzified Neural Networks	283
14.2	Modeling of Fuzzy Mappings	285
14.2.1	Linear Fuzzy Regression Models	285
14.2.2	Fuzzy Rule-Based Systems	286
14.2.3	Fuzzified Takagi–Sugeno Models	286
14.2.4	Fuzzified Neural Networks	287
14.3	Fuzzy Classification	287
14.3.1	Fuzzy Classification of Non-Fuzzy Patterns	288
14.3.2	Fuzzy Classification of Interval Patterns	291
14.3.3	Fuzzy Classification of Fuzzy Patterns	291
14.3.4	Effect of Fuzzification of Input Patterns	292
Index	304

Classification and Modeling with Linguistic Information
Granules

Advanced Approaches to Linguistic Data Mining

Ishibuchi, H.; Nakashima, T.; Nii, M.

2005, XII, 308 p., Hardcover

ISBN: 978-3-540-20767-2