

# Contents

<b>1. Mathematical Preliminaries</b>	<b>1</b>
1.1 Mathematical Concepts and Notations	2
1.1.1 Vector Space Concepts	2
1.1.2 Matrix Notations	8
1.1.3 Eigenvectors and Eigenvalues of Matrices	11
1.1.4 Further Properties of Matrices	13
1.1.5 On Matrix Differential Calculus	15
1.2 Distance Measures for Patterns	17
1.2.1 Measures of Similarity and Distance in Vector Spaces	17
1.2.2 Measures of Similarity and Distance Between Symbol Strings	21
1.2.3 Averages Over Nonvectorial Variables	28
1.3 Statistical Pattern Analysis	29
1.3.1 Basic Probabilistic Concepts	29
1.3.2 Projection Methods	34
1.3.3 Supervised Classification	39
1.3.4 Unsupervised Classification	44
1.4 The Subspace Methods of Classification	46
1.4.1 The Basic Subspace Method	46
1.4.2 Adaptation of a Model Subspace to Input Subspace	49
1.4.3 The Learning Subspace Method (LSM)	53
1.5 Vector Quantization	59
1.5.1 Definitions	59
1.5.2 Derivation of the VQ Algorithm	60
1.5.3 Point Density in VQ	62
1.6 Dynamically Expanding Context	64
1.6.1 Setting Up the Problem	65
1.6.2 Automatic Determination of Context-Independent Productions	66
1.6.3 Conflict Bit	67
1.6.4 Construction of Memory for the Context-Dependent Productions	68
1.6.5 The Algorithm for the Correction of New Strings	68
1.6.6 Estimation Procedure for Unsuccessful Searches	69

1.6.7	Practical Experiments .....	69
<b>2.</b>	<b>Neural Modeling</b> .....	71
2.1	Models, Paradigms, and Methods .....	71
2.2	A History of Some Main Ideas in Neural Modeling .....	72
2.3	Issues on Artificial Intelligence .....	75
2.4	On the Complexity of Biological Nervous Systems .....	76
2.5	What the Brain Circuits Are Not .....	78
2.6	Relation Between Biological and Artificial Neural Networks .....	79
2.7	What Functions of the Brain Are Usually Modeled? .....	81
2.8	When Do We Have to Use Neural Computing? .....	81
2.9	Transformation, Relaxation, and Decoder .....	82
2.10	Categories of ANNs .....	85
2.11	A Simple Nonlinear Dynamic Model of the Neuron .....	87
2.12	Three Phases of Development of Neural Models .....	89
2.13	Learning Laws .....	91
2.13.1	Hebb's Law .....	91
2.13.2	The Riccati-Type Learning Law .....	92
2.13.3	The PCA-Type Learning Law .....	95
2.14	Some Really Hard Problems .....	96
2.15	Brain Maps .....	99
<b>3.</b>	<b>The Basic SOM</b> .....	105
3.1	A Qualitative Introduction to the SOM .....	106
3.2	The Original Incremental SOM Algorithm .....	109
3.3	The "Dot-Product SOM" .....	115
3.4	Other Preliminary Demonstrations of Topology-Preserving Mappings .....	116
3.4.1	Ordering of Reference Vectors in the Input Space .....	116
3.4.2	Demonstrations of Ordering of Responses in the Output Space .....	120
3.5	Basic Mathematical Approaches to Self-Organization .....	127
3.5.1	One-Dimensional Case .....	128
3.5.2	Constructive Proof of Ordering of Another One-Dimensional SOM .....	132
3.6	The Batch Map .....	138
3.7	Initialization of the SOM Algorithms .....	142
3.8	On the "Optimal" Learning-Rate Factor .....	143
3.9	Effect of the Form of the Neighborhood Function .....	145
3.10	Does the SOM Algorithm Ensur from a Distortion Measure? .....	146
3.11	An Attempt to Optimize the SOM .....	148
3.12	Point Density of the Model Vectors .....	152
3.12.1	Earlier Studies .....	152

3.12.2 Numerical Check of Point Densities in a Finite One-Dimensional SOM .....	153
3.13 Practical Advice for the Construction of Good Maps .....	159
3.14 Examples of Data Analyses Implemented by the SOM.....	161
3.14.1 Attribute Maps with Full Data Matrix .....	161
3.14.2 Case Example of Attribute Maps Based on Incomplete Data Matrices (Missing Data): “Poverty Map” .....	165
3.15 Using Gray Levels to Indicate Clusters in the SOM .....	165
3.16 Interpretation of the SOM Mapping .....	166
3.16.1 “Local Principal Components” .....	166
3.16.2 Contribution of a Variable to Cluster Structures.....	169
3.17 Speedup of SOM Computation .....	170
3.17.1 Shortcut Winner Search .....	170
3.17.2 Increasing the Number of Units in the SOM .....	172
3.17.3 Smoothing.....	175
3.17.4 Combination of Smoothing, Lattice Growing, and SOM Algorithm .....	176
<b>4. Physiological Interpretation of SOM .....</b>	<b>177</b>
4.1 Conditions for Abstract Feature Maps in the Brain .....	177
4.2 Two Different Lateral Control Mechanisms .....	178
4.2.1 The WTA Function, Based on Lateral Activity Control .....	179
4.2.2 Lateral Control of Plasticity .....	184
4.3 Learning Equation.....	185
4.4 System Models of SOM and Their Simulations .....	185
4.5 Recapitulation of the Features of the Physiological SOM Model.....	188
4.6 Similarities Between the Brain Maps and Simulated Feature Maps .....	188
4.6.1 Magnification .....	189
4.6.2 Imperfect Maps .....	189
4.6.3 Overlapping Maps .....	189
<b>5. Variants of SOM .....</b>	<b>191</b>
5.1 Overview of Ideas to Modify the Basic SOM .....	191
5.2 Adaptive Tensorial Weights .....	194
5.3 Tree-Structured SOM in Searching.....	197
5.4 Different Definitions of the Neighborhood.....	198
5.5 Neighborhoods in the Signal Space .....	200
5.6 Dynamical Elements Added to the SOM.....	204
5.7 The SOM for Symbol Strings .....	205
5.7.1 Initialization of the SOM for Strings .....	205
5.7.2 The Batch Map for Strings .....	206

5.7.3	Tie-Break Rules . . . . .	206
5.7.4	A Simple Example: The SOM of Phonemic Transcriptions . . . . .	207
5.8	Operator Maps . . . . .	207
5.9	Evolutionary-Learning SOM . . . . .	211
5.9.1	Evolutionary-Learning Filters . . . . .	211
5.9.2	Self-Organization According to a Fitness Function . . . . .	212
5.10	Supervised SOM . . . . .	215
5.11	The Adaptive-Subspace SOM (ASSOM) . . . . .	216
5.11.1	The Problem of Invariant Features . . . . .	216
5.11.2	Relation Between Invariant Features and Linear Subspaces . . . . .	218
5.11.3	The ASSOM Algorithm . . . . .	222
5.11.4	Derivation of the ASSOM Algorithm by Stochastic Approximation . . . . .	226
5.11.5	ASSOM Experiments . . . . .	228
5.12	Feedback-Controlled Adaptive-Subspace SOM (FASSOM) . . . . .	242
<b>6.</b>	<b>Learning Vector Quantization . . . . .</b>	<b>245</b>
6.1	Optimal Decision . . . . .	245
6.2	The LVQ1 . . . . .	246
6.3	The Optimized-Learning-Rate LVQ1 (OLVQ1) . . . . .	250
6.4	The Batch-LVQ1 . . . . .	251
6.5	The Batch-LVQ1 for Symbol Strings . . . . .	252
6.6	The LVQ2 (LVQ2.1) . . . . .	252
6.7	The LVQ3 . . . . .	253
6.8	Differences Between LVQ1, LVQ2 and LVQ3 . . . . .	254
6.9	General Considerations . . . . .	254
6.10	The Hypermap-Type LVQ . . . . .	256
6.11	The “LVQ-SOM” . . . . .	261
<b>7.</b>	<b>Applications . . . . .</b>	<b>263</b>
7.1	Preprocessing of Optic Patterns . . . . .	264
7.1.1	Blurring . . . . .	265
7.1.2	Expansion in Terms of Global Features . . . . .	266
7.1.3	Spectral Analysis . . . . .	266
7.1.4	Expansion in Terms of Local Features (Wavelets) . . . . .	267
7.1.5	Recapitulation of Features of Optic Patterns . . . . .	267
7.2	Acoustic Preprocessing . . . . .	268
7.3	Process and Machine Monitoring . . . . .	269
7.3.1	Selection of Input Variables and Their Scaling . . . . .	269
7.3.2	Analysis of Large Systems . . . . .	270
7.4	Diagnosis of Speech Voicing . . . . .	274
7.5	Transcription of Continuous Speech . . . . .	274
7.6	Texture Analysis . . . . .	280

7.7	Contextual Maps .....	281
7.7.1	Artificially Generated Clauses .....	283
7.7.2	Natural Text.....	285
7.8	Organization of Large Document Files .....	286
7.8.1	Statistical Models of Documents.....	286
7.8.2	Construction of Very Large WEBSOM Maps by the Projection Method .....	292
7.8.3	The WEBSOM of All Electronic Patent Abstracts ....	296
7.9	Robot-Arm Control.....	299
7.9.1	Simultaneous Learning of Input and Output Parameters .....	299
7.9.2	Another Simple Robot-Arm Control .....	303
7.10	Telecommunications .....	304
7.10.1	Adaptive Detector for Quantized Signals .....	304
7.10.2	Channel Equalization in the Adaptive QAM .....	305
7.10.3	Error-Tolerant Transmission of Images by a Pair of SOMs.....	306
7.11	The SOM as an Estimator .....	308
7.11.1	Symmetric (Autoassociative) Mapping .....	308
7.11.2	Asymmetric (Heteroassociative) Mapping.....	309
<b>8.</b>	<b>Software Tools for SOM .....</b>	<b>311</b>
8.1	Necessary Requirements .....	311
8.2	Desirable Auxiliary Features .....	313
8.3	SOM Program Packages .....	315
8.3.1	SOM_PAK .....	315
8.3.2	SOM Toolbox.....	317
8.3.3	Nenet (Neural Networks Tool) .....	318
8.3.4	Viscovery SOMine .....	318
8.4	Examples of the Use of SOM_PAK.....	319
8.4.1	File Formats .....	319
8.4.2	Description of the Programs in SOM_PAK.....	322
8.4.3	A Typical Training Sequence.....	326
8.5	Neural-Networks Software with the SOM Option .....	327
<b>9.</b>	<b>Hardware for SOM .....</b>	<b>329</b>
9.1	An Analog Classifier Circuit .....	329
9.2	Fast Digital Classifier Circuits .....	332
9.3	SIMD Implementation of SOM .....	337
9.4	Transputer Implementation of SOM .....	339
9.5	Systolic-Array Implementation of SOM.....	341
9.6	The COKOS Chip .....	342
9.7	The TInMANN Chip .....	342
9.8	NBISOM.25 Chip .....	344

<b>10. An Overview of SOM Literature</b> .....	347
10.1 Books and Review Articles .....	347
10.2 Early Works on Competitive Learning.....	348
10.3 Status of the Mathematical Analyses.....	349
10.3.1 Zero-Order Topology (Classical VQ) Results .....	349
10.3.2 Alternative Topological Mappings.....	350
10.3.3 Alternative Architectures .....	350
10.3.4 Functional Variants .....	351
10.3.5 Theory of the Basic SOM.....	352
10.4 The Learning Vector Quantization .....	358
10.5 Diverse Applications of SOM .....	358
10.5.1 Machine Vision and Image Analysis .....	358
10.5.2 Optical Character and Script Reading .....	360
10.5.3 Speech Analysis and Recognition .....	360
10.5.4 Acoustic and Musical Studies .....	361
10.5.5 Signal Processing and Radar Measurements .....	362
10.5.6 Telecommunications.....	362
10.5.7 Industrial and Other Real-World Measurements .....	362
10.5.8 Process Control .....	363
10.5.9 Robotics.....	364
10.5.10 Electronic-Circuit Design .....	364
10.5.11 Physics .....	364
10.5.12 Chemistry .....	365
10.5.13 Biomedical Applications Without Image Processing ..	365
10.5.14 Neurophysiological Research .....	366
10.5.15 Data Processing and Analysis .....	366
10.5.16 Linguistic and AI Problems .....	367
10.5.17 Mathematical and Other Theoretical Problems .....	368
10.6 Applications of LVQ .....	369
10.7 Survey of SOM and LVQ Implementations .....	370
<b>11. Glossary of “Neural” Terms</b> .....	373
<b>References</b> .....	403
<b>Index</b> .....	487

<http://www.springer.com/978-3-540-67921-9>

Self-Organizing Maps

Kohonen, T.

2001, XX, 502 p. 178 illus., 1 illus. in color., Softcover

ISBN: 978-3-540-67921-9