

Contents

Preface ix
How to Use This Book xiii

Part I: Background 1

How to Use Part I 3
1.1. Introducing the Neuron 4
Basic Properties of Neurons 4
Receptors and Effectors 7
Neural Models 8
More Detailed Properties of Neurons 10
References 11
1.2. Levels and Styles of Analysis 11
A Historical Fragment 11
Brains, Machines, and Minds 13
Levels of Analysis 14
References 16
1.3. Dynamics and Adaptation in
Neural Networks 17
Dynamic Systems 17
Adaptation in Dynamic Systems 20
References 25

Part II: Road Maps 27

The Meta-Map 29
II. 1. Connectionism: Psychology, Linguistics, and
Artificial Intelligence 31
Connectionist Psychology 31
Connectionist Linguistics 32
Artificial Intelligence and Neural Networks 33
11.2. Dynamics, Self-Organization, and
Cooperativity 34
Dynamic Systems and Optimization 34
Cooperative Phenomena 35
Self-Organization in Neural Networks 36
11.3. Learning in Artificial Neural Networks 37
*Learning in Artificial Neural Networks,
Deterministic* 37
*Learning in Artificial Neural Networks,
Statistical* 38
Computability and Complexity 40
11.4. Applications and Implementations 41
Control Theory and Robotics 41
Applications of Neural Networks 42
Implementation of Neural Networks 43

11.5. Biological Neurons and Networks 45
Biological Neurons 45
Biological Networks 46
Mammalian Brain Regions 48
11.6. Sensory Systems 50
Vision 50
Other Sensory Systems 52
11.7. Plasticity in Development and Learning 53
Mechanisms of Neural Plasticity 53
*Development and Regeneration of
Neural Networks* 54
Learning in Biological Systems 54
11.8. Motor Control 55
Motor Pattern Generators and Neuroethology 55
Biological Motor Control 56
Primate Motor Control 57

Part III: Articles 59

Active Vision 61
Activity-Dependent Regulation of Neuronal
Conductances 63
Adaptive Control: General Methodology 66
Adaptive Control: Neural Network Applications 69
Adaptive Filtering 74
Adaptive Resonance Theory (ART) 79
Adaptive **Signal Processing** 82
Analog VLSI for Neural Networks 86
Analogy-Based Reasoning 91
Applications of Neural Networks 94
Artificial Intelligence and Neural Networks 98
Associative Networks 102
Astronomy 107
Auditory Cortex 110
Auditory Periphery and Cochlear Nucleus 115
Automata and Neural Networks 119
Automatic Target Recognition 123
Averaging/Modular Techniques for Neural
Networks 126
Axonal Modeling 129
Backpropagation: Basics and New Developments 134
Basal Ganglia 139
Bayesian Methods for Supervised Neural Networks 144
Bayesian Networks 149
BCM Theory of Visual Cortical Plasticity 153

-
- Binding in the Visual System 157
 - Biomaterials for Intelligent Systems 159
 - Boltzmann Machines 162
 - Cellular Automata 166
 - Cerebellum and Conditioning 169
 - Cerebellum and Motor Control 172
 - Chains of Coupled Oscillators 178
 - Chaos in Axons 183
 - Chaos in Neural Systems 186
 - Classical Learning Theory and Neural Networks 189
 - Cognitive Development 193
 - Cognitive Maps 197
 - Cognitive Modeling: Psychology and Connectionism 200
 - Collective Behavior of Coupled Oscillators 203
 - Collicular Visuomotor Transformations for Saccades 206
 - Color Perception 210
 - Command Neurons and Command Systems 215
 - Competitive Learning 220
 - Compositionality in Neural Systems 223
 - Computer Modeling Methods for Neurons 226
 - Computing with Attractors 230
 - Concept Learning 234
 - Conditioning 238
 - Connectionist and Symbolic Representations 243
 - Consciousness, Theories of 247
 - Constrained Optimization and the Elastic Net 250
 - Convolutional Networks for Images, Speech, and Time Series 255
 - Cooperative Behavior in Networks of Chaotic Elements 258
 - Cooperative Phenomena 261
 - Corollary Discharge in Visuomotor Coordination 266
 - Cortical Columns, Modules, and Hebbian Cell Assemblies 269
 - Coulomb Potential Learning 272
 - Crustacean Stomatogastric System 275
 - Data Clustering and Learning 278
 - Dendritic Processing 282
 - Dendritic Spines 289
 - Developmental Disorders 292
 - Development and Regeneration of Eye-Brain Maps 295
 - Diffusion Models of Neuron Activity 299
 - Digital VLSI for Neural Networks 304
 - Directional Selectivity in the Cortex 309
 - Directional Selectivity in the Retina 312
 - Disease: Neural Network Models 315
 - Dissociations Between Visual Processing Modes 318
 - Distortions in Human Memory 321
 - Distributed Artificial Intelligence 322
 - Dynamic Clamp: Computer-Neural Hybrids 326
 - Dynamic Link Architecture 329
 - Dynamic Models of Neurophysiological Systems 332
 - Dynamic Remapping 335
 - Dynamics and Bifurcation of Neural Networks 339
 - Echolocation: Creating Computational Maps 344
 - EEG Analysis 348
 - Electrollocation 352
 - Emotion and Computational Neuroscience 356
 - Emotion-Cognition Interactions 360
 - Energy Functions for Neural Networks 363
 - Epilepsy: Network Models of Generation 367
 - Equilibrium Point Hypothesis 370
 - Evolution of the Ancestral Vertebrate Brain 373
 - Expert Systems and Decision Systems Using Neural Networks 377
 - Exploration in Active Learning 381
 - Eye-Hand Coordination in Reaching Movements 385
 - Face Recognition 388
 - Fault Tolerance 390
 - Figure-Ground Separation 395
 - Forecasting 399
 - Fractal Strategies for Neural Network Scaling 403
 - Frog Wiping Reflexes 406
 - Fuzzy Logic Systems and Qualitative Knowledge 410
 - Gabor Wavelets** for Statistical Pattern Recognition 414
 - Gait Transitions 420
 - Gaze Coding in the Posterior Parietal Cortex 423
 - Generalization and Regularization in **Nonlinear** Learning Systems 426
 - “Genotypes” for Neural Networks 431
 - Geometrical Principles in Motor Control 434
 - Grasping Movements: Visuomotor Transformations 438
 - Habituation 441
 - Half-Center Oscillators Underlying Rhythmic Movements 444
 - Handwritten Digit String Recognition 447
 - Head Movements: Multidimensional Modeling 450
 - Hebbian Synaptic Plasticity 454
 - Hebbian Synaptic Plasticity: Comparative and Developmental Aspects 459
 - High-Energy Physics 464
 - Hippocampus: Spatial Models 468
 - Human Movement: A System-Level Approach 472
 - Identification and Control 477
 - Illusory Contour Formation 481
 - Information Theory and Visual Plasticity 484
 - Invertebrate Models of Learning: *Aplysia* and *Hermissenda* 487

Investment Management: Tactical Asset Allocation	49	1	NMDA Receptors: Synaptic, Cellular, and Network Models	644
Ion Channels: Keys to Neuronal Specialization	496		Noise Canceling and Channel Equalization	648
Kolmogorov's Theorem	501		Nonmonotonic Neuron Associative Memory	651
Language Acquisition	503		NSL: Neural Simulation Language	654
Language Change	506		Object Recognition	658
Language Processing	508		Ocular Dominance and Orientation Columns	660
Layered Computation in Neural Networks	5	13	Olfactory Bulb	665
Learning and Generalization: Theoretical Bounds	516		Olfactory Cortex	669
Learning and Statistical Inference	522		Optical Architectures for Neural Network Implementations	673
Learning as Adaptive Control of Synaptic Matrices	527		Optical Components for Neural Network Implementations	677
Learning as Hill-Climbing in Weight Space	531		Optimization Principles in Motor Control	682
Learning by Symbolic and Neural Methods	533		Oscillatory and Bursting Properties of Neurons	686
Learning Vector Quantization	537		Oscillatory Associative Memories	691
Lesioned Attractor Networks as Models of Neuropsychological Deficits	540		PAC Learning and Neural Networks	694
Limb Geometry: Neural Control	543		Pain Networks	698
Linguistic Morphology	546		Parallel Computational Models	702
Localized Versus Distributed Representations	549		Pattern Formation, Biological	705
Locomotion, Invertebrate	553		Pattern Recognition	711
Locust Flight: Components and Mechanisms in the Motor	556		Perception of Three-Dimensional Structure	715
Long-Term Depression in the Cerebellum	560		Perceptrons, Adalines, and Backpropagation	719
Markov Random Field Models in Image Processing	564		Perceptual Grouping	725
Memory-Based Reasoning	568		Perspective on Neuron Model Complexity	728
Mental Arithmetic Using Neural Networks	570		Phase-Plane Analysis of Neural Activity	732
Minimum Description Length Analysis	572		Philosophical Issues in Brain Theory and Connectionism	738
Model-Reference Adaptive Control	576		Planning, Connectionist	741
Modular and Hierarchical Learning Systems	579		Post-Hebbian Learning Rules	745
Modular Neural Net Systems, Training of	582		Potential Fields and Neural Networks	749
Motion Perception	585		Principal Component Analysis	753
Motion Perception: Self-Organization	589		Problem Solving, Connectionist	756
Motivation	59	1	Process Control	760
Motoneuron Recruitment	594		Programmable Neurocomputing Systems	764
Motor Control, Biological and Theoretical	597		Prosthetics, Neural	768
Motor Pattern Generation	600		Protein Structure Prediction	772
Multiprocessor Simulation of Neural Networks	605		Pursuit Eye Movements	775
Muscle Models	609		Radial Basis Function Networks	779
			Reaching: Coding in Motor Cortex	783
Recognition	613		Reaching Movements: Implications of Connectionist Models	788
			Reactive Robotic Systems	793
			Recurrent Networks: Supervised Learning	796
		622	Regularization Theory and Low-Level Vision	800
Neuromodulation in Invertebrate Nervous Systems	63	11	Reinforcement Learning	804
Neurosimulators	634		Reinforcement Learning in Motor Control	809
Neurosmithing: Improving Neural Network Learning	639		Respiratory Rhythm Generation	813
			Retina	816
			Robot Control	820
			Routing Networks in Visual Cortex	823

- Saccades and Listing's Law 826
Schema Theory 830
Scratch Reflex 834
Selective Visual Attention 837
Self-Organization and the Brain 840
Self-Organization in the Time Domain 843
Self-Organizing Feature Maps: Kohonen Maps 846
Self-Reproducing Automata 851
Semantic Networks 854
Sensor Fusion 857
Sensorimotor Learning 860
Sensory Coding and Information Theory 864
Short-Term Memory 867
Silicon Neurons 871
Simulated Annealing 876
Single-Cell Models 879
Somatosensory System 884
Somatotopy: Plasticity of Sensory Maps 888
Sound Localization and Binaural Processing 891
Sparse Coding in the Primate Cortex 895
Sparsely Coded Neural Networks 899
Spatiotemporal Association in Neural Networks 902
Speaker Identification 905
Speech Recognition: A Hybrid Approach 907
Speech Recognition: Feature Extraction 910
Speech Recognition: Pattern Matching 913
Spinal Cord of Lamprey: Generation of Locomotor Patterns 918
Statistical Mechanics of Generalization 922
Statistical Mechanics of Learning 925
Statistical Mechanics of Neural Networks 930
Steelmaking 934
Stereo Correspondence and Neural Networks 937
Stochastic Approximation and Neural Network Learning 941
Structural Complexity and Discrete Neural Networks 945
Structured Connectionist Models 949
Synaptic Coding of Spike Trains 953
Synaptic Currents, Neuromodulation, and Kinetic Models 956
Synchronization of Neuronal Responses as a Putative Binding Mechanism 960
Telecommunications 964
Temporal Pattern Processing 967
Textured Images: Modeling and Segmentation 971
Thalamocortical Oscillations in Sleep and Wakefulness 976
Thalamus 981
Time Complexity of Learning 984
Time Perception: Problems of Representation and Processing 987
Topology-Modifying Neural Network Algorithms 990
Traveling Activity Waves 994
Unsupervised Learning with Global Objective Functions 997
Vapnik-Chervonenkis Dimension of Neural Networks 1000
Vestibulo-Ocular Reflex: Performance and Plasticity 1003
Vision for Robot Driving 1008
Vision: Hyperacuity 1009
Visual Coding, Redundancy, and "Feature Detection" 1012
Visual Cortex Cell Types and Connections 1016
Visual Processing of Object Form and Environment Layout 1021
Visual Scene Perception: Neurophysiology 1024
Visual Schemas in Object Recognition and Scene Analysis 1029
Visuomotor Coordination in Flies 1031
Visuomotor Coordination in Frogs and Toads 1036
Visuomotor Coordination in Salamanders 1042
Walking 1045
Wavelet Dynamics 1049
Wave Propagation in Cardiac Muscle and in Nerve Networks 1054
Winner-Take-All! Mechanisms 1056

Editorial Advisory Board 1061
Contributors 1063
Subject Index 1075