Foreword
Neural Pulse Coding
Spike Timing
Population Codes
Hippocampal Place Field
Hardware Models
References
Preface
The Isaac Newton Institute
Overview of the Book
Acknowledgments
Contributors
Basic Concepts and Models
Spiking Neurons
The Problem of Neural Coding
Motivation
Rate Codes
Rate as a Spike Count (Average over Time)
Rate as a Spike Density (Average over Several Runs)
Rate as Population Activity (Average over Several Neurons)
Candidate Pulse Codes
Time-to-First-Spike
Phase
Correlations and Synchrony
Stimulus Reconstruction and Reverse Correlation
Discussion: Spikes or Rates?
Neuron Models
Simple Spiking Neuron Model
First Steps towards Coding by Spikes
Threshold-Fire Models
Spike Response Model -- Further Details
Integrate-and-Fire Model
Models of Noise
Conductance-Based Models
Hodgkin-Huxley Model
Relation to the Spike Response Model
Compartmental Models
Rate Models
Conclusions
References
Computing with Spiking Neurons
Introduction
A Formal Computational Model for a Network of Spiking Neurons
McCulloch-Pitts Neurons versus Spiking Neurons
Computing with Temporal Patterns
Coincidence Detection
RBF-Units in the Temporal Domain
Computing a Weighted Sum in Temporal Coding
Universal Approximation of Continuous Functions with Spiking Neurons Remarks:
Other Computations with Temporal Patterns in Networks of Spiking Neurons
Computing with a Space-Rate Code
Computing with Firing Rates
Computing with Firing Rates and Temporal Correlations
Networks of Spiking Neurons for Storing and Retrieving Information
Computing on Spike Trains
Conclusions
References
Pulse-Based Computation in VLSI Neural Networks
Background
Pulsed Coding: A VLSI Perspective
Pulse Amplitude Modulation
Pulse Width Modulation
Pulse Frequency Modulation
Phase or Delay Modulation
Noise, Robustness, Accuracy and Speed
A MOSFET Introduction
Subthreshold Circuits for Neural Networks
Pulse Generation in VLSI
Pulse Intercommunication
Pulsed Arithmetic in VLSI
Addition of Pulse Stream Signals
Multiplication of Pulse Stream Signals
MOS Transconductance Multiplier
MOSFET Analog Multiplier
Learning in Pulsed Systems
Summary and Issues Raised
References
Encoding Information in Neuronal Activity
Introduction
Synchronization and Oscillations
Temporal Binding
Phase Coding
Dynamic Range and Firing Rate Codes
Interspike Interval Variability
Synapses and Rate Coding
Summary and Implications
References
Implementations
Building Silicon Nervous Systems with Dendritic Tree Neuromorphs
Introduction
Why Spikes?
Dendritic Processing of Spikes
Tunability
Implementation in VLSI
Artificial Dendrites
Synapses
Dendritic Non-Linearities
Spike-Generating Soma
Excitability Control
Spike Distribution -- Virtual Wires
Neuromorphs in Action
Feedback to Threshold-Setting Synapses
Discrimination of Complex Spatio-Temporal Patterns
Processing of Temporally Encoded Information
Conclusions
Acknowledgments
References
A Pulse-Coded Communications Infrastructure for Neuromorphic Systems
Introduction
Neuromorphic Computational Nodes
Neuromorphic aVLSI Neurons
Address Event Representation (AER)
Implementations of AER
Silicon Cortex
Basic Layout
Functional Tests of Silicon Cortex
An Example Neuronal Network
An Example of Sensory Input to SCX
Future Research on AER Neuromorphic Systems
Acknowledgements
References
Analog VLSI Pulsed Networks for Perceptive Processing
Introduction
Analog Perceptive Nets Communication Requirements
Coding Information with Pulses
Multiplexing of the Signals Issued by Each Neuron
Non-Arbitered PFM Communication
Analysis of the NAPFM Communication Systems
Statistical Assumptions
Detection
Detection by Time-Windowing
Direct Interpulse Time Measurement
Performance
Detection by Time-Windowing
Direct Interpulse Time Measurement
Data Dependency of System Performance
Discussion
Detection by Time-Windowing
Detection by Direct Interpulse Time Measurement
Address Coding
Silicon Retina Equipped with the NAPFM Communication System
Circuit Description
Noise Measurement Results
Projective Field Generation
Overview
Anisotropic Current Pulse Spreading in a Nonlinear Network
Analysis of the Spatial Response of the Nonlinear Network
Analysis of the Size and Shape of the Bubbles Generable by the Nonlinear Network
Description of the Integrated Circuit for Orientation Enhancement
Overview
Circuit Description
System Measurement Results
Other Applications
Weighted Projective Field Generation
Complex Projective Field Generation
Display Interface
Conclusion
References
Preprocessing for Pulsed Neural VLSI System
Introduction
A Sound Segmentation System
Signal Processing in Analog VLSI
Continuous Time Active Filters
Sampled Data Active Switched Capacitor (SC) Filters