

Contents

1	Introduction	1
1.1	Background	1
1.2	Motivation	2
1.3	Overview of the Book	4
	References	5
2	Time Encoding and Decoding in Bandlimited and Shift-Invariant Spaces	7
2.1	Introduction	7
2.2	Nonuniform Sampling and Reconstruction of Bandlimited Functions	8
2.3	Time Encoding and Decoding in Bandlimited Spaces	11
2.3.1	The Ideal IF Neuron	12
2.3.2	The Ideal IF Neuron with Refractory Period	15
2.3.3	The Leaky IF Neuron	16
2.3.4	The Leaky IF Neuron with Random Threshold	17
2.3.5	The Hodgkin-Huxley Neuron	18
2.3.6	The Asynchronous Sigma-Delta Modulator	20
2.4	Time Encoding and Decoding in Shift-Invariant Spaces	22
2.5	Conclusions	27
	References	27
3	A Novel Framework for Reconstructing Bandlimited Signals Encoded by Integrate-and-Fire Neurons	31
3.1	Introduction	31
3.2	A New Method of Reconstructing Functions from Local Averages	32
3.3	Direct Reconstruction Algorithms for Inputs Encoded with Ideal IF Neurons	37
3.4	The Integrate-and-Fire Neuron as a Uniform Sampler	38

3.5	Fast Indirect Reconstruction Algorithms for Inputs Encoded with Ideal IF Neurons.	43
3.6	Numerical Study.	46
3.6.1	Numerical Study for Algorithm 3.1.	48
3.6.2	Numerical Study for Algorithm 3.2.	53
3.6.3	Error Evaluation for the Interpolation Step of the Proposed Algorithms.	55
3.7	Conclusions	56
	References.	57
4	A Novel Reconstruction Framework in Shift-Invariant Spaces for Signals Encoded with Integrate-and-Fire Neurons	59
4.1	Introduction	59
4.2	A New Non-iterative Method for Reconstructing Signals in Shift-Invariant Spaces from Spike Trains Generated with IF-TEMs.	61
4.3	Direct Reconstruction Algorithms for Inputs Encoded with Ideal IF Neurons.	67
4.4	Fast Indirect Reconstruction Algorithms for Inputs Encoded with Ideal IF Neurons.	70
4.5	Numerical Study.	75
4.5.1	Comparative Numerical Study of the Iterative Algorithms	76
4.5.2	Comparative Numerical Study of the Non-iterative Algorithms	78
4.6	Conclusions	79
	References.	80
5	A New Approach to the Identification of Sensory Processing Circuits Based on Spiking Neuron Data	81
5.1	Introduction	81
5.2	Identification of Spiking Neural Circuits.	83
5.2.1	Identification of [Linear Filter]-[Ideal IF] Circuits.	83
5.2.2	Identification Methods for Different Circuit Structures	86
5.3	The NARMAX Identification Methodology	89
5.3.1	An Overview of the NARMAX Model.	89
5.3.2	The Orthogonal Least Squares Estimator	90
5.3.3	The Orthogonal Forward Regression Algorithm	92
5.3.4	The Generalised Frequency Response Functions.	95
5.4	A New Method for the Identification of [Nonlinear Filter]-[Ideal IF] Circuits.	98
5.4.1	Problem Statement	98
5.4.2	Numerical Study	100

5.5	A New Methodology for the Identification of [Linear Filter]-[Leaky IF] Circuits	103
5.5.1	Problem Statement	103
5.5.2	Numerical Study	107
5.6	Conclusions	109
	References.	109
6	A New Method for Implementing Linear Filters in the Spike Domain.	113
6.1	Introduction	113
6.2	Problem Statement	114
6.3	Direct Computation of Spike Times	116
6.4	Numerical Study.	120
6.5	Conclusions	123
	References.	124
7	Conclusions and Future Work	125
	Appendix A: An Overview of Hilbert Spaces and Frames.	129
	Appendix B: Proof of Theorems	135

Reconstruction, Identification and Implementation
Methods for Spiking Neural Circuits

Florescu, D.

2017, XIV, 139 p. 42 illus., 27 illus. in color., Hardcover

ISBN: 978-3-319-57080-8