

Higher-order correlation analysis in massively parallel recordings in behaving monkey

Alessandra Stella

Information Band / Volume 81 ISBN 978-3-95806-640-3



Mitglied der Helmholtz-Gemeinschaft

Forschungszentrum Jülich GmbH Institute of Neurosciences and Medicine (INM) Computational and Systems Neuroscience (INM-6)

Higher-order correlation analysis in massively parallel recordings in behaving monkey

Alessandra Stella

Schriften des Forschungszentrums Jülich Reihe Information / Information

Band / Volume 81

ISSN 1866-1777

ISBN 978-3-95806-640-3

1	INTRODUCTION 1			
	1.1	One n	euron and one spike 1	
	1.2	Multiple neurons and multiple spikes 2		
	1.3	Neural coding hypotheses 2		
	1.4	Precise	Precise time spike correlations: theory and evidences 4	
	'	1.4.1	Pairwise correlation 5	
		1.4.2	Higher-order synchronization and synchronous	
		•	spike patterns 6	
		1.4.3	Spatio-temporal spike patterns 6	
		1.4.4	Fuzzy patterns 7	
		1.4.5	Sequences of synchronous patterns 7	
	1.5	Metho	ds of detection of precisely timed spike correla-	
	9	tions	7	
		1.5.1	Cross-correlation histogram 9	
		1.5.2	Complexity analysis 9	
		1.5.3	Unitary events analysis 10	
		1.5.4	SPADE 10	
		1.5.5	CAD 11	
		1.5.6	EDIT 11	
		1.5.7	SPOTDisCLUST 12	
		1.5.8	SCCFNAD 12	
		1.5.9	Seg MNF and PP-seg 13	
		1.5.10	Bayesian methods 14	
		1.5.11	ASSET 14	
		1.5.12	SPIKE-ORDER 15	
	1.6	Big data sets as a computational challenge for analysis		
		metho	ds 15	
	1.7	Model	ing experimental parallel spike trains with point	
		proces	ses 16	
2	3D-5	3D-SPADE: SIGNIFICANCE EVALUATION OF SPATIO-TEMPORAL		
	PATTERNS OF VARIOUS TEMPORAL EXTENTS 19			
	2.1	Introd	uction 20	
	2.2	SPADI	E 20	
		2.2.1	Frequent item set mining 20	
		2.2.2	Pattern spectrum filtering (2-dimensional) 21	
		2.2.3	Pattern set reduction 23	
	2.3	Extens	ion of SPADE's statistical test 24	
		2.3.1	Motivations for the extension 24	
		2.3.2	The concept of the 3d-pattern spectrum 24	
		2.3.3	Comparison and improvements of the new sta-	
			tistical test 25	
		2.3.4	Validation of 3d-SPADE 29	

2.4 Software implementation of SPADE 32 Profiling of computational performance 2.4.132 Software and reproducibility 2.4.2 34 2.5 Conclusion and discussion 36 **3** ACCELERATION OF SPADE: IMPROVEMENTS IN PATTERN MINING 39 3.1 Introduction 40 3.2 Optimization of FP-Growth 41 Frequent Itemset Mining 3.2.1 41 The FP-Growth algorithm 3.2.2 42 FP-Growth within SPADE 3.2.3 42 Bottlenecks of SPADE and proposed solutions 3.2.4 43 Custom FP-Growth implementation for SPADE 3.2.5 44 3.3 Experimental data used for FP-Growth evaluation 45 Reach-to-grasp experiment 3.3.1 46 Data preparation: R2G data for SPADE 3.3.2 47 3.4 SPADE workflow for data analysis 48 3.4.1 Workflow in the context of FP-Growth evaluation 49 FP-Growth and its improvements on experimental data 50 3.5 Devices used for testing 3.5.1 50 Improvements in time, memory, and energy effi-3.5.2 ciency 51 Scaling in terms of recording length and number 3.5.3 of neurons 55 3.6 Reproducibility and code publication on Elephant 56 3.7 Conclusion and discussion 57 REALISTIC MODELING OF EXPERIMENTAL DATA THROUGH POINT PROCESSES 61 4.1 Introduction 62 4.2 Relevant features of experimental data and how to reproduce them 63 Number of parallel processes and recording length 4.2.1 4.2.2 Firing rate (stationary and non-stationary) 64 Dead time and refractory period 65 4.2.3 Regularity 4.2.4 65 Pairwise correlation 4.2.5 67 Higher-order correlation 68 4.2.6 4.3 Point process models for generation of artificial data 68 Poisson point process 4.3.1 69 4.3.2 Poisson point process with dead time 69 4.3.3 Gamma point process 70 Generation of non-stationary point processes 71 4.3.4 Surrogates as alternative to point process mod-4.3.5 els 71

64

4.4 The data sets 71

- 4.4.1 PPD data set 73
- 4.4.2 Gamma data set 73
- 4.4.3 Baseline correlation data set 73
- 4.4.4 Functional correlation data set 73
- 4.4.5 Dithered data set 74
- 4.5 Intermezzo: educational context of ANDA spring school 74

87

- 4.6 Statistical characteristics of the data sets 75
 - 4.6.1 Firing rate 75
 - 4.6.2 ISI distribution 76
 - 4.6.3 Spike count 76
 - 4.6.4 Variability of ISIs and spike counts 79
 - 4.6.5 Pairwise correlations 83
 - 4.6.6 Higher-order correlations 84
- 4.7 Workflow for data generation 86
- 4.8 Conclusion and discussion
- 5 GENERATING SURROGATES FOR SIGNIFICANCE ESTIMA-
 - TION OF SPATIO-TEMPORAL SPIKE PATTERNS 91
 - 5.1 Introduction 93
 - 5.2 Formulation of a null-hypothesis through surrogate generation 95
 - 5.3 Spike count reduction in surrogates generated by uniform dithering 98
 - 5.3.1 Uniform dithering 99
 - 5.3.2 Origin of spike count reduction 101
 - 5.3.3 Consequences of spike count reduction 103
 - 5.4 Alternative surrogate techniques 104
 - 5.4.1 Uniform dithering with dead time 106
 - 5.4.2 Joint-ISI dithering 106
 - 5.4.3 ISI dithering 107
 - 5.4.4 Trial shifting 107
 - 5.4.5 Window shuffling 107
 - 5.5 Statistical comparison of surrogate methods 108
 - 5.5.1 Spike Count Reduction in relation to to Spike Train Statistics 111
 - 5.5.2 Are surrogates uncorrelated? 115
 - 5.5.3 Coefficient of Variation of ISIs 116
 - 5.5.4 Ratio of moved spikes 116
 - 5.5.5 Rate change in surrogates 117
 - 5.5.6 Summary of the effects of surrogates on the spike-train statistics **11**8
 - 5.6 SPADE analysis of artificial data across surrogate techniques 119
 - 5.6.1 Simulation of experimental data and SPADE analysis 119
 - 5.6.2 False positive analysis 120
 - 5.7 Application to experimental data 123

5.8 Observations on past analysis and on CoCoNAD 124

5.9 Discussion 126

- 6 SPATIO-TEMPORAL SPIKE PATTERNS IN MACAQUE MO-TOR CORTEX 131
 - 6.1 Introduction
 - 132
 - 6.2 Materials and methods 133
 - 6.2.1 Data 133
 - 6.2.2 SPADE analysis 133
 - 6.2.3 Calculation of pattern specificity to behavior 134
 - 6.3 Results 136
 - Statistics of detected spatio-temporal spike pat-6.3.1 terns 136
 - 6.3.2 Pattern specificity to behavior 138
 - Spatial distribution of patterns on the electrode 6.3.3 array 142
 - 6.3.4 Overlap of STP members 145
 - 6.3.5 Firing rate of STP members 147
 - 6.4 Discussion 147
- 7 DISCUSSION AND PERSPECTIVES 157

Information Band / Volume 81 ISBN 978-3-95806-640-3

