10th International Workshop

Neural Coding 2012

Book of Abstracts

Prague, Czech Republic,
September 2–7, 2012

10th International Workshop

Neural Coding 2012

Book of Abstracts

Prague, Czech Republic,
September 2–7, 2012

`http://nc2012.biomed.cas.cz/`

Local Organising Agency:

CONFORG, Ltd.

`http://www.conforg.cz`

Institute of Physiology
Academy of Sciences
of the Czech Republic

Supported by:

Office of Naval Research Global

Grant No.: N62909-11-1-1111

Contents

Using the structure of inhibitory networks to unravel mechanisms of spatiotemporal patterning 1
Maxim Bazhenov

On dependency properties of the ISIs generated by a two compartmental neuronal model 3
Elisa Benedetto and Laura Sacerdote

Modelling of Sensory Pathway of Swimming Initiation in Young Frog Tadpole Spinal Cord: a Developmental Approach 5
Roman Borisyuk, Kalam Abul AlAzad, Alan Roberts, Steve Soffe, Deborah Conte and Edgar Buhl

Determinism, Randomness and the Question of the "Free Will" – Examined from a Neural Coding Perspective 7
Hans A. Braun

Fast learning in single synapses and behavioral learning times 9
Guido Bugmann

A Simple Algorithm for Simulating Firing Times predicted by a LIF Model 11
Aniello Buonocore, Luigia Caputo and Enrica Pirozzi

Precise coding of interaural level differences in the auditory brainstem 13
Zbynek Bures

Image coding at the electrosensory lobe of pulse gymnotiforms 15
Ángel Ariel Caputi, Ana Carolina Pereira and Alejo Rodríguez-Cattaneo

Interplay between Endogenous and Exogenous Rhythms in Recurrent Networks with Conductance-Based neurons 17
Stefano Cavallari, Alberto Mazzoni and Stefano Panzeri

Independent components of wing kinematics in the fruit fly Drosophila 19
Soma Chakraborty, Jan Bartussek, Steven N. Fry and Martin Zapotocky

FM responses of midbrain auditory neurons modeled with artificial neural network based on multiple trigger features 21
T.R. Chang, T.W. Chiu and Paul W.F. Poon

Coding of woody and fruity odorant mixtures: Interactions of odorants with olfactory receptors and receptor neurons match the perceptual dynamics 23
M. A. Chaput, F. El Mountassir, T. Thomas-Danguin, A. M. Le Bon, B. Ferry and P. Viret

Patterns of single-trial auditory evoked potentials on the human temporal cortex extracted with the adaptive filter 25
T.W. Chiu, W. Qiu, Paul W.F. Poon, Kirill Nourski, Hiroyuki Oya, John F. Brugge and Matthew A. Howard III

Diffusion approximation of neuronal models revisited 27
Jakub Cupera

Some remarks on a spike train model of interacting neurons 29
Antonio Di Crescenzo, Maria Longobardi and Barbara Martinucci

Firing mechanisms in the stochastic Morris-Lecar neuron model and its embedded leaky integrate-and-fire model 31
Susanne Ditlevsen

Brain States revealed by Bispectral Analysis of Microsleep 33
Pierre Dutoit, Vladyslav V. Shaposhnyk, Alessandro E. P. Villa and Stephen Perrig

Coding in the presence of adaptation 35
Wulfram Gerstner and Richard Naud

A simple estimator for mutual information 37
Maria Teresa Giraudo, Laura Sacerdote and Roberta Sirovich

Neural Encoding of Saccadic Stimuli in the Retina 39
Tim Gollisch, Vidhyasankar Krishnamoorthy and Christian B. Mendl

Inter Neuron Nearest Spike Intervals based Method to Measure Synchrony under Low Firing Rates 41
Aldana M. Gonzalez-Montoro, Ricardo Cao, Christel Faes and Geert Molenberghs

The Mechanism of Orientation Selectivity in Primary Visual Cortex without a Functional Map 43
David Hansel and Carl van Vreeswijk

Genesis, dynamics and role of nested theta to gamma oscillations in an attractor network model of cortical memory 45
Pawel Andrzej Herman, Mikael Lundqvist and Anders Lansner

A computational modelling approach to the problem of odour mixture segmentation 47
Pawel Andrzej Herman, Simon Benjaminsson and Anders Lansner

Activity Patterns in Networks Stabilized by Background Oscillations 49
Frank Hoppensteadt

Channel Capacity of a Spiking Neuron 51
Shiro Ikeda and Jonathan H. Manton

Inverse Problem for Leaky Integrate-and-Fire Neuronal Models using Spike-Times Data: The sinusoidally-driven case 53
Alexandre Iolov and Andre Longtin

Can discrete Response-Stimulus Correlation distinguish Integration from Coincidence Detection? 55
Jacob Kanev, Achilleas Koutsou and Chris Christodoulou

Estimating Nonstationary Inputs from Firing Rate and Non-Poisson Irregularity in a Single Spike Train 57
Hideaki Kim and Shigeru Shinomoto

A model-based inference of synaptic connectivity from simulated multi-neuronal spike data 59
Katsunori Kitano and Ryota Kobayashi

A Bayesian approach for estimating time-varying input signals from membrane potential of a neuron 61
Ryota Kobayashi, Shigeru Shinomoto and Petr Lansky

On reliable information transmission in simple neuronal systems 63
Lubomir Kostal and Ryota Kobayashi

Input synchrony estimation in the Ornstein-Uhlenbeck model through the slope of depolarisation at threshold crossing 65
Achilleas Koutsou, Petr Lansky, Jacob Kanev and Chris Christodoulou

Coding efficiency and detectability of rate fluctuations with non-Poisson neuronal firing 67
Shinsuke Koyama

Non-markovian spiking statistics of a neuron with delayed feedback in the presence of refraction 69
Kseniia Kravchuk and Alexander Vidybida

Estimating latency in the case of inhibitory response 71
Marie Levakova and Petr Lansky

Information filtering by stochastic neurons 73
Benjamin Lindner

An electrophysiological study of cortico-thalamic networks in PV depleted mice 75
Alessandra Lintas, Beat Schwaller and Alessandro E. P. Villa

The effect of prestimulus oscillatory dynamics on the performance of a cortical attractor network model in a simulated stimulus detection task 77
Mikael Lundqvist, Pawel Andrzej Herman and Anders Lansner

Stochastic pooling networks embedded in cortical networks of excitatory and inhibitory neurons 79
Mark D. McDonnell, Pierre-Olivier Amblard and Minh-Son To

Optically Mapping Electrical Activity in the Ganglion of the Leech Hyrudo Medicinalis 81
Majid Moshtagh Khorasani, Evan W. Miller and Vincent Torre

A novel mechanism for sparse and reliable stimulus coding in sensory cortices 83
Martin Paul Nawrot and Farzad Farkhooi

Estimation of the information pathway for a motor command generation in an insect brain based on the physiological data 85
Ikuko Nishikawa, Yoshihiko Yamagishi, Hidetoshi Ikeno, Tomoki Kazawa, Shigehiro Namiki and Ryohei Kanzaki

Coding of temporally incoherent odour mixtures in the antennal lobe of honeybees 87
Thomas Nowotny, C. Giovanni Galizia and Paul Szyszka

Discrimination of binary patterns by perceptrons with binary weights 89
Andrey Olypher and Jean Vaillant

The interplay between network topology and structural synaptic plasticity in a model of cortical sequence learning 91
Daniel E. Padilla and Mark D. McDonnell

Effectiveness of information transmission in the brain-like communication models 93
Bartosz Paprocki and Janusz Szczepanski

Noise correlations in cortical networks 95
Nestor Parga

Calcium Activated Potassium Currents Contribute to High Fat Diet Induced Inhibition of POMC Neurons of the Mouse Hypothalamus 97
Andreas Pippow, Moritz Paehler, Simon Hess, Lars Paeger, Merly C. Vogt, Tim Klöckener, Christophe Pouzat, Jens C. Brüning and Peter Kloppenburg

Nonparametric estimation of interspike interval distribution and its characteristics 99
Ondrej Pokora and Lubomir Kostal

Fano Factor Estimation 101
Kamil Rajdl and Petr Lansky

Novelty detection and jamming avoidance share common computational mechanisms in pulse gymnotiforms 103
Alejo Rodríguez-Cattaneo, Pedro Aguilera, Ana Carolina Pereira and Ángel Ariel Caputi

Response Properties of First- and Second-Order Neurons in the Olfactory Systems of a Moth and a Frog 105
Jean-Pierre Rospars, Philippe Lucas and Patricia Viret

A model of Trial-to-Trial Variability in Monkey Motor Cortex 107
Thomas Rost, Alexa Riehle and Martin P. Nawrot

Dependency problems in neuronal network modeling 109
Laura Sacerdote, Massimiliano Tamborrino and Cristina Zucca

Spike-triggered covariance revisited 111
Inés Samengo and Tim Gollisch

Ideal observer in the stochastic interpolation model of the auditory brainstem 113
Pavel Sanda and Petr Marsalek

Synchronization of stochastic neuronal networks 115
Lutz Schimansky-Geier

Order patterns networks (ORPAN) – Concept and applications 117
Stefan Schinkel, Gorka Zamora-López, Olaf Dimigen, Werner Sommer and Jürgen Kurths

Inferring nonstationary input activities from non-Poisson firing of a neuron 119
Shigeru Shinomoto

Slope-based suprathreshold stochastic resonance in populations of phasic neurons due to intrinsic ion channel noise 121
Brett Schmerl, Daniel E. Padilla and Mark D. McDonnell

Analysis of non-renewal spiking in neuron models with adaptation 123
Tilo Schwalger

(Leaky) Integrate and Fire models can be coincidence detectors 125
Roberta Sirovich, Luisa Testa, Petr Lansky and Laura Sacerdote

Transmission efficiency in the brain-like neuronal networks. Information and energetic aspects 127
Janusz Szczepanski and Bartosz Paprocki

Identification of noisy response latency in presence of a background signal 129
Massimiliano Tamborrino, Susanne Ditlevsen and Petr Lansky

Modeling the Relations between Neuronal Membrane Potentials, Ion Currents and Ion Channel Dynamics 131
Aubin Tchaptchet, Svetlana Postnova, Martin T. Huber and Hans A. Braun

Understanding disordered topography of auditory cortex through natural sound statistics 133
Hiroki Terashima and Masato Okada

Analysis of synaptic action in stochastic interpolation model of the auditory brainstem 135
Peter G. Toth and Petr Marsalek

Very Slow Synchronization and Variability of Interspike Intervals in a Globally Coupled Neuronal Oscillators 137
Ryotaro Tsuneki, Shinji Doi and Junko Inoue

Structural phase transition in the neural networks 139
Tatyana Turova

Network Inference with Stochastic Hidden Units 141
Joanna Tyrcha and John Hertz

Computational investigation of Glutamate-AMPA interaction in synaptic transmission 143
Francesco Ventriglia and Vito Di Maio

Efficient coding beyond the retina 145
Jonathan D. Victor, Yunguo Yu and Mary M. Conte

Event-related potentials associated to decision-making in emotionally-primed Ultimatum Game 147
Alessandro E. P. Villa, Alessandra Lintas, Sarah Mesrobian and Marina Fiori

Synthetic and elemental coding of the pineapple “accord” and its components 149
Patricia Viret, Petryszyn Sarah, Michel Chaput and Barbara Ferry

Representational capacity of neural codes in the cortex 151
Lawrence York, Jan Pieczkowski and Mark van Rossum

Dynamics of axon fasciculation and its consequences for ephaptic coupling 153
Martin Zapotocky and Debasish Chaudhuri

Index of Authors 155

Transmission efficiency in the brain-like neuronal networks. Information and energetic aspects

Janusz Szczepanski
Institute of Fundamental Technological Research, Polish Academy of Sciences
Warsaw, Pawinskiego 5B, Poland
`jszczepa@ippt.gov.pl`
`www.ippt.gov.pl/~jszczepa/`

Bartosz Paprocki
Institute of Mechanics and Applied Computer Science, Kazimierz Wielki University
Bydgoszcz, Kopernika 1, Poland
`bartekp@ukw.edu.pl`

Biological systems evolve as compromises and many of them can be expressed in terms of energy efficiency [1, 2]. Inspired by brain network architecture we analyze the communication channels composed of the main brain ingredients. We study the information-energetic transmission efficiency of such neuronal networks. The Shannon Information Theory is applied and the fundamental concept of this theory, Mutual Information between input and output signals is estimated with high accuracy. The entropy estimator is that of high quality proposed in [3] and the encoded information were of 10^6 bits long to reach high accuracy. The model of neuron considered is that in the spirit of probabilistic approach proposed by [1] and further explored in [4].

The network constitutes from *nodes* each of them being a pair *excitatory* neuron and corresponding *inhibitory* one. The nodes are distributed uniformly over the circle (Fig. 1). Each node is connected with neighboring nodes and additionally the nodes can be connected through *long-range connections*. Source signals are modeled by Bernoulli process (*spike* or *no-spike*) and they can support excitatory neurons only. We study a variety of complementary architectures (Fig. 1). The following parameters affect the effectiveness of this communication system: Source parameter – firing rate f_r, entropy h; Neuron parameters – synaptic failure s, threshold activation g, inhibitory level of dumping b, number of synapses l; Network parameters – size r, number of nodes n. We assume that most energy is consumed by spikes. Thus, with Mutual Information for a given neuron denoted by MI, we analyze the information-energetic formula:

$$\Lambda(b) = \max_g \left(\frac{\max_{(s,f_r)} MI(s, f_r, b, g)}{\vartheta(s^0, f_r^0)} \right),$$

where $\vartheta(s, f_r)$ is equal to $s \cdot (n f_r + b f_I + \sum_w f_w)$, $s \cdot (b f_I + \sum_w f_w)$, $s \cdot \sum_w f_w$ for with- and without access to the source and for inhibitor, respectively. $\vartheta(s^0, f_r^0)$ are the values maximizing MI. The denominator is proportional to the number of spikes actually used to transfer information. The role of inhibitors, long-range connections and size-delay effects are studied and information-energetic optimal parameters are determined.

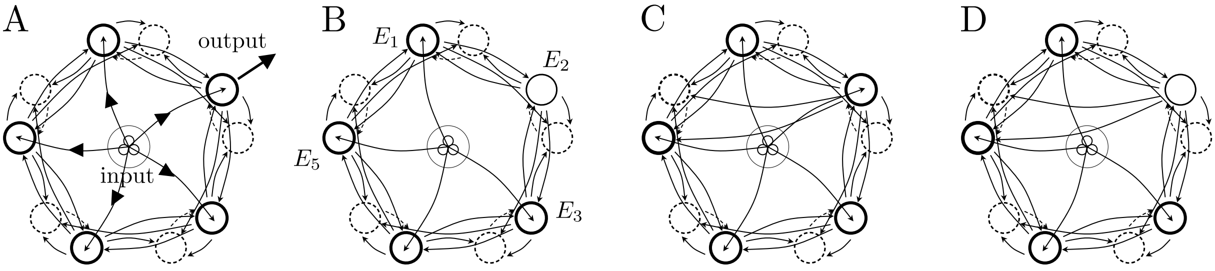

Figure 1: *Brain-like* neural architectures we studied. Each one has five nodes and source of size $l = 3$. **A**, a *symmetric* case. **B**, E_2 has no access to the source of information. **C**, symmetric case with added *long-range* connection from E_2 to E_5. **D**, a combination of B and C.

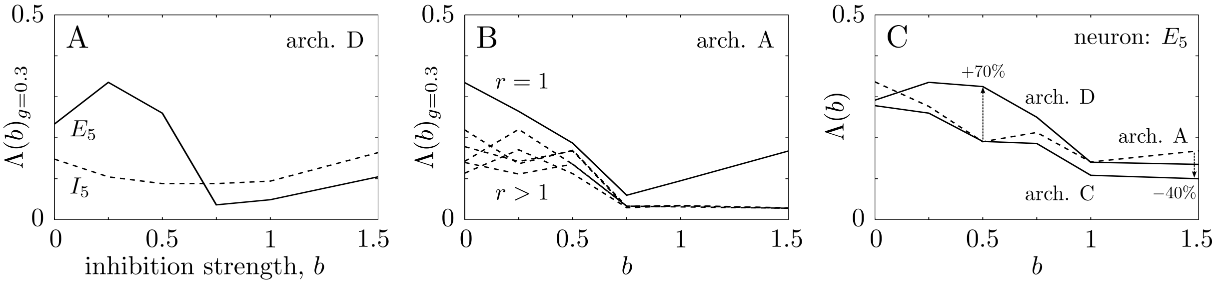

Figure 2: **A**, illustration of inhibition influence. **B**, size effects. **C**, long-range connection role.

Inhibitors influence: Parameter b, being a ratio of inhibitory neurons' strength in relation to excitatory neurons' strength, affects every signal that I neuron sends forward. If $b = 0$, then amplitude of every inhibition signal is reset to zero as if I neurons had completely no effect on the structure's behavior. The bigger the b is, the more potent inhibition signals are in relation to excitatory ones. If $b = 1$ then both types of neurons react with the same strength. It turned out that inhibitors can strength the effectiveness of transmission even by 50 percent (Fig. 2A).

Size effects: The most important effect of the size increase is a delay in transferring the information. Therefore it was expected that the transmission is most efficient for smaller size, i.e. for $r = 1$ (r is radius of the circle) but surprisingly further increase of the size ($r = 2, 3, 4$) does not change effectiveness significantly (Fig. 2B). We also observe that a two times increase of the size can cause even three times decrease of the information-energetic efficiency.

Long-range connections role: We observe that long-range connection can lead to improve target neuron's information-energetic efficiency significantly (even by 70 percent) if the neuron starting it has no access to the source of the stimuli. If the connection originates from neuron that has such access, it can bring a 40 percent loss to the target neuron's efficiency (Fig. 2C) – however this connection increases the efficiencies of starting neuron and neurons neighboring target neuron by up to 24 percent.

Conclusions: Our research shows, both through qualitative and quantitative results, that the brain-like networks significantly improve the information-energetic transmission efficiency.

Acknowledgments: This paper has been supported by NCN grant N N519 646540.

Keywords: Neuronal Communication, Brain-like Network, Shannon Theory.

Bibliography

[1] Levy, W.B., Baxter, R.A. (2002) Energy-efficient neuronal computation via quantal synaptic failures, *The Journal of Neuroscience*, **22**: 4746–4755.

[2] Sejnowski, T.J., van Hemmen, J.L. (2006) *23 problems in systems neuroscience*. Oxford University Press, Oxford.

[3] Strong, S.P., Koberle, R., de Ruyter van Steveninck, R.R., Bialek, W. (1998) Entropy and information in neural spike trains, *Physical Review Letters*, **80**: 3197–200.

[4] Paprocki, B., Szczepanski, J. (2011) Efficiency of neural transmission as a function of synaptic noise, threshold, and source characteristics, *BioSystems*, **105(1)**: 62–72.