Romanian Institute
of Science and Technology

2011 Annual Report

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Institutul Român de Ştiinţă şi Tehnologie (Romanian Institute of Science and Technology - RIST) is a non-governmental, not-for-profit, independent research institute, founded in 2009.

RIST currently performs research on computational, theoretical and experimental neuroscience, nonlinear science, and complex systems.

RIST aims to provide appropriate institutional and administrative support for world class scientists that would like to work in Romania and are not satisfied by the conditions offered by existing Romanian research institutions, which are often much too bureaucratic. RIST especially welcomes Romanian scientists currently working abroad.

RIST is a grassroots initiative, resulting from the enlargement of the Center for Cognitive and Neural Studies (Coneural), another independent, not-for-profit research institution, founded in 2002 by several Romanian scientists. Although Asociaţia Coneural is formally still a distinct legal entity, Coneural is informally part of RIST and we expect Coneural to officially merge with RIST in about 2 years, after current contracts involving Coneural expire. Coneural is also the founder of RIST.

Affiliated scientists

Experimental and Theoretical Neuroscience Laboratory

Raul C. Mureşan - Principal investigator
Vasile V. Moca
Ioana Ţincaş
Ovidiu F. Jurjuţ (on leave at the Frankfurt Institute of Advanced Studies, Germany)
Sergiu P. Paşca (on leave at Stanford University, USA)

Computational neuroscience

Răzvan V. Florian - Principal investigator
Cătălin V. Rusu

Nonlinear science

Marius F. Danca - Principal investigator

Complex systems

Dumitru Dumitrescu - Principal investigator
Ligia D. Cremene

Staff

Cosmina Pavel

Board of directors

Răzvan V. Florian
Liviu Giosan
Raul C. Mureşan

Research

Experimental and Theoretical Neuroscience Laboratory

The lab led by Raul C. Mureşan explores the brain by means of experimentally recorded data from humans (using EEG and eye tracking) and from the visual cortex of mammals (highly parallel recordings) and also through computer simulations of realistic models of cortical microcircuits. In addition, it develops new, non-conventional techniques of data analysis.

The first important line of investigation is related to the analysis of neuronal data recorded from real brains. The lab explores high-density EEG and eye tracking data recorded in humans, as well as parallel recordings from mammalian visual cortex. The second line of research investigates neurocomputational principles in simulations of large scale networks of spiking neurons. This includes studies ranging from new biologically-inspired computational models of vision to general studies related to the dynamics of large-scale neuronal microcircuits and issues regarding their computational simulation. Finally, the lab develops new and non-conventional analysis tools for spike-trains, LFP and EEG signals, as well as for the characterization of the complex, non-linear dynamics of neuronal populations.

Computational neuroscience

The group led by Răzvan V. Florian studies learning in spiking neural networks. Dr. Florian has developed several general learning rules for spiking neurons that allow computational neuroscientists to study biologically-relevant spiking neural networks that perform given information processing tasks. The learning rules also allow using spiking neural networks in machine learning applications and shed light on the functioning of the brain.

Dr. Florian has derived analytically a reinforcement learning rule for probabilistic spiking neurons, which resulted in a plasticity mechanism very similar to the spike-timing dependent plasticity (STDP) experimentally-observed in the brain, modulated by the reward signal. Dr. Florian has also shown in computer simulations that the modulation of classical models of STDP by a reward signal leads to reinforcement learning in networks of deterministic spiking neurons. The neuromodulation of spike-timing-dependent plasticity that this work predicted theoretically has been later observed experimentally in the brain.

More recently, dr. Florian has developed two new supervised learning rules for spiking neurons with temporal coding of information, also called chronotrons. One rule is analytically-derived and highly efficient (E-learning), and the other one has a high degree of biological plausibility (I-learning). Both learning rules allow neurons to fire spikes at the desired timings, with sub-millisecond precision. Dr. Florian has showed how chronotrons can learn to classify their inputs, by firing identical, temporally-coded spike trains for different inputs belonging to the same class. When the input is noisy, the classification also leads to noise reduction.

The group has also developed a new class of metrics for spike trains , inspired by the Pompeiu-Hausdorff distance. The new metrics show a higher sensitivity than existing metrics to the precise timings of spikes in the considered spike trains. One of the new metrics, the modulus-metric, does not depend on any parameters and can be computed using a fast algorithm. All these suggest the modulus-metric as a candidate of choice when there is a need of measuring differences between two spike trains.

Nonlinear science

There are many different interactions in nature and systems could evolve according to more than one dynamics for short periods of time. Therefore, it is reasonable to think that the evolution of some natural processes could be explained by the alternation of different dynamics for relatively short periods of time. Marius F. Danca has found that if the control parameter p, of a continuous-time nonlinear system belonging to a large class of systems, is switched within a set of chosen values in a deterministic or even random manner, while the underlying model is numerically integrated, the obtained attractor is a numerical approximation of one of the existing attractors of the considered system. The numerically obtained trajectory is extremely similar to the trajectory obtained for p replaced with the averaged value of the switched parameters. The algorithm could be considered as an excellent alternative for control and anticontrol of chaos for continuous-time systems. Moreover, this kind of attractor synthesis resembles Parrondo's philosophy in a winning game: "losing + losing = winning".

Complex systems

Dumitru Dumitrescu and Ligia C. Chira work at the intersection of artificial intelligence, game theory, and decision theory.

Publications in 2011

O. F. Jurjuţ, D. Nikolic, W. Singer, S. Yu, M. N. Havenith, R. C. Mureşan (2011), Timescales of multineuronal activity patterns reflect temporal structure of visual stimuli. *PLoS One*, 6 (2), e16758.

V. V. Moca, I. Ţincaş, L. Melloni, R. C. Mureşan (2011), Visual exploration and object recognition by lattice deformation. *PLoS One* 6 (7), e22831.

M. F. Danca (2011), Numerical approximation of a class of discontinuous systems of fractional order. *Nonlinear Dynamics*, 66 (1), pp. 133-139.

G. Pastor, M. Romera, A. Orue, A. Martin, M. F. Danca, F. Montoya (2011), Calculation of the structure of a shrub in the Mandelbrot set. *Discrete Dynamics in Nature and Society*, 837262.

M. F. Danca (2011), Approach of a class of discontinuous systems of fractional order: Existence of solutions. *International Journal of Bifurcation and Chaos*, 21 (11), pp. 3273–3276.

M. F. Danca (2011), Synthesizing the Lü attractor by parameter-switching. *International Journal of Bifurcation and Chaos*, 21 (1), pp. 323-331.

M. F. Danca, C. Morel (2011), Attractors synthesis of a class of networks. *Dynamics of Continuous, Discrete & Impulsive Systems, Series B: Applications & Algorithms*, 18, pp. 601-614.

L. C. Cremene, D. Dumitrescu, R. Nagy, M. Cremene (2011), Game theoretic modelling for dynamic spectrum access in TV whitespace. *6th International ICST Conference on Cognitive Radio Oriented Wireless Networks and Communications* - CrownCom 2011, Osaka, Japan.

C. V. Rusu, H. S. Ahn (2011), Optimal network localization by particle swarm optimization. *Proceedings of the 2011 Multi-Conference on Systems and Control*, Denver, CO, USA.

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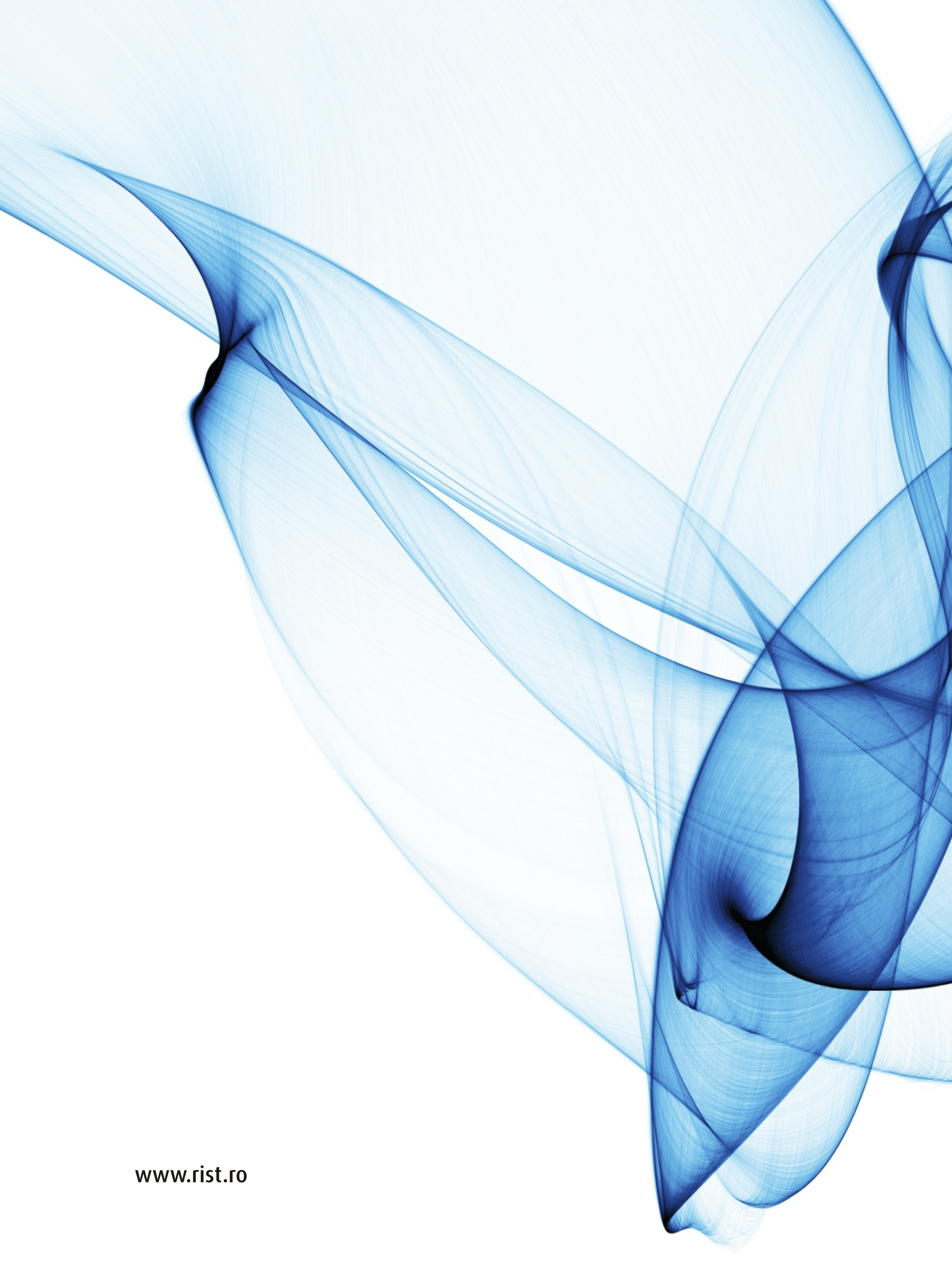

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