Nonlinear Dynamics of Electronic Systems (NDES) 2015

Como, Italy. Sept. 7-11, 2015

Abstract Booklet

Organizers:

Prof. Dr. Guilio Casati, Como
Prof. Dr. Giorgio Mantica, Como
Prof. Dr. Ruedi Stoop, Zurich
Prof. Dr. Sebastiano Stramaglia, Bari

Plenary talks

On global stability of delayed and non-delayed networks

Leonid Bunimovich
Georgia Institute of Technology, Atlanta, USA.

We show that for a large class of time delayed networks their global stability follows from global stability of non-delayed networks. This result is surprising and allows to simplify analysis of dynamics of some time delayed networks.

10:30-11:15, Monday 7 September.

Symmetries, cluster synchronization, and isolated desynchronization in complex networks

Lou Pecora
US Naval Res. Labs, Washington DC, USA.

Many networks are observed to produce patterns of synchronized clusters, but it has been difficult to predict these clusters in general or understand the conditions for their formation. We show the intimate connection between network symmetry and cluster synchronization. We apply computational group theory to reveal the clusters and determine their stability. In complex networks the symmetries can number in the millions, billions, and more. The connection between symmetry and cluster synchronization is experimentally explored using an electro-optic network. We observe and explain a surprising and common phenomenon (isolated desynchronization) in which some clusters lose synchrony while leaving others connected to them synchronized. We show the isolated desynchronization is intimately related to the decomposition of the group of symmetries into subgroups. The results could guide the design of new power grid systems or lead to new understanding of the dynamical behavior of networks ranging from neural to social.

11:45-12:30, Monday 7 September.

Chemobrionics: Nonlinear dynamics, electronic systems, and the origin of life

Julyan Cartwright
University of Granada, Spain

Chemical gardens are perhaps the best example in chemistry of a self-organizing nonequilibrium process that creates complex structures. Many different chemical systems and materials can form these self-assembling structures, which span at least eight orders of magnitude in size, from nanometers to meters. Key to this magic is the self-propagation under fluid advection of reaction zones forming semipermeable precipitation membranes that maintain steep concentration gradients, with osmosis and buoyancy as the driving forces for fluid flow. Chemical gardens have been studied from the alchemists onwards, but now in the 21st century we are beginning to understand how they can lead us to a new domain of self-organized structures of semipermeable membranes and amorphous as well as polycrystalline solids produced at the interface of chemistry, fluid dynamics, and materials science. We propose to call this emerging field chemobrionics.

14:00-14:45, Monday 7 September.

Dynamics of buoyancy-driven flows in the Earth's subsurface and in the ocean

Silvana Cardoso
Dept. of Chem. Eng. and Biotechnology, University of Cambridge, UK.

Chemical and physical disequilibrium in the ocean, atmosphere and in the Earth's subsurface can lead to gigantic convective flows of methane and carbon dioxide. Examples in the atmosphere and oceans include the turbulent plumes formed during the Icelandic volcanic eruption (2010), the BP oil spill in the Gulf of Mexico (2010), and the large number of methane plumes found recently in the Arctic Sea (2013). In the sub-surface, when carbon dioxide dissolves in the water contained in the porous rock, the heavy CO2-rich fluid sinks driving vigorous laminar convection. A further example is the flow of dissolved methane under osmotic forces in the porous rock near mud volcanoes on the seabed. In this talk, we focus on the non-linear interaction between hydrodynamics and chemistry, including chemical reaction or dissolution/precipitation, in such flows. Using complementary theoretical, numerical and experimental approaches, we quantify the spatiotemporal development of the flow pattern caused by ongoing chemical processes and mixing in the fluids.

14:50-15:35, Monday 7 September.

Network physiology: How complex physiologic organ systems dynamically interact

Plamen Ch. Ivanov
Physics Department, Boston University and Division of Sleep Medicine, Harvard Medical School, USA.

The human organism is an integrated network where multi-component organ systems, each with its own regulatory mechanisms, continuously interact to optimize and coordinate their function. Organ-to-organ interactions occur at multiple levels and spatiotemporal time scales to produce distinct physiologic states: wake and sleep; light and deep sleep; consciousness and unconsciousness. Disrupting organ communications can lead to dysfunction of individual systems or to collapse of the entire organism. Yet, we know almost nothing about the nature of the interactions between diverse organ systems and their collective role in maintaining health. We propose a framework to probe dynamical interactions among physiological systems, and we identify a physiological network. We find that each physiological state is characterized by a specific network structure, demonstrating a robust interplay between network topology and physiologic function. Across physiological states, the network undergoes topological transitions associated with fast reorganization of physiological interactions on time scales of a few minutes, indicating high network flexibility in response to perturbations. The proposed system-wide integrative approach facilitates the development of a new field, Network Physiology.

9:00-9:45, Tuesday 8 September.

Rayleigh-Benard instability in curved elastic bilayer systems: Wrinkles, dimples, and the early universe

Norbert Stoop
Department of Mathematics, MIT, Cambdrige MA, USA.

Wrinkling in curved bilayer surfaces is a ubiquitous phenomenon, occuring, for instance, in embryogenesis, biological tissue differentiation or structure formation in heterogenous thin films. Due to the curved substrate and the strong nonlinearities in the elastic strains, predictions for the wrinkling morphology are notoriously difficult to obtain using classical analysis. Here, we choose a different approach and derive a generalized Swift-Hohenberg theory to describe wrinkling morphologies and their pattern selection. Testing the theory against experiments on spherically shaped surfaces, we find quantitative agreement with analytical predictions for the phase transition curves separating labyrinth, hybrid and hexagonal wrinkling phases. As our approach builds on general differential-geometric properties, it can be extended to arbitrary surfaces. To demonstrate the general approach, we apply our wrinkling theory to toroidal geometries in the hexagonal wrinkling phase as a generic means to study defect formation.

9:50-10:35, Tuesday 8 September.

Chaos in optimal communication waveforms

Ned Corron
U.S. Army Redstone Arsenal, AL, USA.

Modern communication technology is built upon the foundation established by Nyquist, Shannon, Wiener and others in the 1940s, whose theories enabled the rigorous derivation of optimal solutions to practical communication problems. In this talk, we apply the methods of communication theory to derive optimal waveforms for transmitting information through noise using very simple filters as receivers. Specifically we presume passive, linear RLC filters and derive the communication waveforms that maximize the receiver signal-to-noise performance. From routine application of standard methods, we surprisingly find that the optimal communication waveforms are provably chaotic. We extrapolate from simple examples to argue that the optimal communication waveform for any stable infinite impulse response filter is similarly chaotic. If true, this conjecture implies the phenomena of nonlinear dynamics and chaos are fundamental and essential to full understanding of modern communication theory.

14:00-14:45, Tuesday 8 September.

Hierarchical block matrices as looking glasses for multi scale biology

Pietro Lio'
Dept. of Computer Science, University of Cambridge, UK.

In this talk I will discuss the utility of hierarchical block matrices for calibrating multi omics data and to analyse multi scale biological systems from chromosome dynamics to tissue dynamics.

14:50-15:35, Tuesday 8 September.

Correlations in the brain

Lucilla de Arcangelis
Seconda Università di Napoli, Italy.

Neuronal avalanches are a novel mode of spontaneous brain activity, experimentally found in vitro and in vivo, which exhibits a robust critical behaviour. The temporal organization of neuronal avalanches can be characterized by the distribution of waiting times between successive events. Experimental measurements in the rat cortex in vitro exhibit a non-monotonic behavior, not usually found in other natural processes. Numerical simulations provide evidence that this behavior is a consequence of the alternation between states of high and low activity, leading to a dynamic balance between excitation and inhibition. During these different states, both the single neuron behaviour and the network excitability level, keeping memory of past activity, are tuned by homeostatic mechanisms. This behavior has been verified on a larger scale, i.e., on fMRI data from resting patients. By monitoring temporal correlations in high amplitude BOLD signal, we find that the activity variations with opposite sign are correlated over a temporal scale of few seconds, suggesting a critical balance between activity excitation and depression in the brain.

9:00-9:45, Wednesday 9 September.

Conserved Ising model on the human connectome

Daniele Marinazzo
Gent University, Belgium.

A crucial issue interesting experimental and computational neuroscientists is the link between brain structure and function. A typical approach to address this problem consists in implementing a dynamical model on the known structural architecture of the brain and observing the resulting emerging dynamics. Several families of dynamical models have been used to this purpose, ranging from the most abstract ones to highly biologically motivated compartmental models. All these classes of models were somehow able to reproduce the typical patterns of functional connectivity (statistical dependencies between time series at the different brain locations) observed in real data, characterized by long-range correlations. The common characteristic of the models behind this result is the metastability (or criticality, or balanced state): these correlations arise when the links are not too strong nor to weak, and the individual systems somehow excitable, but not too much. A characteristic which is rarely reproduced in these general models is the presence of negative correlations. In this study we hypothesize that these negative correlations are a direct consequence of a conservation law, and we show this by implementing an Ising spin model with conserved magnetization (Kawasaki dynamics) on the brain structural architecture. In this way we observe patterns of long range correlations, both positive and negative, in networks with rough and fine spatial resolution.

9:50-10:35, Wednesday 9 September.

Spatiotemporal dynamics of neuron activity in brain microcircuits

Egidio D'Angelo
Dip. Scienze del sistema nervoso, Università di Pavia, Italy.

I will present a realistic computational model of the cerebellar granular layer to explain how it can transform incoming mossy fiber signals into new spike patterns to be related to Purkinje cells. This model is used to address four main functional hypotheses: center-surround organization, time-windowing, high-pass filtering in responses to spike bursts and coherent oscillations in response to diffuse random activity. The model network was activated using patterns inspired by those recorded in vivo. Burst stimulation of a small mossy fiber bundle resulted in granule cell bursts delimited in time (time windowing) and space (center-surround) by network inhibition. This burst-burst transmission showed marked frequency-dependence configuring a high-pass filter with cut-off frequency around 100 Hz. The contrast between center and surround properties was regulated by the excitatory-inhibitory balance. The stronger excitation made the center more responsive to 10-50 Hz input frequencies and enhanced the granule cell output (with spike occurring earlier and with higher frequency and number) compared to the surround. Finally, over a certain level of mossy fiber background activity, the circuit generated coherent oscillations in the theta-frequency band. All these processes were fine-tuned by NMDA and GABA-A receptor activation and neurotransmitter vesicle cycling in the cerebellar glomeruli. This model shows that available knowledge on cellular mechanisms is sufficient to unify the main functional hypotheses on the cerebellum granular layer and suggests that this network can behave as an adaptable spatio-temporal filter coordinated by theta-frequency oscillations.

14:00-14:45, Wednesday 9 September.

Rolling and synchronization in dense packings of spheres

Hans Herrmann
Computational Physics, ETH Zurich, Switzerland.

A large family of packing topologies allows for slip-less rotations between space-filling touching disks or spheres and thus form systems of bearings. I will discuss their construction and their fractal dimensions. Bearings are mechanical dissipative systems that, when perturbed, relax toward a synchronized (bearing) state. In fact bearings can be perceived as physical realizations of complex networks of oscillators with asymmetrically weighted couplings. Accordingly, these networks can exhibit optimal synchronization properties tuning of the local interaction strength as a function of node degree. I show that, in analogy, the synchronizability of bearings can be maximized by counterbalancing the number of contacts and the inertia of their constituting rotor disks through a power-law mass-radius relation with an optimal exponent alpha. Under this condition, and regardless of the presence of a long-tailed distribution of disk radii composing the mechanical system, the average participation per disk is maximized and the energy dissipation rate is homogeneously distributed among elementary rotors. The synchronization of rotations occurs in avalanches following a broad size distribution. The bearing configurations fulfill Kolmogoroff scaling and display Richardson's diffusion law in the limit of small Stokes numbers and constitute also an interesting toy model for turbulence. In two dimensions there exist many space-filling solutions of different topologies classified by three integers, while in three dimensions up to now we only know one topology, but which has a many bearing states classified by four real positive numbers.

14:50-15:35, Wednesday 9 September.

Treating many-body quantum systems by means of classical mechanics

Andrey Kolovsky
L.V. Kirensky Institute of Physics, Siberian Branch of Russian Academy of Sciences, Russia.

Many-body physics of identical particles is commonly believed to be a sovereign territory of Quantum Mechanics. The aim of this talk is to show that it is actually not the case and one gets useful insights into a quantum many-body system by using the theory of nonlinear dynamical systems. In the talk we focus on one paradigmatic model of many-body quantum physics - the Bose-Hubbard model, which, in particular, describes interacting ultracold Bose atoms in an optical lattice. After a preliminary, purely quantum analysis of the system we introduce a classical counterpart of the Bose-Hubbard model and its governing equations of motion. We analyze these equations for the problem of Bloch oscillations of cold atoms where a number of experimental results are available. We compare the results obtained by using pure classical arguments with those obtained quantum-mechanically, and with those observed in the laboratory experiment.

9:00-9:45, Thursday 10 September.

Exploring topological and magnetic order with ultracold fermions in optical lattices

Gregor Jotzu
Institute for Quantum Electronics, ETH Zurich, Switzerland.

Complex quantum many-body systems are ubiquitous in nature, yet their behaviour often remains very challenging to predict with analytical or numerical calculations - especially when it comes to dynamics. However, using ultracold atoms in optical lattices it is possible to create precisely tunable, yet very accessible complex systems, which can be probed with a variety of observables. Using this experimental set-up, we demonstrate how a periodically modulated system can be described by an effective Floquet-Hamiltonian on longer time-scales - even when driving the system far from equilibrium. This allows for implementing Haldane's model for a topological insulator by applying an oscillating force to a honeycomb lattice. A transverse drift arising from a non-zero Berry curvature, as well as a closing band-gap at the transition between two topological regimes, are observed. Furthermore we present the dynamics of anti-ferromagnetic correlations in the Hubbard model. Starting from a situation where short-range correlations are present, we deform the lattice geometry, on time-scales ranging from the sudden to the adiabatic regime. We then study how correlations re-arrange as a function of time.

9:50-10:35, Thursday 10 September.

Explosive synchronization of networked oscillators

Stefano Boccaletti
ISC CNR Firenze, Italy.

Recently, it was pointed out that, for an ensemble of networked phase oscillators, the transition from incoherence to synchronization can be first-order like, discontinuous and irreversible, called explosive synchronization (ES). Since its finding in 2005, ES has been paid a great attention, as abrupt transitions in real world networks include epileptic seizures in the brain, cascading failure of power grids and jamming in the Internet. For instance, ES was studied in the context of periodic phase oscillators for scale-free (SF) networks, with an ad-hoc imposed positive correlation between the natural frequencies of the oscillators and the degrees of the nodes, and the experimental verification was given with electronic circuits. Later on, ES was described for generic network's topologies (either SF or non-SF) in a modified Kuramoto model, with a positive correlation between the natural frequencies of oscillators and their coupling strengths. The accepted state of knowledge on this matter is that ES has a basic microscopic root in the frustration of the path leading the system to synchronize. I my talk, I will discuss all different methods to induce ES in a generic network, and highlight the microscopic mechanisms that are at the basis of its emergence and generality.

14:00-14:45, Thursday 10 September.

Nonlinear systems characterization using phase space density

Thomas L. Carroll
US Naval Res. Labs, Washington DC, USA.

In the early days of nonlinear dynamics, density base measures such as fractal and multifractal dimensions were used to characterize attractors from nonlinear systems. While measures based on derivatives have become more popular recently, density is still a useful way to characterize attractors. In this work, a simple experiment consisting of a pair of operational amplifiers is driven with a chaotically modulated signal. The output signal is embedded in phase space and characterized by its density. Although op amps are usually considered to be linear devices, comparing densities as the op amp gain increases reveals the nonlinear gain of the amplifier. Clustering analysis shows that amplifiers tend to cluster by gain level, not by the individual amplifier, suggesting that the nonlinearities in different amplifiers are similar. It is also noted for system characterization that a chaotically modulated signal works better than a randomly modulated signal.

17:50-18:35, Thursday 10 September.

Monday 7 September 16:10-17:50

Room 1: Control

Stabilization of hyperbolic Plykin attractor by the Pyragas method

Sergey Belyakin[a], Arsen Dzhanoev[a] and Sergey Kuznetsov[b]

In the present contribution consideration is being given to an autonomous physical system which is characterized by the presence of the attractor of a hyperbolic type. We study the possibility of controlling and stabilizing the Plykin attractor of this type by the Pyragas method. The choice of the method of control. As such it is possible to use an external signal or the introduction of additional delayed feedback. (Both methods can be realized primarily during the schematic simulation then in a real experiment). It might also be interesting to think about the realization of a more complicated scheme of control of the type suggested in the work for the stabilization of unstable periodic orbits belonging to the attractor.

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Method of generalized synchronization detection without using an auxiliary system approach

Vladimir Ponomarenko[a] and Mikhail Prokhorov[a]

Designing and development of methods for detecting generalized synchronization is an actual problem of modern nonlinear dynamics [1-2]. The criterion for establishing the generalized synchronization is the presence of a functional relationship between the states of unidirectionally coupled dynamical systems [1]. Different methods have been proposed to detect the regime of generalized synchronization. The most popular among them are the auxiliary system approach [3], the conditional Lyapunov exponent calculation [4], and the nearest neighbor method [5].

The most suitable method for detecting the generalized synchronization in a physical experiment is the method of the auxiliary system. However, its major drawback is the necessity to implement two identical generators, the response system and auxiliary system. In this paper, we propose a new method of generalized synchronization which exploits the idea of auxiliary system approach, but utilizes only one response system which is driven in turn by the transmitted signal itself and its delayed copy. If we drive the self-oscillating response system twice with the same input signal from the autonomous drive system, then after the transient process it will exhibit identical oscillations in both cases in the presence of the generalized synchronization between the drive and response systems.

In this paper, the efficiency of the proposed method is demonstrated in a numerical experiment for unidirectionally coupled time-delay systems. At first, within the time interval τ we drive the response system in the receiver with the signal of the drive system. Then, within the same time interval τ we drive the same response system with the delayed signal incoming from the output of the delay line having the delay time τ. At last, we compare the signals of the response system in the considered two cases. With this purpose we calculate the difference between the signal at the response system output and the signal of the response system which is passed through one more delay line with the delay time τ. In the presence of the generalized synchronization, this difference vanishes after the transient process.

It is shown that the proposed method allows one to detect the presence of generalized synchronization even in the presence of very high levels of noise comparable to the amplitude of the drive signal. The method is promising for constructing a secure communication system with high tolerance to noise in a communication channel.

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[2] L. M. Pecora, T. L. Carroll, "Synchronization in chaotic systems," *Phys. Rev. Lett.*, vol.64, pp.821–824, 1990.
[3] H. D. I. Abarbanel, N. F. Rulkov, M. M. Sushchik, "Generalized synchronization of chaos: The auxiliary system approach," *Phys. Rev. E*, vol.53, pp.4528–4535, 1996.
[4] L. M. Pecora, T. L. Carroll, J. F. Heagy "Statistics for mathematical properties of maps between time series embeddings," Phys. Rev. E, vol. 52, pp.3420-3439, 1995.
[5] K. Pyragas, "Conditional Lyapunov exponents from time series," *Phys. Rev. E*, vol.56, pp. 5183–5188, 1997.

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Non-identical chaos anti-synchronization via passive control

Uğur Erkin Kocamaz[a], Yılmaz Uyaroğlu[b], Mustafa Urin[c] and Tuğrul Taşcı[d]

This paper investigates the anti-synchronization of non-identical chaotic systems by means of passive control technique. Based on the property of passivity theory, the passive controllers are constructed for the anti-synchronization between Lorenz and Liu chaotic systems. Lyapunov function is used to realize that the passive controllers ensure the global asymptotic stability of error system. Numerical simulations are performed to demonstrate the efficiency of the proposed non-identical anti-synchronization strategy.

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Controlling chaotic permanent magnet synchronous motor with a single state speed feedback controller

Uğur Erkin Kocamaz[a] and Yılmaz Uyaroğlu[b]

This study investigates the control of chaotic permanent magnet synchronous motor with a single state speed feedback controller. Time series and phase por-traits of chaotic permanent magnet synchronous motor are presented graphically from its differential equations. The sufficient conditions for the speed feedback control gains are obtained by the Routh-Hurwitz criterions. Numerical simulations are demonstrated to validate the feasibility of the proposed method. Simulation results have also shown that the controlled permanent magnet synchronous motor system effectively stabilizes towards its non-zero equilibrium points in the state space.

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Monday 7 September 16:10-17:50

Room 2: Synchronization

Chaos synchronization between finance and Rikitake systems by active control with unknown parameters

Uğur Erkin Kocamaz[a], Gültekin Çağıl[b], Yılmaz Uyaroğlu[c] and Zeynep Çağıl[b]

The aim of this research is to investigate the non-identical synchronization of a chaotic finance system. Once the chaotic finance system is synchronized to the widely-used Rikitake chaotic system, all the theories and applications based on the Rikitake chaotic system such as control can be applied for the finance system. Active controllers are designed for the synchronization of chaotic finance system to Rikitake chaotic system with unknown parameters. The asymptotical stability of synchronization errors is ensured based on the properties of Lyapunov theory. Numerical simulations are demonstrated to validate the theoretical analyses. They have also shown that these chaotic systems can be synchronized in a proper amount of time with the active controllers, which verifies the efficiency of proposed chaos synchronization technique.

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Synchronization of chaotic three time scales brushless DC motor system by means of one state passive controller

Yılmaz Uyaroğlu[a], Uğur Erkin Kocamaz[b] and Barış Cevher[a]

This study investigates the synchronization of two identical chaotic three time scales Brushless DC Motor (BLDCM) systems with the passive control method. The three time scales BLDCM system is described briefly from its differential equations, time series and phase space portraits are given graphically. Based on passive control theory, a Lyapunov function is used to ensure the asymptotic stability of error system. Numerical simulations are presented to validate the feasibility of the proposed method. The simulation results are satisfied in view of achieving the synchronization of all states using only one state controller.

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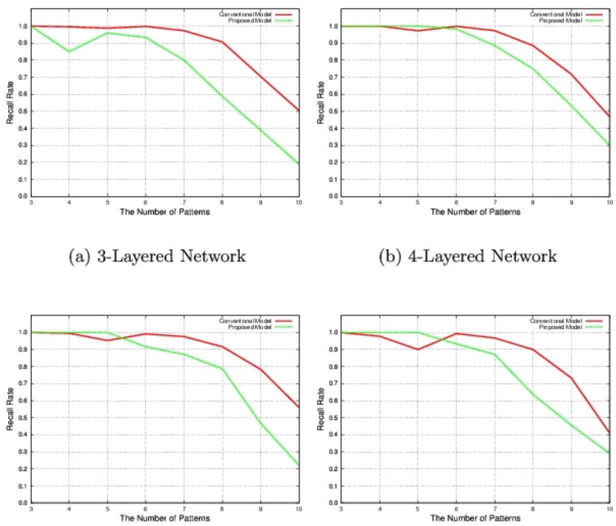
Chaotic quaternionic multidirectional associative memory with adaptive scaling factor of refractoriness

Ryohei Ito[a] and Yuko Osana[a]

The association ability of associative memories composed of chaotic neuron models or chaotic neuron-based models such as chaotic complex-valued neuron model and chaotic quaternionic neuron model are very sensitive to chaotic neuron parameters such as scaling factor of refractoriness α, damping factor k and so on. And, in these models, appropriate parameters have to determined by trial and error. In this research, we propose a Chaotic Quaternionic Multidirectional Associative Memory with adaptive scaling factor of refractoriness which can realize one-to-many associations

of multi-valued patterns and whose parameters can be determined automatically.

The proposed Chaotic Quaternionic Multidirectional Associative Memory with adaptive scaling factor of refractoriness has three or more layers as similar as the conventional Chaotic Quaternionic Multidirectional Associative Memory [1]. Each layer consists of two parts; (1) Key Input Part composed of quaternionic neuron models [2] and (2) Context Part composed of chaotic quaternionic neuron models [3]. Since chaotic quaternionic neuron models in the Context Part change their states by chaos, plural multi-valued patterns corresponding to the input common term can be recalled, that is, one-to-many association can be realized. In the conventional Chaotic Quaternionic Multidirectional Associative Memory, scaling factor of refractoriness α is tuned manually. In the proposed model, scaling factor of refractoriness α varies depending on time and average internal states of neurons.



(a) 3-Layered Network

(b) 4-Layered Network

Fig. 1: One-to-Many Association Ability.

We compared the one-to-many association ability in the 3∼6-layered proposed model with the well-turned 3∼6-layered conventional Chaotic Quaternionic Multidirectional Associative Memory with variable scaling factor of refractoriness (Conventional Model). Figure 1 shows the one-to-many association ability of the proposed model and the conventional model. As shown in this figure, the one-to-many association ability of the proposed model almost equals to that of the conventional model. We also examined the one-to-many association ability of the various size proposed model and confirmed that the proposed model in various size has good one-to-many association ability as similar as in the result shown in Fig. 1.

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[3] Y. Osana: "Chaotic quaternionic associative memory", Proceedings of IEEE and INNS International Joint Conference on Neural Networks, Brisbane, 2012.

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Explosive synchronization in complex network

Xiyun Zhang[a]

Recently, discontinuous synchronization transition called explosive synchronization has become a hot topic. In my poster, I will introduce our work on explosive synchronization, including 3 parts: 1) A weighted model which can generate explosive synchronization in complex network with different degree distribution and different frequency distribution of nodes, 2) The suppressive rule in explosive synchronization. Meanwhile, on microscope, explosive synchronization can be regarded as explosive percolation in dynamical space, 3) Explosive synchronization in adaptive and multilayer networks. In this part, a model with no correlation between frequency and coupling strength is introduced.

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Tuesday 8 September 11:10-12:25

Room 1: Networks and Applications

Mechanisms of complex pattern formation in chemical systems

Andrey A. Polezhaev[a]

Spatial-temporal self-organization has long been the subject of both experimental and theoretical investigations. So far, not only autowaves and dissipative structures are discovered but such new types of patterns as antispirals, wave packets, segmented waves, oscillons - localized oscillating spots and others. All this variety of patterns were observed in particular in Belousov-Zhabotinsky reaction proceeding in microemulsion (BZ-AOT system). Mechanisms of formation of some of these patterns are quite clear but others need explanation. Now it is common knowledge that diffusion can cause instability of the uniform state in a spatially distributed system. It was first demonstrated by Turing in his classical paper, published in 1952. Turing instability is the reason for formation of non-uniform stationary patterns ("dissipative structures") which can be obtained in relatively simple two component models of the "reaction-diffusion" type. In the present talk I will show that other experimentally observed patterns need for their explanation more complex models containing at least three or even four equations. The reason is that in these patterns either wave instability is involved, which needs at least a three-variable model, or they are the consequence of interaction of several instabilities, each of which being described by a corresponding sub-model. It will be demonstrated that some complex patterns, such as segmental waves and oscillons, for instance, can be explained in the frame of four-component reaction-diffusion models consisting of two interacting two-variable sub-models.

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Hebbian learning clustering using networks of Rulkov neurons

Jenny Held[a] and Ruedi Stoop[a]

The ability to group data items into clusters based on similarity is essential for the analysis of the structure of a system. Despite decades of development, clustering of big data sets and real-time clustering remain a challenge. Biology-inspired approaches using local learning among neurons, such as the Integrate-and-Fire Hebbian Learning Clustering (HLC), have been shown to be well suited for tackling intrinsic clustering problems, but in past implementations required large computation times. Here, we propose a clustering algorithm that is based on pair-wise interactions in a network of Rulkov neurons. Hebbian learning is used to favour the potentiation of intra-cluster synaptic connections and the depression of extra-cluster connections, so that clusters emerge as groups of strongly coupled, synchronised neurons. The discrete time Rulkov neuron dynamics overcome time complexity limitations of former (time continuous) implementations. The algorithm is able to find a natural, system-dependent number of clusters of arbitrary shape in an unsupervised way, even in the presence of background noise data. We present several data sets and compare the clustering results to those of standard algorithms. We outperform traditional algorithms such as k-means and Ward's clustering by far in terms of quality. We also produce clustering results of at least equal and often higher quality than previous HLC implementations, with computation times reduced by two orders of magnitude.

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Saturation effect produces deviations from power law statistics in real-world networks

Tom Lorimer[a], Florian Gomez[a] and Ruedi Stoop[a]

The distribution of node degree in complex real-world networks has often been claimed to follow a power law, the origin of which is generally attributed to the fundamental principle of preferential attachment. In all real-world networks however, a perfect power law is not observed, and is instead often terminated by a hump at high node degree. Imperfections of this sort have previously been explained away as finite size effects by reference to the thermodynamic limit. We show, however, that such humps arise as the result of a second fundamental principle active during network growth: saturation. We introduce a simple network growth algorithm which exemplifies these two fundamental principles, and reproduces the observed power law deviations. Through a semi-analytic treatment, we demonstrate that the origin of the hump may be understood in terms of a mean-field 'failure function' which expresses the edge-saturation of the nodes in the network. Numerical investigation of this function reveals remarkable scaling properties, and it is approximated as a double power law function of network size. Applying this approximation in a conventional node degree rate equation reproduces the growth behaviour of the algorithm, and demonstrates the link between saturation and the formation of the hump. We calculate a phase diagram of the hump size and power law exponent as a function of our algorithm parameters, which suggests a new window into the understanding of meso-scale network structures and processes from modelling the power law deviations of network statistics.

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Tuesday 8 September 11:10-12:25

Room 2: Stochastic Systems

Bayesian parameter inference for stochastic differential equation models

Carlo Albert[a]

Bayesian parameter inference for stochastic differential equation models is a computationally hard problem as the density of the posterior parameter distribution is given by a path-integral. We rephrase this Bayesian inference problem as the problem of simulating the dynamics of a linear polymer with harmonic bonds in an external potential, and with model parameters representing degrees of freedom that couple to all other system coordinates. Depending on the number of measurement points and the number of discretization points the dynamics of the system happens on very different time-scales. Using a suitable parameterization the fastest dynamics reduces to the dynamics

of uncoupled standard harmonic oscillators and can be disentangled from the slower dynamics by means of a Trotter formula. The resulting algorithm is highly parallelizable, very fast, and, employing automated differentiation techniques, readily applicable to a wide range of inference problems.

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Conditions for persistence of stochastic processes

Raffaello Seri[a]

Consider a $K-$dimensional stochastic process $\{\mathbf{X}_t\}_{t\in\mathbb{Z}}$ describing a physical, chemical or biological system with nonnegative components such that 0 is an absorbing state for each component. Leading examples concern ecosystems, with each component describing the abundance of a species, or chemical systems, in which each component describes the amount of a reagent. In the ecosystem example, reaching the value 0 corresponds to extinction of the species. The absorption condition, i.e. the fact that when a component reaches the value 0 it will take on that value thereafter, means that no recovery is possible from extinction. We suppose that the stochastic process can be described by an Iterated Function System (IFS); this is equivalent to the requirement that the stochastic process is first-order Markovian. We then describe a condition, called "stochastic boundedness," first introduced by P.L. Chesson, that guarantees that no component of the system is absorbed by 0. We provide a sufficient condition for stochastic boundedness involving the functions describing the IFS. As this sufficient condition is quite difficult to check, we provide a statistical procedure based on sampling from the IFS to test for it.

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Detecting influences - a network analysis of the European bond market based on partial mutual information

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The need for an analysis of supposed dependencies between variables or processes arises in many areas of scientific investigation. Typically, the correlation structure of the differenced time series generated by the underlying processes is studied, i.e., the structure arrived at by computing pair-wisely the Pearson correlation coefficients. Often, one is particularly interested in temporal changes of this correlation structure which may point to structural breaks. As the correlation coefficient is a symmetric measure, such an analysis does however not reveal the influences that bring out these correlations, i.e., whether a correlation is due to some direct influence between variables or rather due to the influence of some other variable. One way to deal with this issue is to consider the partial correlation coefficient which allows to separate different possible influences. Based on the partial correlation measure, one may then derive some measure of influence that allows to set up and analyse a network depicting the directed influences between variables, see e.g. Schwendner et al. [1]. This approach raises however the following difficulties: First, the Pearson correlation coeffcient only detects a possible linear dependence between variables and, second, in order to avoid spurious correlations, the differenced time series data is assumed to be stationary. In response to this, we propose in this contribution to detect influences of variables by using an influence measure based on the mutual information and the partial mutual information measure [2]. The mutual information measure can also detect nonlinear statistical dependencies between processes and, while the involved stochastic processes are usually assumed to be stationary, information theory may provide ways to deal also with the nonstationary case. Partial mutual information is then postulated in analogy to partial correlation and allows to separate different indirect and direct influences of variables. Based on partial mutual information, we further postulate a measure of influence that allows to set up a network of directed influences, generalized to the nonlinear and possibly nonstationary case. We illustrate this fairly general method by applying it to financial market data, namely the movements of European government bond yields in the period 1990-2015. An analysis of the correlation and influence structure of the data has been carried out in [1], which further allows to compare and discuss benefits and pitfalls of the two approaches.

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Tuesday 8 September 16:10-17:50

Room 1: Networks and Applications

Analysis of digital maps based on simple feature quantities

Hiroyuki Kusano[a], *Hiroki Yamaoka*[a] *and Toshimichi Saito*[a]

The digital map (Dmap) is digital dynamical system defined on a set of lattice point [1]. Since the number of the lattice point is finite, the steady state is a periodic orbit (PEO). Although analog one-dimensional maps (e.g., the logistic map) can generate chaos, the Dmap can generate various PEOs. The Dmaps are related to various systems such as cellular automata, digital spiking neurons, dynamic binary neural networks, and logical/sequential circuits ([1], [2], and references therein). Such digital systems have been applied to various engineering systems. Analysis of the Dmaps is important not only as a basic study but also for engineering applications. The Dmap is described by $\theta_{n+1} = F_D(\theta_n)$, $\theta_n \in L_N \equiv \{l_1, l_2, ..., l_N\}$, where L_N is a set of N lattice points l_1 to l_N. Figure 1 illustrates the Dmap where several PEOs co-exist. Depending on initial condition and parameters, the Dmap exhibits either PEO. In general, the Dmap can have a variety of PEOs and transient phenomena. In order to analyze of Dmap, we introduce two feature quantities. The first quantity α represents plentifulness of the steady states. The second quantity β represents deviation of transient phenomena to steady states. One Dmap corresponds to one point on the α vs β plane on which we can classify/consider the dynamics. There exist many examples of the Dmaps and their general consideration is extremely hard. For simplicity, we consider one example: the digital tent map given by discretizing the tent map on the set of lattice points. Using the feature quantities, we have given basic classifications.

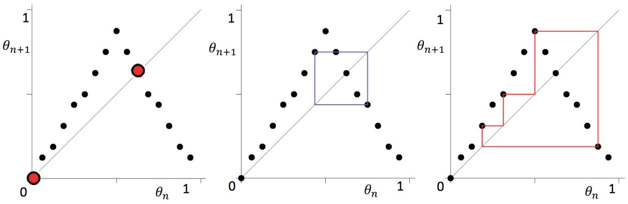

Fig. 1: Digital tent map. Left to right: Fixed points; PEO with period 2; PEO with period 4.

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New tools to determine the optimal embedding of a time series

Leonardo Ricci[a], *Davide Tabarelli*[a] *and Matteo Franchi*[a]

According to the Takens-Mane embedding theorem, embedding makes up a basic tool to analyze a time series and thus investigate the dynamical properties of the underlying chaotic system. Unfortunately the embedding theorem provides no clues on how to choose the embedding dimension m and the embedding lag L. Although in the last two decades several methods have been devised to tackle this crucial issue, a conclusive criterion to make the most appropriate choice is still lacking. We present a new approach that relies on the analysis of the statistical properties of the uncertainty of the maximum Lyapunov exponent (MLE), calculated via the divergence rate method on finite-time sequences [1]. Using chaotic systems with explicit analytic representation that are widely used as references in the scientific literature we show that 'good' embedding pairs (m, L) tend to form Gaussian-like clusterings of the uncertainty. This property can be used also in the reverse way: embedding pairs that form quasi-normally distributed clusterings of the MLE uncertainty are to correspond to optimal embedding choices. The method complies with the theory of the statistical properties of the finite-time MLE first discussed by Grassberger, Badii and Politi [2]. A second aspect regards the investigation of how the MLE uncertainty scales with the sampling frequency: the theory [2] predicts a power law scaling with typical exponents (for example, -0.5 in the case of continuous systems with short correlation times). We discuss how this scaling can be exploited to provide an additional tool to identify optimal embedding parameters, and in particular the lag L. Finally, we present preliminary results concerning the application of these methods to the analysis of time series generated by synthetic chaotic and noisy systems and to electroencephalografic recordings.

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Hyperchaos and synchronization in paralleled power converters

Yasuo Murata[a] *and Toshimichi Saito*[a]

The paralleled systems of switching power converters have been studied from fundamental and application viewpoints. In the fundamental study, the paralleled systems are interesting examples of switched dynamical systems that can exhibit a variety of nonlinear phenomena [1,2]. In the applications, the paralleled systems can realize current sharing and ripple reduction which are effective in robust and reliable power management [2,3]. In these studies, analysis of nonlinear phenomena is important and single power converters have been studied sufficiently [2]. However, the analysis of the paralleled systems is not easy because they are higher dimensional systems with various complex behavior. This paper studies hyperchaos and related bifurcation phenomena in the paralleled boost converters (PBC). Figure 1 (a) shows a circuit model of the PBC. In the circuit, the input current iin is shared by the two boost converters and the input current sharing is basic for efficient power extraction. Each converter includes the switch Si and the diode D_i ($i = 1, 2$) which can be either State A (S_i conducting and D_i blocking, x_i rises) or State B (S_i blocking and D_i conducting, x_i decays). We assume that the output voltage regulation is achieved and the output load is replaced with constant voltage sources V_{o1} and V_{o2}. Applying a current-mode switching rule, the dynamics is described by the following equation

$$\frac{dx_1}{dt} = \begin{cases} -\gamma x_1 + a & \text{for State A} \\ -\gamma x_1 - b_1 & \text{for State B,} \end{cases}$$

$$\text{SW rule} \begin{cases} \text{State A} \to \text{State B if } x_1 > x_2 \text{ at } t = nT \\ \text{State B} \to \text{State A if } x_1 = X_-, \end{cases}$$

$$\frac{dx_2}{dt} = \begin{cases} -\gamma x_2 + a & \text{for State A} \\ -\gamma x_2 - b_2 & \text{for State B,} \end{cases}$$

$$\text{SW rule} \begin{cases} \text{State A} \to \text{State B if } x_2 > x_1 \text{ at } t = nT \\ \text{State B} \to \text{State A if } x_2 = X_-, \end{cases}$$

where x_i is proportional to i_i ($i = 1, 2$) and X_- is the lower threshold. The PBC has clock signal with period T. The dimensionless parameters γ, a, b_1, and b_2 are proportional to $1/L$, V_{in}, V_{o1}, and V_{o2}, respectively. Since this system is piecewise linear, the dynamics can be analyzed precisely. Figure 1 (b) shows inverse-phase synchronization that is suitable for current sharing and ripple reduction. Figure 1 (c) shows hyperchaos where the orbit is expanding in two directions (x_1 and x_2). As parameters vary, the PBC exhibit complicated bifurcation phenomena between the inverse-phase synchronization and hyperchaos. The bifurcation phenomena are investigated on b_1 versus b_2 plane. Presenting a simple test circuit, typical phenomena are confirmed experimentally.

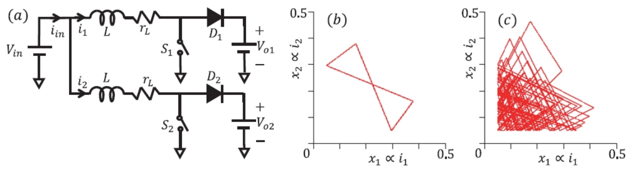

Fig. 1: Paralleled Boost Converters. (a) Circuit model. (b) Inverse-phase synchronization for $b_1 = b_2 = 0.5$, $\gamma = 1 = 0.3$, and $X_- = 0.05$. (c) Hyperchaos for $b_1 = b_2 = 0.05$, $\gamma = a = 0.3$, and $X_- = 0.05$.

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Simulating neural oscillations with map-based neurons

Karlis Kanders[a] and Ruedi Stoop[a]

Oscillations are a salient phenomenon in the nervous system spanning a large range of scale from single tonically spiking cells to ensembles of thousands of synchronized neurons. In order to simulate oscillatory behavior on the network scale relevant to the brain, one needs biologically plausible neuron models and the computational power to simulate networks with a large number of such neurons. To satisfy both requirements, a solution has been proposed in the form of low-dimensional, discrete map-based phenomenological neuron models that are capable of a rich repertoire of neural responses while being computationally very inexpensive [1]. A notable example is the Rulkov's two-dimensional map [2] which can exhibit spike rate adaptation, chaotic spiking and bursting, and which can be tuned to have similar responses to the more complex, conductance-based Hodgkin-Huxley type models [3]. The collective behavior (e.g., synchronization) of a network is highly sensitive to the phase response properties of the single neurons [4]. In the present study we analyze and explain the phase responses to perturbations of spiking Rulkov neurons and compare them to real neurons. We show that the models proposed in [2,3] can be classified as type I and type II neurons in terms of the bifurcation to the spiking state and, consequently, the type of phase response curve. We characterize the dependencies of the phase response curves to perturbation strength and spiking frequency, and conclude that the Rulkov's map can successfully replicate the phase response properties of biological neurons.

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Tuesday 8 September 16:10-17:50

Room 2: Coupled Oscillators

Complex bifurcations of Arnol'd tongues generated in three-coupled delayed logistic maps

Daiki Ogusu[a], Shuya Hidaka[a], Naohiko Inaba[b], Munehisa Sekikawa[c] and Tetsuro Endo[a]

This study investigates quasi-periodic bifurcations and Arnol'd resonance webs generated in three-coupled delayed logistic maps. Complex bifurcation structure is observed when a conventional Arnol'd tongue transits to a higher-dimensional Arnol'd tongue. We discovered that at least two periodic attractors coexist in the conventional Arnol'd tongue.

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Chimera states in ensembles of time-delayed feedback oscillators with the mean field

Danil Kulminskiy[a], Vladimir Ponomarenko[a] and Mikhail Prokhorov[a]

Recently, investigation of specific states in ensembles of coupled identical oscillators, named as chimera states, attracts a lot of attention [1-3]. These states are characterized by the presence of two different clusters, in one of which the oscillators exhibit synchronous behavior, and in another, the asynchronous one. The chimera state can occur in ensembles of bistable oscillators where depending on initial conditions each element of the ensemble can exhibit different oscillating behavior. In the present paper we investigate the chimera state in a ring of time-delayed feedback oscillators with a specific form of nonlinear function which are coupled through a mean field. The mean field is formed by summation of outputs of all oscillators. The obtained sum is filtered and fed into each oscillator as an external driving. The dynamics of each oscillator in the ensemble is described by the following equation: $\epsilon = -x + f(x(t-\tau) + k\gamma)$, where τ is the delay time, ϵ is the parameter that characterizes the inertial properties of the system, γ is the mean field, k is the coupling strength, and f is a nonlinear function. All oscillators in the ensemble are identical. The nonlinear function has the following form:$f(x) = a\sin(x-b)$, where $a = 3$ and $b = -0.8$. In this case, the time-delay system (1) possesses bistability. At the negative initial conditions the chaotic attractor is realized, while at the positive initial conditions the periodic attractor is realized. We investigate the ensemble of six time-delayed feedback oscillators coupled in a ring. Each oscillator consists of a delay line with $\tau = 100$, a nonlinear element, and a low-pass first-order Butterworth filter with cutoff frequency $f_c = 1/\epsilon = 0.4$. To form the mean field the signals from the filter output of each oscillator are added to a summator. Then the signal from the summator output is passed through a low-pass filter and fed into each oscillator. The initial conditions are chosen in such a way that the oscillators 1-3 generate a chaotic attractor on the third harmonic of the basic mode, and the oscillators 4-6 generate a periodic attractor on the basic mode. Thus, two clusters are formed in the ensemble. The structure of the considered ensemble corresponds to the Kuramoto system of phase oscillators coupled through the mean field [4] which shows the transition from synchronous to asynchronous dynamics under the change of the phase shift of the mean field. If the phase shift is less than $\pi/2$, then the ensemble exhibits synchronous behavior, and if the phase shift is greater than $\pi/2$, then the ensemble exhibits asynchronous behavior. We have shown that under the change of the phase shift of the mean field the studied ensemble can exhibit three substantially different regimes. At the small phase shift the oscillators 4-6 are synchronized (they form a cluster with periodic behavior), and the oscillators 1-3 are phase synchronized. When the phase shift is greater than $\pi/2$ for the third harmonic but less than $\pi/2$ for the basic mode, the oscillators 4-6 are synchronized and the oscillators 1-3 are asynchronous. Under the greater phase shift, all oscillators in the ensemble exhibit asynchronous behavior. Thus, we have demonstrated the presence of the chimera state in the ensemble of time-delayed feedback oscillators with the mean field.

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Experiments on clustering and synchronous patterns in a configurable network of chaotic oscillators

Soudeh Yaghouti[a], Carlo Petrarca[a] and Massimiliano de Magistris[a]

We present new experimental results, on a recently developed set-up, implementing a dynamically configurable network of chaotic oscillators with Chua's circuits as nodes. The set-up has been designed and tailored to easily perform real time experiments on complex networks with arbitrary topology. We focus here on the emergence of symmetry related synchronization patterns, as well as the switching among different clusters due to modification of the network structure and/or coupling strength, that are experimentally analyzed for the first time in such type of networks. The observed behavior confirm basic theoretical expectations on small networks, as recently appeared in literature. The scalability to higher complexity network, as allowed by the considered setup, will be briefly discussed.

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Prediction of the Indian Summer Monsoon as a spatially organized critical transition

Veronika Stolbova[a,b], Elena Surovyatkina[a,b,c] and Jürgen Kurths[a,b,d]

The prediction of the Indian Summer Monsoon onset and withdrawal is a vital question for more than one billion people. A slight deviation of the monsoon timing as delay (or early arrival) may lead to drastic droughts (floods) extremely affecting croplands, livelihood and prosperity of the inhabitants of the Indian subcontinent. As the onset of the Indian summer monsoon takes place abruptly, its predictability in advance (more than two weeks) remains a challenge, despite numerous deduction methods. In our study, we consider Indian Monsoon as a spatially organized critical transition from the sporadic rainfall (pre-monsoon state) to spatially organized and temporally sustained rainfall (monsoon state). Using critical phenomena associated with critical transitions, we detect areas on the Indian subcontinent sensitive to the approaching monsoon, and by monitoring dynamics in the detected areas we track arrival of Indian Summer Monsoon on the Indian subcontinent. Within this framework, we propose an early (more than one month in advance) predictability scheme for Indian Monsoon onset and withdrawal. Our approach allows to predict the onset date of the Indian Summer Monsoon two weeks earlier and withdrawal date more than a month earlier than existing methods for the period 1965-2015. In addition, our results provide information about the influence of El-Nino/Southern Oscillation on the Indian Monsoon in considered year. Our approach opens a perspective for prediction of critical transitions advancing in spatially organized systems in Climate, Physiology, and Neuroscience.

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Wednesday 9 September 11:10-12:25

Room 1: Brain

Robust spatial memory maps in flickering neuronal networks: a topological model

Yuri Dabaghian[a,b]

The interest on the interaction between neurons and electrical devices started in 1924, when the human brain activity was recorded for the first time. After almost 100 hears the modern semiconductor technology is able to produce devices with nano-metrical dimensions, which can be used to control and modulate the cells behavior. These new hybrid devices can improve the therapeutic approach in many pathologies such as cord injury, epilepsy, Parkinson's disease. Actually just few theoretical results are available in literature. In this work we will present a simplifed mathematical approach to describe the behaviour of a nano-sized semiconductor device coupled with a neuronal cellular membrane. From the mathematical point of view the semiconductor device is described using the quantum hydrodynamical equation (QHD), whereas the ions moving across the cellular membrane, through ionic channels, are modelled by a modifed version of the Poisson-Nerst-Plank equation (PNP), which is able to include size exclusion effects. A suitable set of interface conditions is presented in order to prove the existence and the uniqueness of the solution. Finally the model is tested numerically on a simplifed geometry.

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Nonlinear dynamics and low-frequency fluctuations in network hubs: tentative analogy between the resting human brain and coupled single-transistor chaotic oscillators

Ludovico Minati[a,b], Pietro Chiesa[b], Davide Tabarelli[b], Ludovico D'Incerti[c] and Jorge Jovicich[b]

It is well-established that the node degree of structural and functional connectivity in the human brain follows a scale-free distribution wherein few nodes, referred to as hubs, have a disproportionately high number of links. It however remains less understood if activity in such nodes exhibits dynamical properties different from the rest of the network. Here, high-temporal resolution resting-state fMRI data from a group of healthy participants were analyzed. Large node degree of functional connectivity (inter-regional synchronization) was strongly associated with i) evidence of non-linear structure, manifest as lower correlation dimension with clearer dimensional saturation compared to surrogate data, ii) spectral shift towards lower frequency fluctuations. We speculated that such findings could represent an at least partially generalizable relationship, and went on to realize a 90-ring network of diffusively coupled single-transistor chaotic oscillators, in which 4 'areas' were hardwired as hubs through addition of long-distance connections. Near criticality, transition to chaotic dynamics was selectively observed for oscillators in these hub areas, with findings closely recalling those from brain data. These results are also in accord with meso-scale recordings of neural cultures performed elsewhere. It appears that there may a relationship between network topology and transition to non-linear, potentially chaotic dynamics, which could hold across very different systems and scale levels.

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A simplifed mathematical model for nano-bio interface

Federica Di Michele[a], Bruno Rubino[a] and Rosella Sampalmieri[a]

The interest on the interaction between neurons and electrical devices started in 1924, when the human brain activity was recorded for the first time. After almost 100 years the modern semiconductor technology is able to produce devices with nano-metrical dimensions, which can be used to control and modulate the cells behavior. These new hybrid devices can improve the therapeutic approach in many pathologies such as cord injury, epilepsy, Parkinsonn's disease. Actually just few theoretical results are available in literature. In this work we will present a simplifed mathematical approach to describe the behaviour of a nano-sized semiconductor device coupled with a neuronal cellular membrane. From the mathematical point of view the semiconductor device is described using the quantum hydrodynamical equation (QHD), whereas the ions moving across the cellular membrane, through ionic channels, are modelled by a modifed version of the Poisson-Nerst-Plank equation (PNP), which is able to include size exclusion effects. A suitable set of interface conditions is presented in order to prove the existence and the uniqueness of the solution. Finally the model is tested numerically on a simplifed geometry.

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Wednesday 9 September 11:10-12:25

Room 2: Coupled Oscillators

Modified microwave chaotic Colpitts oscillator

A. I. Panas[a] and N. A. Maximov[a]

The report is devoted to the problem of a practical implementation of microwave chaotic oscillators. This important issue is urgent problem because of the need to design energy-efficient sources of ultra wideband microwave chaotic signals for wireless devices meets the IEEE standards 802.15.4 and 802.15.6. The chaotic Colpitts oscillator is known as one of the generators with a simple structure. It has experimentally approved implementations in the microwave range. A standard oscillator circuit includes an active element (bipolar transistor) and three external reactive elements (two capacitors and inductor). The oscillator implementation, results of the simulation and experiments are presented in the report. The generation of ultra wideband chaotic signals in the frequency range 1.5 – 6.5 GHz. with the efficiency of 2% is shown. On the other hand, a modified scheme of the chaotic Colpitts oscillator is proposed in the report. It eliminates external capacitors from the oscillator circuit. In this case, the capacitances of p-n junctions of the transistor play the role of external capacitors. It is shown, when using BFP620F bipolar transistor as active element the frequency band of the generated chaotic signal is increased to 7.5 GHz while the efficiency raise up to 7%.

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Cloning of 3D chimera states

Volodymyr Maistrenko[a], Oleksandr Sudakov[a], Oleksiy Osiv[a] and Yuri Maistrenko[a]

In this contribution we propose the method for cloning of 3D chimera states that display a self-organized spatial pattern of coexisting coherence and incoherence for nonlocally coupled oscillators in three-dimensional networks. 3D chimera states were reported recently in [1] for a Kuramoto network of N^3 identical oscillators

$$\dot{\phi}_{ijk} = \omega + \frac{K}{P^3} \sum_{(i'j'k') \in B_P(i,j,k)} \sin(\phi_{i'j'k'} - \phi_{ijk} - \alpha),$$

$i, j, k = 1, ..., N$, where ϕ_{ijk} are phase variables, indexes i, j, k are periodic mod N which induces a 3D torus structure on the array. The coupling is assumed to be long-ranged and isotropic: each oscillator ϕ_{ijk} is coupled with equal strength K to all its nearest neighbors $\phi_{i'j'k'}$ within a range P. i.e. to those oscillators falling in the ball-like neighborhood

$$B_P(i, j, k) := \{(i', j', k') : (i' - i)^2 + (j' - j)^2 + (k' - k)^2 \leq P^2\}$$

Here the distances $i' - i$, $j' - j$, and $k' - k$ are calculated regarding the periodic boundary conditions of the network. The phase lag parameter α is assumed to belong to the attractive coupling range from 0 to $\pi/2$, the second control parameter is the coupling radius $r = P/N$. Two large families of the 3D chimera states: stationary - incoherent/coherent balls, tubes, crosses, layers (I), and scroll waves - incoherent rolls in spirally rotating coherent surround- ing, which are generated by random initial conditions, were found [1] in large domains of the parameter space (r, α).

The cloning process of 3D chimera states can be described as follows: we take eight initial conditions $\{\phi_{i_0 j_0 k_0}\}$ of 3D chimera states obtained for N3 oscillators and using periodic boundary condition, build initial conditions $8\{\phi_{i_0 j_0 k_0}\}$ for $(2N)^3$ oscillators, which generate the 3D chimera states clones with double value of N in system (1), and so on indefinitely. As a result we get multiheaded [2] 3D chimera states with increasing number of coherence and incoherence parts where their number of heads tends to infinity when $N \to \infty$. Examples of 3D chimera states clones obtained from original 4 spiral incoherent rolls are presented in Fig.1. We also find stability regions for these 3D clones in the parameter space (r, α).

The contribution comprises video presentation illustrating the origin and evolution of the 3-D chimera states. The massive calculations were performed at the computer cluster "CHIMERA" (http://nll.biomed.kiev.ua/cluster).

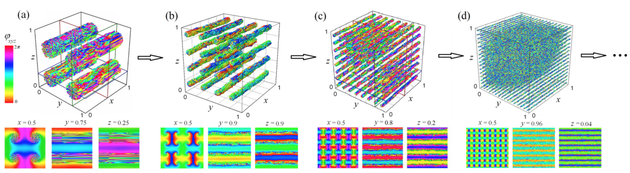

Fig. 1: Example of 3D chimera state and its clones: (a) original 4 spiral incoherent rolls ($r = 0.12$, $N = 50$), (b) 16 spiral incoherent rolls ($r = 0.06$, $N = 100$), (c) 64 spiral incoherent rolls ($r = 0.03$, $N = 200$), (d) 256 spiral incoherent rolls ($r = 0.015$, $N = 400$). Coordinates $x_i = i/N$, $y_j = j/N$, $z_k = k/N$, $\alpha = 0.7$.

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Emergence of complex structure and behavior from elementary adaptive network automata

Daniel Wechsler[a] and Ruedi Stoop[a]

A variety of real-world systems can be modeled as adaptive networks, that combine an evolving network with a dynamical process on that network. Social, transportation and neural networks, for example, may show robust self-organization towards a dynamically critical state or the formation of complex network topologies. How, exactly, these system level behaviors emerge from the local rules governing evolving topology and node dynamics, is poorly understood. We introduce an elementary automaton model that evolves a network and a dynamical process on it according to simple local rules to shed light on this problem. We perform exhaustive simulations of all of our 256 different possible update rules, allowing a systematic study of their impact on emerging system level behaviors. The in-depth analysis of an exemplary rule reveals a rich interplay between topology and node dynamics, with evidence of critical dynamics and a the emergence of a complex network topology. Our model may be a promising candidate to investigate the question of whether there are general principles that relate the local rules to the emerging system level behaviors.

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Wednesday 9 September 16:10-17:50

Room 1: Brain

Multiplex network based features for early Alzheimer characterization

Nicola Amoroso[a,b], Marianna La Rocca[a,b], Rosangela Errico[c,d], Annarita Fanizzi[a], Elena Garuccio[e], Anna Monda[a], Sabina Tangaro[b], Andrea Tateo[a] and Roberto Bellotti[a,b]

Magnetic resonance imaging (MRI) has been extensively studied along with pattern recognition techniques to detect signifcant biomarkers for the early diagnosis of Alzheimers disease (AD). Features involving either the whole brain or local regions of interest related to the disease bring substantially complementary information about the pathology. Brain scans naturally define connectivity networks among the several regions a brain can be parcellated in. Accordingly, (i) we studied how multiplex networks can supply a convenient mathematical framework to describe AD patterns of disease in terms of features modeling the structural inter and infra subject brain connectivity. (ii) We used FreeSurfer to perform volume based morphometry and use it to assess the method performances. We studied a set of 100 structural T1 brain scans from subjects of the Alzheimers Disease Neuroimaging Initiative including AD patients, normal controls (NC) and mild cognitive impairment (MCI) subjects. Finally, we evaluated the classification performances including the comparison of two state-of-the-art classification techniques, Random Forests and Support Vector Machines. The experimental results, obtained with a 5-fold cross validation, showed that classification performances could be significantly improved with the use of multiplex network based features.

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Simple analog electronic model of a spiking neuron featuring short- and long-term memory, and inhibitory/excitatory synaptic-like behavior

Guillermo V. Savino[a]

This paper presents an analogue discrete electronic circuit implementation of a neuron model with many synaptic like connections. The single neuron cell circuit synapses and the soma make use of an unusual reversal bipolar transistor (BJT) connection. It has a compact layout and very low energy consumption, in the range of 10 microJoule per spike. Experimental results show the capability of the circuit to generate periodic spikes that are triggered delayed (inhibitory) or advanced (excitatory) in response to synaptic-like external excitations and/or its own activity (synaptic weight). The circuit dynamic includes a self generated long-term soma memory and a short-term synaptic memory. The synapse number can be increases, from a minimum of two transistors, just adding as many as transistors as desired. Hence, the circuit provides a foundation or building block for designing massively parallel analogue, small silicon area and power consumed neuromorphic or any specific application VLSI integrated neural networks.

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Complex network for DRD2 gene community identification in Schizophrenia

Anna Monda[a], *Nicola Amoroso*[a,b], *Alessadro Bertolino*[d], *Giuseppe Blasi*[c], *Pasquale Di Carlo*[c], *Marco Papalino*[c], *Giulio Pergola*[c], *Sabina Tangaro*[b], *Andrea Tateo*[a] *and Roberto Bellotti*[a,b]

In this work we used topological features of gene co-expres- sion networks to pin down the relationships between genes related to a specific disease. We adopted a graph theory framework to investigate a genetic co-expression module previously associated with schizophrenia in 199 non-psychiatric subjects. We identified communities of co-expressed genes, combining the study of basic topological properties, such as de- gree and betweenness, and assessed the method robustness in several cross-validation configurations. We found a small and stable community of genes interacting with DRD2, whose relevance in schizophrenia is a cutting edge research theme. The detected community preserves the in- formation essential to understand the dynamic of the genetic process. By investigating the neurophysiological correlates of genetic variants associated with this community we found that this technique outperformed previous procedures to identify genetic markers of schizophrenia-related phenotypes. Thus, topological features of gene co-expression networks are critical for marker detection.

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Stabilization of steady states in an array of the coupled FitzHugh–Nagumo oscillators

Arūnas Tamaševičius[a], *Elena Adomaitienė*[a], *Gytis Mykolaitis*[a] *and Skaidra Bumelienė*[a]

A well known phenomenon in nonlinear dynamics is that dynamical behavior of a system can be changed by means of applying external periodic force. Specifically, high frequency forcing can change the stability properties of the inherent steady states. An example is the stabilization of the unstable upside-down position of a mechanical pendulum by vibrating its pivot up and down at a relatively high frequency. Recently this "mechanical" idea has been successfully exploited [1] in a seemingly unexpected area, namely to explain the mechanism of the so-call deep brain stimulation (DBS), conventionally used to avoid the tremor for patients with the Parkinson disease. Unfortunately, the common DBS treatment is often accompanied with unpleasant and dangerous side effects, since it requires permanent high frequency high amplitude current injection into the brain. We suggest to exploit the tracking filter technique (TFT) for suppressing neuronal oscillators in an array of coupled cells and compare it with the commonly used DBS. The investigations have been carried out with an array of thirty electronic FitzHugh–Nagumo type oscillators. We demonstrate that the TFT has and advantage over the DBS in the sense that the controlling forces are vanishing.

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Wednesday 9 September 16:10-17:50

Room 2: Coupled Oscillators

Ultrawideband chaotic transmitter panel

Yu.V. Andreyev[a] and A.S. Dmitriev[b]

Due to severe restrictions on power spectral density (-41/3 dBm/MHz) [1], ultrawideband (UWB) communication systems of 3-10 GHz frequency range are intended to be short-distance (10 to 30 m), local and personal-area devices. Yet first tests indicate increasing demand for longer-range UWB applications. While the obvious way to increase the distance range is to increase the transmitter emission power, this mehod is limited by the above restriction, i.e., in the whole 3-10 GHz band the total emission power must not exceed 600 mW. However, this restriction pertains only to the power of individual transmitter. Here we propose to combine the energy of many transmitters in order to step over this restriction and to flexibly control the distance of communications. This goal can easily be achieved with chaotic UWB communications systems (direct chaotic communications), in which information is encoded with a sequence of ultrawideband chaotic radio pulses [2, 3]. The idea is to organize collective simultaneous emission of chaotic radio pulses produced by chaotic oscillators of individual transmitters (Fig. 1). Since the UWB oscillators are independent (and the receiver is noncoherent), their chaotic signals are uncorrelated and are summed by power at the receiver input, so that the signal power of an ensemble of N transmitters is N times the power of an individual transmitter. In this report we investigate the properties of chaotic transmitter panel, i.e., an array of UWB transmitters with independent UWB chaotic oscillators, which are synchronized by LF information signal, so that all transmitters emit chaotic radio pulses at the same time, each with its own antenna. The panel properties are studied in numerical simulation as well as in physical experiment. The panel is shown to be an efficient method for increasing communication range; and unlike antenna arrays, due to the use of uncorrelated chaotic signals the panel does not add directivity to the emission pattern.

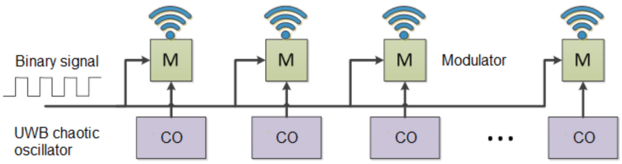

Fig. 1: Block diagram of UWB chaotic transmitter panel.

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Frequency-sharpening and scale-invariance in a system of forcing-coupled Hopf oscillators

Florian Gomez[a], Tom Lorimer[a] and Ruedi Stoop[a]

Traditionally, the study of coupled oscillators involves elements that intrisically oscillate even when uncoupled, such as Kuramoto oscillators [1]. However, many systems, especially in biology, are composed of elements that are found to be in an excitable state, below the threshold to oscillation. This state is characterized by its vicinity to a bifurcation, typically of saddle-node or Andronov-Hopf type. Motivated by recent results from the modeling of sound processing in the mammalian cochlea, we look at a system of forcing-coupled sub-threshold Hopf oscillators. This system is shown to exhibit a higher-level Hopf bifurcation, where the coupling strength acts as the bifurcation parameter. In particular, the proximity to the higher-level bifurcation gives rise to a frequency sharpening of the response to external input. Moreover, we show that this coupled system can effectively be described by a single Hopf oscillator. This scale-invariance corroborates the mesoscopic Hopf modeling approach to hearing systems.

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Recovery of couplings and parameters of elements in networks of time-delay systems

Mikhail Prokhorov[a], Vladimir Ponomarenko[a] and Ilya Sysoev[a]

The problem of detecting the presence, structure, and characteristics of couplings in various networks from their time series has attracted a lot of attention in recent years. To solve this problem a variety of methods has been proposed including Granger causality, phase dynamics modeling, and adaptive feedback control. However, in most of studies, either the network elements were without time-delayed feedback or the delays were assumed to be known in advance.

A method for estimating both the network connectivity and node parameters including the delay time for networks of time-delay systems has been proposed by us recently in [1]. It is based on the reconstruction of model delay-differential equations for the network elements and the diagnostics of statistical significance of couplings. However, the problem of network reconstruction is solved in this method in two steps. At first, the delay time of each element in the network is recovered. Then, other parameters and nonlinear functions of the elements and coupling architecture are reconstructed. Moreover, the results of coupling recovery sometimes depend on the choice of the initial coupling distribution used in the procedure of reconstruction.

In the present paper, we propose a method for reconstructing the parameters of elements and architecture and strengths of couplings in networks of time-delay systems which is devoid of the above mentioned drawbacks and is more quick-operating than the iterative method in [1]. The proposed method is based on the minimization of the objective function which characterizes the distance between the points of the reconstructing nonlinear function ordered with respect to the abscissa. This minimization is carried out for different trial delay times chosen from some interval. The global minimum of the objective function is observed at the true choice of the delay times. To separate the recovered coupling coefficients into significant and insignificant ones we use the method of K-means.

The proposed method can be applied to the networks composed of diffusively coupled time-delay systems, each described by the equation

$$\dot{x}_i(t) = -x_i(t) + f_i(x_i(t-\tau_i)) + \sum_{j=1 (j\neq i)}^{M} k_{i,j}(x_j(t) - x_i(t)),$$

where $i = 1, \dots, M$, M is the number of elements in the network, τ_i is the delay time, f_i is a nonlinear function, and $k_{i,j}$ are the coupling coefficients characterizing the strength of influence $j \to i$, i.e., from the jth element to the ith one.

We verified the method by applying it to chaotic time series produced by model equations of the network composed of sixteen diffusively coupled Ikeda equations in the presence of noise. The parameter values of all coupled Ikeda equations were different. The cases of complicated coupling architecture are considered. It is shown that the method allows us to recover accurately the coupling architecture and delay times of all elements. The other parameters and nonlinear functions of Ikeda equations are reconstructed with a high accuracy.

The method is also successfully applied to experimental time series obtained from a ring of ten electronic oscillators with delayed feedback coupled by resistors.

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Power laws as the result of exponentially decaying spiking frequency during synchronized activity

Damian Berger[a] and Ruedi Stoop[a]

Neuronal activity, measured in *in vitro* and *in vivo* experiments, can exhibit spontaneous bursts of spikes, followed by periods of reduced activity. Several experiments showed that the bursting periods consist of distinct spatiotemporal patterns, so called avalanches, with a size distributed according to a power law. In order to explain the power laws in the neuronal avalanche size distributions, comparisons to critical branching processes and second order phase transitions have been made. Here we present evidence for a simpler process that may lead to the power law in the avalanche size distribution. We studied *in vitro* the activity of dissociated hippocampal rat neurons. For both the avalanche size distribution and the inter-event interval distribution we found power laws. Additionally we observed that the activity within isolated bursts decays exponentially. We consequently modeled bursts by an exponentially decaying spiking probability and found avalanche size and inter-event interval distributions that are well-modeled by power laws and reflect our biological data very well. We found the power law exponent generated by our model analytically for the inter-event interval case, which shows very good agreement with the biological data.

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Thursday 10 September 11:10-12:25

Room 1: Control

Quantum transport in light-harvesting systems

Fausto Borgonovi[a]

Natural photosynthetic systems interact with different environments, which are a source of noise but can also induce cooperative coherent effects, such as superabsorption of light and supertransfer of excitation. Both cooperativity and noise can be essential to achieve efficient energy transport in natural complexes and in bio-inspired quantum devices. We show this point with the aid of the non Hermitian Hamiltonian approach to open quantum systems and analyzing both general quantum disordered networks and realistic models of photosynthetic antenna complexes (such as LHI, FMO).

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Transport and non-equilibrium dynamics with cold atoms

Sandro Wimberger[a]

State-of-the-art experiments with ultracold atoms and molecules allow for an unprecedented control of microscopic degrees of freedom and the bottom-up construction of nano-structures in various regimes (glasses, crystals, superfluids). In close collaboration with experiments, we propose to create structures consisting of a few hundred to a few million particles, covering the cross-over from microscopic to macroscopic matter. We focus hereby on both the production of stable many-body structures, such as static lattices mimicking magnetic materials or coherent solitons in optical lattices [1], as well as on quantum transport problems. The dynamics of ultracold fermions and bosons simulates the transport of electrons in solids, with the great advantage of unprecedented experimental control and in situ observation possibilities [2]. New forms of current transport, including materials with negative differential resistivity [3], driven by many-body correlation effects have been observed already. This opens many frontiers for the design of matter and the control of currents [4,5] on the verge between the quantum and the classical world.

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Thermal conduction and thermoelectricity in one-dimensional nonlinear systems

Shunda Chen[a,b], *Jiao Wang*[c], *Giulio Casati*[a,d] *and Giuliano Benenti*[a,b]

Deriving the empirical Fourier heat conduction law from microscopic dynamics is an old but still challenging problem. We study in one-dimensional momentum-conserving nonlinear systems, how nonintegrable dynamics may affect thermal transport properties [1]. We find that when the system is close to integrable limit, the heat conductivity may keep significantly unchanged over a certain range of the system size, and as the system tends to integrable limit, the range of this Fourier-like behavior may expand rapidly. These results establish a new connection between the macroscopic thermal transport properties and the underlying dynamics. An application of the Fourier-like behavior to thermoelectric transport of nonlinear interacting particles is also discussed [2].

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Thursday 10 September 11:10-12:25

Room 2: Networks and Applications

Cellular neural networks based emulation of analog filters: theory and design principle

Nkiediel Alain Akwir[a], *Jean Chamberlain Chedjou*[a] *and Kyandoghere Kyamakya*[a]

We develop and validate through some illustrative examples an efficient concept based on cellular neural networks for the synthesis of analog filters. Several types of filters (i.e. Low-pass, High-pass, Band-pass, and Band-stop) are envisaged each of which is emulated in the form of the CNN mathematical model. The resulting coefficients of the CNN mathematical model (called CNN templates) are derived for each type of filters. Correspondences are established between the parameters of the CNN mathematical model and the physical components (i.e. resistors, capacitors, inductances, op-amps, etc.) of the filters. The key contribution of this work is to demonstrate the potential of using cellular neural networks (CNN) as a universal concept for analog filters modelling and simulation. The main motivation of developing the CNN- concept for the emulation of analog filters is justified by its excellent features (e.g. high flexibility, good stability, and high accuracy). Further, the CNN-concept developed is a framework which can be efficiently used for a straightforward conversion of analog filters into digital filters.

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Experimental investigation of chaos synchronization in nonlinear oscillators via cyclic coupling

O.I. Olusola[a], A.I. Egunjobi[b], A.N. Njah[a] and S.K. Dana[c]

This paper investigates chaos synchronization in experimental circuits using Sprott, Rössler and van der Pol oscillators as paradigmatic oscillators. Using multiSIM 12.0 software the threshold coupling is first determined when complete synchronization (CS) is observed via bidirectional and cyclic mutual coupling as well. MultiSIM simulation results are experimentally verified using off-the-shelve electronic components in a breadboard. It is found that, by applying cyclic coupling in some of the variables, it is possible to synchronize two oscillators where the conventional bidirectional coupling failed to achieve. Furthermore, it is found that the synchronization behaviour can be enhanced by applying cyclic coupling to a selected set of variables of the oscillators at least for the model systems considered here.

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A novel recurrent neural network based ultra-fast, robust and scalable solver for time varying matrix inversion

Vahid Tavakkoli[a], Jean Chamberlain Chedjou[a] and Kyandoghere Kyamakya[a]

Various algorithms exist to solve matrix inversion. Most of them are very good algorithms however, which could be implemented only on single processor computers. This makes these algorithms becoming inefficient when trying to implement them on multi-processor platforms. The main root of the problem lies in the nature of the algorithms as they are essentially designed to be used on single processors. Hence, the search for new algorithms that fit better for implementation on parallel systems is necessary. Using parallel computing frameworks like neural networks can provide a good basis to support algorithms or concepts highly compatible with parallel platforms and thereby ensuring a low implementation cost. In this paper, we do suggest and demonstrate a new way of solving linear algebraic equations using a Cellular Neural Network (CNN) Processor. Although similar works have been performed by using different types of Neural Networks such as Recurrent Neural Network (RNN) and Artificial Neural Network (ANN) the fact of developing novel RNN methods constructed on CNN- platforms to solve matrix inversion does increase convergence speed and provide feasible solutions for an implementation on analog processors.

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Thursday 10 September 16:30-17:45

Room 1: Synchronization

Phase and frequency locking in complex model of blood pressure dynamics

A.S. Karavaev[a,b], Y.M. Ishbulatov[b], V.I. Ponomarenko[a,b] and M.D. Prokhorov[a]

Construction of mathematical models of the real-world complex systems is an important part of their investigation. Using the adequate models one can better understand the system operation and predict its behavior in time and under parameter variation. It allows one to obtain new fundamental knowledge about the structure of the studied complicated systems and comprehend the features of their individual and collective dynamics.

In the present study we propose a model for description of the complex blood pressure dynamics. The model simulates the operation of sinus node and its frequency modulation by the signals of autonomous control system, models the baroreflex regulation of mean arterial pressure, and takes into account the influence of respiration. The structure of the proposed model of cardiovascular system is chosen similarly to the one proposed by Kotani K. et al [1]. To simulate the baroreflex regulation of mean arterial pressure we use the model of self-oscillating time-delayed feedback oscillator [2]. We consider various types of introducing the respiration into the model. The influence of dynamical and measurement noises on the observed dynamics of the model is taken into account.

The obtained results indicate that including of nonautonomous time-delayed feedback oscillator into the model results in much better qualitative and quantitative coincidence of the model cardiointervalogram power spectra with those observed for the real signals. In particular, the model power spectra exhibit clearly distinguished peaks corresponding to the frequencies of the regulatory systems activity as well as in the power spectra of experimental cardiointervalograms [3].

Moreover, the proposed model demonstrates for the first time the phenomena of phase and frequency locking of the regulatory system slow oscillations by the respiration that is typical for the real cardiorespiratory dynamics. It is shown that the system of baroreflectory regulation of mean arterial pressure could be synchronized by the signal of respiration with linearly increasing frequency similarly to the synchronization of radio technical oscillator by the external signal. Analogous effect has been observed earlier in our experimental study of healthy subjects [4].

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A spin physics-based framework for hybrid recommendation systems

Thomas Ott[a], Thomas Eggel[a], Roland Gassmann[a], Erich Zbinden[a] and Michael Reinhold[b]

Recommendation systems guide and support users in the process of finding relevant items, such as products or services, in a potentially huge space of options. There are different schemes upon which recommendation systems are based such as collaborative filtering [1], content-based filtering [2] or knowledge-based systems [3]. Each scheme comes along with certain strengths and weaknesses, depending on the application context and the available data. Hybrid systems try to take advantage of different schemes by combining them. They often show better performance than single schemes [4,5]. We report on the development of *Dayzzi.com*, a broker recommendation platform for the business of promotional items. The development has been facing the challenges of data sparsity, limited availability of ex-ante user data and a relatively small number of user activities or transactions over time. To overcome this, we developed a specific knowledge-based system that incorporates the market expertise in the form of sales agents' thorough understanding of customer needs and purchasing behavior [6]. The core process of the engine comprises (1) a mapping from a set of variables that characterize the user's preferences to a set of hidden variables, akin to a feature selection or dimensionality reduction procedure, and (2) a Bayesian classifier to identify relevant items. In order to increase the learning aptitude of the system based on a hybridization with other recommendation schemes, we reformulate the original scheme in terms of a system of uncoupled Ising spins that are exposed to variable magnetic fields. This framework allows us to easily add and combine recommendation schemes in the form of magnetic field components, while keeping the advantage of having no direct coupling between the recommendations of products. This leads to a form of mixed hybridization and keeps the learning process simpler than in similar approaches, e.g. based on Boltzmann machines [5].

We explain the construction of the framework and its magnetic field components in more detail and illustrate its advantages in comparison to non-hybrid solutions. Furthermore, we report on some implementation issues regarding recommendation platforms for small and medium-sized enterprises such as *Dayzzi.com*, pointing out the quest for specific approaches in the case of specific e-business situations with, e.g., a rather small number of transactions.

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Controlling the range of a Schmitt trigger's switching oscillations by means of external noise and nonlinear feedback

G.A. Zarza[a], S.E. Mangioni[a], L. Vassallo[a] and R.R. Deza[a]

Recently, one of us has shown numerically that it is possible to confine—by means of a suitably tailored multiplicative external noise—the response of a bistable system within beforehand-established bounds [1]. Figure 1 shows that when a simple bistable system like $u\,(1-u^2)$—whose stationary pdf is depicted in red—is submitted to multiplicative Gaussian white noise, namely $\partial_t u = u\,(1-u^2) + \Gamma^{1/2}(u)\,\eta(t)$ with $\langle\eta(t)\eta(t')\rangle = 2\,\lambda^2\,\delta(t-t')$ and

$$\Gamma = \begin{cases} \exp[2b\,(|u|-u_l)] & \text{if} \quad |u| < u_l, \\ 1 & \text{if} \quad |u| > u_l, \end{cases}$$

the system's response becomes confined (blue curves). So astounding a result was worth confirming through an experiment. By means of filters, we have trimmed the external noise's bandwidth down to the range in which the Schmitt trigger's hysteresis cycle is not strongly frequency-dependent, and we have devised a circuit featuring nonlinear feedback whose behavior in `Spice` simulations (Fig. 2) shows the same qualitative features as the numerical simulations. We are now undertaking the real experiment, whose definitive reults will be communicated at the Conference.

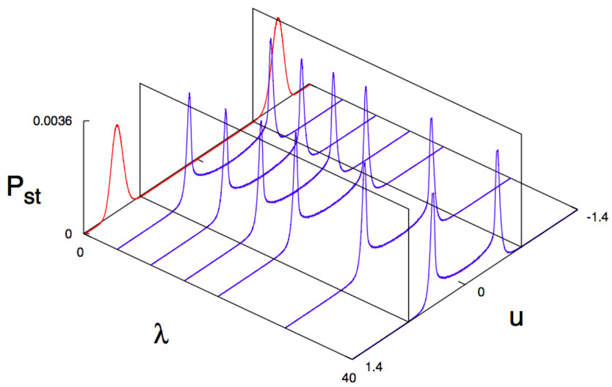

Fig. 1: Stationary probability ($P_{\rm st}$) *vs.* u and λ. Red curve: $\lambda = .02$ and $b = 0$. Blue curves: $b = 20$. The $u_l = \pm .7$ lines are the chosen confinement bounds.

[1] S. E. Mangioni, "Systems confined by pusher multiplicative noises", Eur. Phys. J. B **88**, 53–58 (2015)

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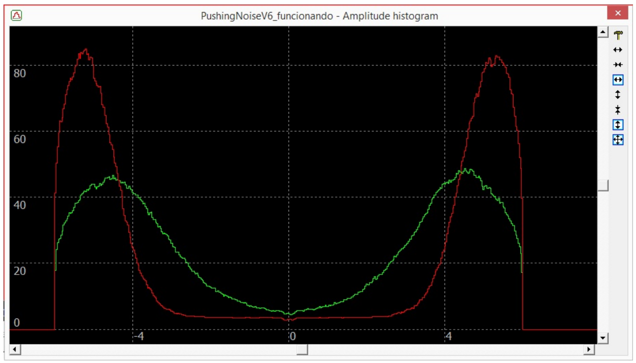

Fig. 2: `Spice` simulation of the devised nonlinear circuit.

Thursday 10 September 16:30-17:45

Room 2: Coupled Oscillators

Continuous and differentiable approximation of a TaO memristor model for robust numerical simulations

Alon Ascoli[a], Ronald Tetzlaff[a] and Leon Chua[b]

The interest on the interaction between neurons and electrical devices started in 1924, when the human brain activity was recorded for the first time. After almost 100 hears the modern semiconductor technology is able to produce devices with nano-metrical dimensions, which can be used to control and modulate the cells behavior. These new hybrid devices can improve the therapeutic approach in many pathologies such as cord injury, epilepsy, Parkinsonn's disease. Actually just few theoretical results are available in literature. In this work we will present a simplifed mathematical approach to describe the behaviour of a nano-sized semiconductor device coupled with a neuronal cellular membrane. From the mathematical point of view the semiconductor device is described using the quantum hydrodynamical equation (QHD), whereas the ions moving across the cellular membrane, through ionic channels, are modelled by a modifed version of the Poisson-Nerst-Plank equation (PNP), which is able to include size exclusion effects. A suitable set of interface conditions is presented in order to prove the existence and the uniqueness of the solution. Finally the model is tested numerically on a simplifed geometry.

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Ultrawideband microwave 3-7 GHz chaotic oscillator implemented as SiGe integrated circuit

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Microwave chaotic oscillations are a promising information carrier for ultrawideband communication systems [1,2]. The possibility of a wide use of such a carrier type depends on succesful solution of the key task - creation of small, energy-efficient generators of chaotic oscillations. By this moment, a set of discrete-component chaotic oscillators is developed, with characteristics sufficient for ultrawideband communication systems [3-5]. However, the development level of modern communications calls for implementation of such devices using elements of modern solid-state electronics, i.e., monolithic integrated circuits. In this report, creation of such devices is demonstrated on example of microwave chaotic generator on silicon-germanium (SiGe) technology. A structure of chaotic generator is proposed that provides chaotic oscillations with a required form of signal spectrum. A model system on 0.25 micron SiGe process component library is developed, and IC layout is designed. An experimental sample of microwave chaotic source with bipolar transistor as the active element is fabricated on SiGe 0.25 micron process. Operation modes of this integrated circuit are investigated. The system demonstrates generation of ultra-wideband chaotic oscillations of the frequency range 3-7 GHz. Results of numerical simulation and experimental study of the chip are analyzed. Characteristics of the integrated-circuit chaotic oscillator are compared with those of a similar discrete-component generator.

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[2] IEEE 802.15.6-2012. IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks 2012. http://standards.ieee.org/about/get/802/802.15.html

[3] Dmitriev A.S., Efremova E.V., Maksimov N.A., Grigoriev Ye.V. "Generator of microwave chaotic oscillations based on a self-oscillating system with 2.5 degrees of freedom" // Journal of Communications Technology and Electronics, 2007, V. 52, No. 10, P. 1137-1145.

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[5] Efremova E.V. "Generator of 3-10 GHz ultrawideband microwave chaos" // Proc. 21th Int. Conf. Nonlinear Dynamics of Electronic Systems (NDES), Bari, Italy, 10-12 July 2013.

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Cryptanalysis of a random number generator based on a chaotic oscillator

Salih Ergün[a]

This paper introduces an algebraic cryptanalysis of a random number generator (RNG) based on a chaotic oscillator. An attack system is proposed to discover the security weaknesses of the chaos-based RNG. Convergence of the attack system is proved using master slave synchronization scheme where the only information available are the structure of the RNG and a scalar time series observed from the chaotic oscillator. Simulation and numerical results verifying the feasibility of the attack system are given. The RNG does not fulfill NIST-800-22 and Diehard statistical test suites, the previous and the next bit can be predicted, while the same output bit sequence of the RNG can be reproduced.

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Poster Abstracts

Search accuracy improvement in artwork retrieval based on similarity of touch

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Recently, some similarity-based image retrieval systems using neural networks which make use of flexible and soft information processing ability of the neural networks have been proposed. However, most of the conventional similarity-based (content-based) image retrieval systems deal with only scenery image, landscape photographs and so on. In this paper, we propose an artwork retrieval based on similarity of touch by self-organizing map with refractoriness. This system is based on the artwork retrieval based on similarity of touch [1]. In this system, the number of colors, color information, outline information, LBP (Local Binary Patterns) [3] and so on are used as the image features. In the proposed system, some new features such as histogram of saturation and brightness, LBP and so on are introduced in order to improve search accuracy.

The proposed image retrieval system is based on the self-organizing map with refractoriness [2], and it has the input layer and the map layer. The input layer is composed of three parts corresponding to (1) the number of colors, (2) color information, (3) outline information and (4) LBP. And each stored image is trained to correspond to one of the neuron in the map layer. In the proposed system, the feature vector for the key image is given to the neurons in the input layer as the query, and the neurons corresponding to the images which have similar touch fire sequentially.

In this experiment, we used the proposed system which memorizes 500 images which can be divided into 25 groups based on the similarity of touch. Figure 1 shows a part of the retrieval results of the proposed system. In this figure, top four images which are retrieved are shown. Table 1 shows F-measure of the proposed system and conventional system [1].

[1] K. Kadokura and Y. Osana: "Image (artwork) retrieval based on similarity of touch by self-organizing map with

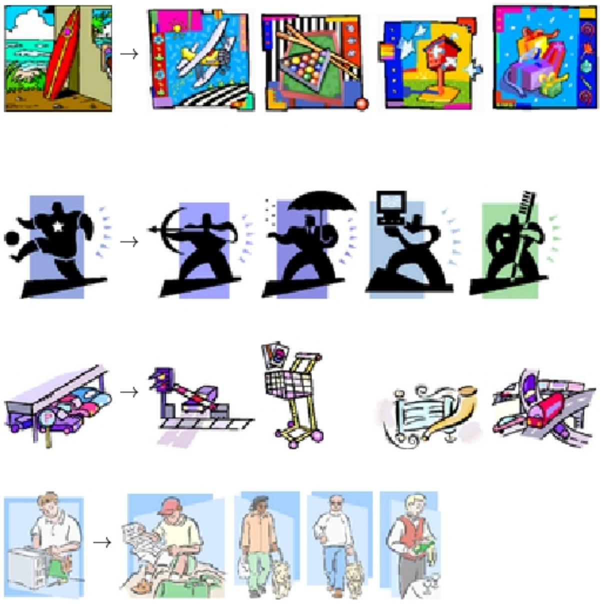

Fig. 1: Retrieval Results.

Proposed Model			Conventional Model[1]		
Recall	Precision	F-measure	Recall	Precision	F-measure
0.411700	0.581935	0.461912	0.369200	0.524348	0.412474

Table 1: F-measures.

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Fault tolerant adaptive control and synchronization of linearizable chaotic systems using RBF neural network and feedback linearization second order sliding mode control

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This paper addresses the design of adaptive controllers for linearizable nonlinear systems, especially chaotic ones, subject to external disturbances, unknown system parameters changes and actuator faults. The design approach utilises the Input-Output Feedback Linearization technique combined with the Second Order Sliding Mode Control approach. A Radial Basis Function Neural Network is used in order to approximate the unknown nonlinear function associated with the unknown system parameters. For compensating the effects of the external disturbances and the actuator faults for which the upper bounds are unknown, a dynamic switch-gain is used in the Sliding Mode Controller. The Lyapunov method is used to derive the update rules for the switch-gain and for the Neural Network, and to study the closed loop system asymptotic stability. Compared with existing works, the key achievements in this paper are related to the fact that: (a) no knowledge of the upper or/and lower bounds of the uncertainty in the system dynamics, external disturbances and actuator faults is required for the controller design; (b) there is a possibility of achieving successful complete synchronization of two non-identical chaotic systems or controlling high-order nonlinear systems using a single chattering free control signal, with good transient and steady state performances despite all the aforementioned perturbations. In order to demonstrate these results, numerical simulations are performed for cases where a Lur'e like system is synchronized with a Chua's circuit, and where it is controlled to track a given trajectory.

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Harvesting energy from fat-tail random vibrations: an incomplete electronic analogy

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In recent work [1], we have found strong evidence that nonlinear "springs" with square well-like dynamics are more efficient for piezoelectric energy harvesting from random vibrations the "fatter" their tail becomes, because they better profit from the large and strongly self-correlated excursions of the environmental vibration process. We considered a 1D anharmonic oscillator mediating between a source of mechanical vibrations and a piezoelectric transducer, whose voltage $V(t) = K_c x(t)$ is fed onto a load circuit with resistance R and capacitance τ_p/R. The oscillator (mass m, damping constant γ) undergoes the transducer's back-reaction $K_v V(t)$, and its autonomous dynamics is governed by $U(x)$. The source of mechanical vibrations (to which it is coupled with strength σ) is regarded as stochastic, producing a *strongly colored* instantaneous force $\eta(t)$. The system is thus described by

$$m\ddot{x} = -U'(x) - \gamma\dot{x} - K_v V + \sigma\eta(t), \; \dot{V} = K_c\dot{x} - \frac{1}{\tau_p}V.$$

Being $V^2(t)/R$ the instantaneous power delivered to the load resistance, the measure of performance is V_{rms} during the observation interval. We have chosen a potential of the form

$$U(x) = -V_0/\{1 + \exp\left[(|x| - R)/a\right]\}$$

(left frame in Fig. 1) [2], which for $a \to 0$ becomes a square well of depth V_0 and width $2R$, whereas for $R >> a$ and $|x| > a$ resembles a harmonic potential.

It thus allows us to monitor the deviation from the linear case by just varying parameter a, whereas avoiding unreal infinite walls as it occurs with polynomial potentials [3].

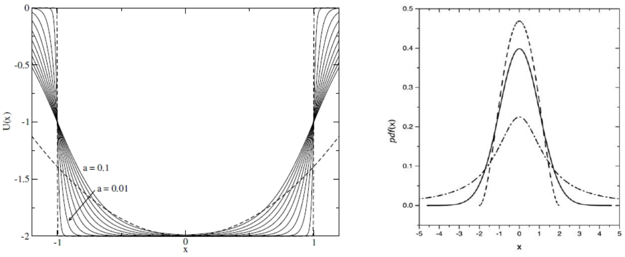

Fig. 1: Left: Woods-Saxon potential for $V_0 = 2$ and $R = 1$; right: pdf of the Tsallis noise.

As the source of mechanical vibrations we have chosen the Tsallis noise $\eta(t)$ [4], which is dynamically generated by

$$\dot{\eta} = -\frac{1}{\tau}\frac{d}{d\eta}V_q(\eta) + \frac{1}{\tau}\xi(t),$$
$$\text{with } V_q(\eta) = \frac{1}{\tau(q-1)}\ln\left[1 + \tau(q-1)\frac{\eta^2}{2}\right],$$

and $\xi(t)$ is Gaussian, centered, of variance 1 and white, namely $\langle\xi(t)\xi(t')\rangle = 2\delta(t-t')$. For $q = 1$, $\eta(t)$ is an Ornstein-Uhlenbeck process with self-correlation time τ. For $q > 3$, its pdf is not normalizable. For $1 < q < 5/3$, $\eta(t)$ is a supra-Gaussian process, and for $q < 1$, its pdf has compact support (right frame in Fig. 1). Our focus here are the supra-Gaussian ($1 < q < 5/3$) and Lévy-like ($5/3 < q < 3$) regimes; namely fat-tail distributions, which are commonly found in nature.

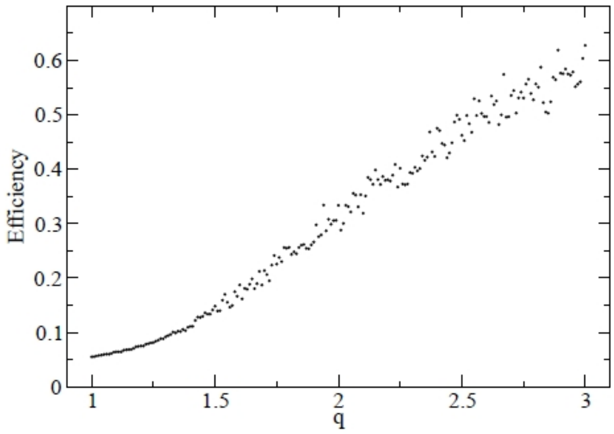

Fig. 2: Efficiency as a function of q, for $1 \leq q \leq 3$ (supra-Gaussian and Lévy-like regimes).

Through Heun integration of the framed equations here we show that in fact, the efficiency of the energy harvesting process - the power ratio between $V^2(t)$ (delivered by the system to a unit load resistance) and $\eta\dot{x}$ (delivered by the noise to the system) - grows monotonically as a function of q, up to its maximum value $q = 3$ (Fig. 2). These results spectacularly confirm our hypothesis. Moreover, in order to vividly illustrate the mechanism taking place, we have fed (through the audio output of a computer and using MATLAB's sound functions) a Zener diode, as a metaphor of a square well. The circuit is shown in panel 3(a), whereas the succession of scope captures in panels 3(b)-(d) illustrates how as q increases, surpassing the dashed line becomes more probable.

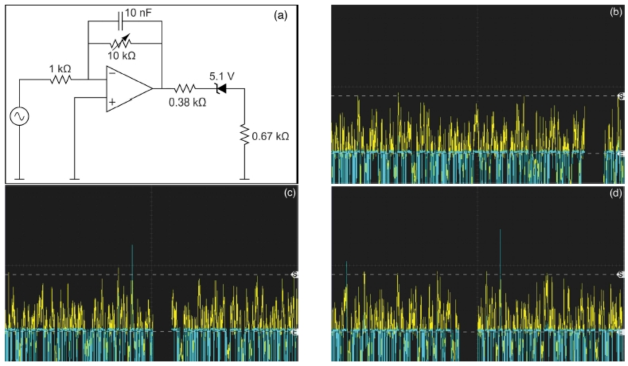

Fig. 3: (a) Circuit of the electronic analogy; (b,c and d) scope captures for $q = 1.0$, $q = 1.3$, and $q = 1.6$ respectively.

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Stochastic-resonant spatiotemporal patterns in an inhibitorily coupled FitzHugh-Nagumo ring

A.D. Sánchez[a], G.G. Izús[a], M.G. dell'Erba[a], G.A. Zarza[a], N. Martínez[a], L. Vassallo[a], R.R. Deza[a], G.V. Savino[b] and C.M. Formigli[b]

We study the stochastic-resonant synchronization properties of a ring of *excitable* FitzHugh–Nagumo cells, when nearest-neighbor units are coupled *diffusively* with strength E through their *inhibitor* fields. The system is submitted to a common *subthreshold* adiabatic signal $S(t) = A_0 \sin \Omega t$, and independent Gaussian white noises with common variance η:

$$\begin{aligned}
\dot{u}_i &= b\,u_i(1-u_i^2) - v_i + r_1\,\xi_i^{(u)}(t) + r_2\,\xi_i^{(v)}(t) + A_0 \sin\Omega t, \\
\dot{v}_i &= \epsilon\,(\beta\,u_i - v_i + C) + r_3\,\xi_i^{(u)}(t) + r_4\,\xi_i^{(v)}(t) \\
&\quad + E\,[(v_{i+1} - v_i) + (v_{i-1} - v_i)],
\end{aligned}$$

with $i = 1, \ldots, N$, $u_{N+1} \equiv u_1$ and $u_0 \equiv u_N$. The parameters (some of them dictated by consistency) are $E = 0.5$, $A_0 = 0.011$, $\Omega = 0.002$, $\epsilon = 0.01$, $b = 0.01$, $\beta = 0.035$, $C = 0.02$, $r_1 = \cos 0.05$, $r_2 = \sin 0.05$, $r_3 =$

ϵr_1, $r_4 = \epsilon r_2$. The germ of the numerically observed stochastic-resonant spatiotemporal self-organization of the excitation activity, is captured in a two-cell model for which both analytical [1] and experimental results (on an electronic analogue [2]) are discussed. Figures 1 and 2 depict respectively the electronic analogue of the two-cell model and an oscilloscope capture showing the (stochastic-resonant) noise-induced alternance between activation patterns.

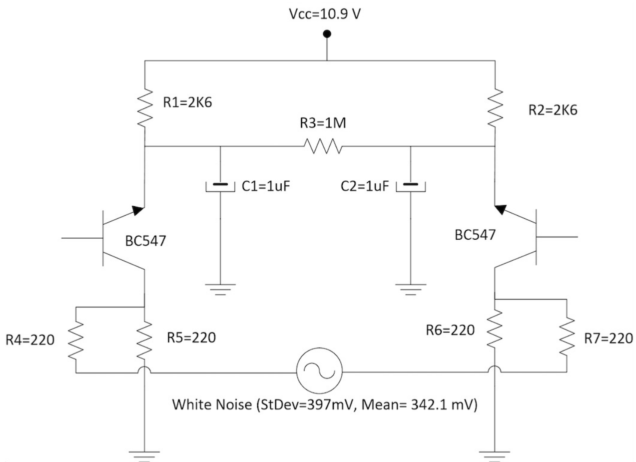

Fig. 1: Electronic analogue of the two-cell model.

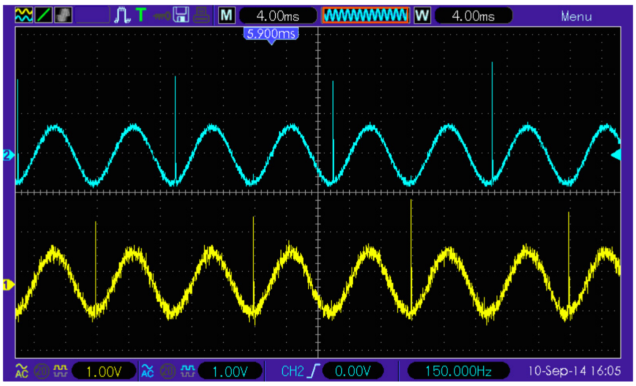

Fig. 2: Oscilloscope capture showing the (stochastic-resonant) noise-induced alternance between activation patterns.

[1] A.D. Sánchez, G.G. Izús, M.G. dell'Erba and R.R. Deza, "A reduced gradient description of stochastic-resonant spatiotemporal patterns in a FitzHugh–Nagumo ring with electric inhibitory coupling", Phys. Lett. A **378**, 1579–1583 (2014).

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Automatic melody generation considering motif using genetic algorithm

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Since the first approach to the automatic composition in 1957, a lot of methods for the automatic composition have been proposed. In this research, we propose an automatic melody generation considering motif using genetic algorithm [1]. In the proposed automatic melody generation system, sample melody is divided into some motifs, and rhythm sequences of all motifs are generated randomly considering rhythm features of the sample melody. And then, the melodies are generated to the rhythm sequences by genetic algorithms.

In the proposed system, the sample melody is divided into some motifs, and the new melodies are generated considering motifs. In this system, first, rhythm sequences of all motifs are generated considering rhythm features of sample melody. And then, some melodies are generated to the rhythm sequences by genetic algorithm. In this system, the number corresponding to tone candidates for each sound in basic motifs and derivation motif generation rules are expressed as genes. In the proposed system, the fitness of the gene for each melody is calculated based on (1) sequences of non-harmonic tones, (2) distribution of difference between two tones, (3) sequences of leaps, (4) derived notes and (5) last tone.

Figure 1 shows an example of generated melody by the proposed system. In this figure, A_0 and so on show the beginning of motif. Figure 2 shows a transition of fitness. Figure 3 shows the distribution of difference between two tones. As shown in this figure, the distribution of difference between two tones of initial individuals is not similar to that in the sample melody. In contrast, the distribution of difference between two tones in the 100th generation is similar to that in the sample melody.

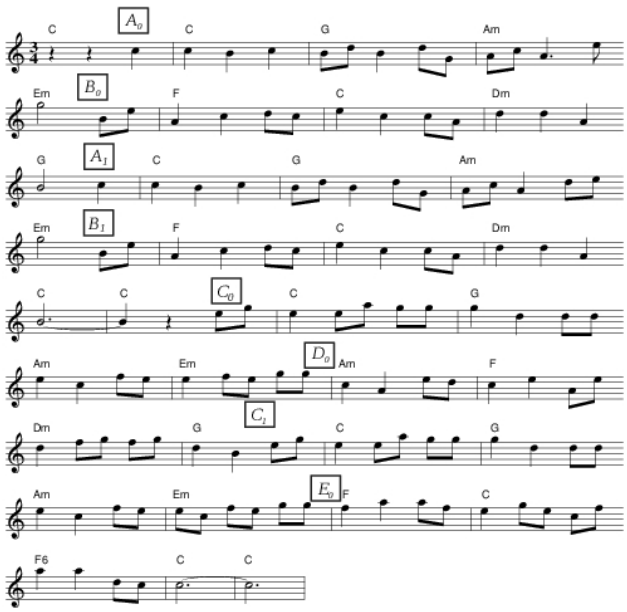

Fig. 1: Example of generated melody.

[1] D.E. Goldberg: Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley Longman Publishing, 1989.

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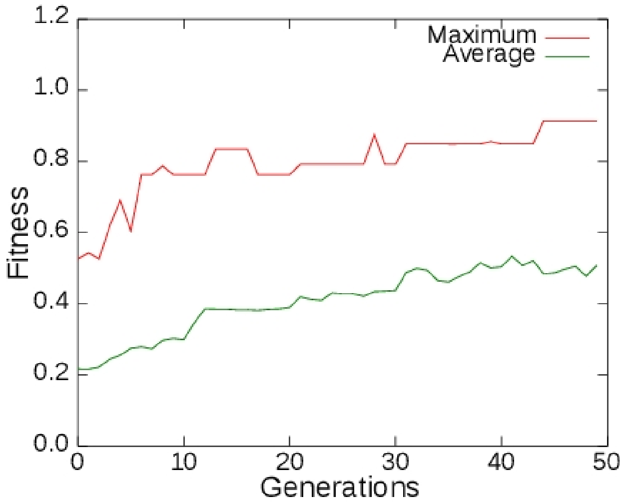

Fig. 2: Transition of fitness.

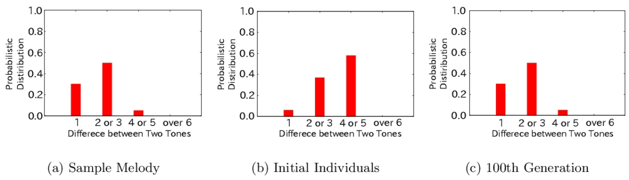

Fig. 3: Distribution of difference between two tones.

Booklet composed by T. Lorimer and F. Gomez.