

# CHAOS 2009

## Book of Abstracts

Chaotic Modeling and Simulation

International Conference

**Editor**

**Christos H. Skiadas**



**June 1 - 5, 2009**

**Chania Crete Greece**

**MAICh**  
**Prefecture of Chania**  
**Swets**

# Introduction

## Chaotic Modeling and Simulation International Conference

Chania, Crete (Greece) June 1 - 5, 2009

It is our pleasure to welcome the guests, participants and contributors to the 2<sup>nd</sup> International Conference (CHAOS2009) on Chaotic Modeling, Simulation and Applications. The study of nonlinear systems and dynamics has emerged as a major area of interdisciplinary research and found very interesting applications. This conference is intended to provide a widely selected forum among Scientists and Engineers to exchange ideas, methods, and techniques in the field of Nonlinear Dynamics, Chaos, Fractals and their applications in General Science and in Engineering Sciences.

The principal aim of CHAOS2009 International Conference is to expand the development of the theories of the applied nonlinear field, the methods and the empirical data and computer techniques, and the best theoretical achievements of chaotic theory as well. CHAOS2009 Conference provides a forum for bringing the various groups working in the area of Nonlinear Systems and Dynamics, Chaotic theory and Application for exchanging views and reporting research findings.

We thank all the contributors to the success of this conference and especially the authors of this *Book of Abstracts* of CHAOS2009.

Chania, May 2009



*Christos H. Skiadas*  
Conference Chair

## Honorary Committee

### David Ruelle

Academie des Sciences de Paris

Honorary Professor at the Institut des Hautes Etudes Scientifiques of Bures-sur-Yvette, France

### Leon O. Chua

EECS Department, University of California, Berkeley, USA

Editor of the International Journal of Bifurcation and Chaos

### Ji-Huan He

Donghua University, Shanghai, China

Editor of Int. Journal of Nonlinear Sciences and Numerical Simulation

## International Scientific Committee

- C. H. Skiadas (Technical University of Crete, Chania, Greece), Chair  
H. Adeli (The Ohio State University, USA)  
N. Akhmediev (Australian National University, Australia)  
M. Amabili (McGill University, Montreal, Canada)  
J. Awrejcewicz (Technical University of Lodz, Poland)  
S. Bishop (University College London, UK)  
T. Bountis (University of Patras, Greece)  
Y. S. Boutalis (Democritus University of Thrace, Greece)  
C. Chandre (Centre de Physique Theorique, Marseille, France)  
M. Christodoulou (Technical University of Crete, Chania, Crete, Greece)  
P. Commendatore (Universit  di Napoli 'Federico II', Italy)  
D. Dhar (Tata Institute of Fundamental Research, India)  
J. Dimotikalis (Technological Educational Institute, Crete, Greece)  
B. Epureanu (University of Michigan, Ann Arbor, MI, USA)  
G. Fagiolo (Sant'Anna School of Advanced Studies, Pisa, Italy)  
V. Grigoras (University of Iasi, Romania)  
L. Hong (Xi'an Jiaotong University, Xi'an, Shaanxi, China)  
G. Hunt (Centre for Nonlinear Mechanics, University of Bath, Bath, UK)  
T. Kapitaniak (Technical University of Lodz, Lodz, Poland)  
A. Kolesnikov (Southern Federal University, Russia)  
G. P. Kapoor (Indian Institute of Technology Kanpur, Kanpur, India)  
V. Krysko (Dept. of Math. and Modeling, Saratov State Technical University, Russia)  
W. Li (Northwestern Polytechnical University, China)  
B. L. Lan (School of Engineering, Monash University, Selangor, Malaysia)  
V. J. Law (Dublin City University, Glasnevin, Dublin, Ireland)  
V. Lucarini (University of Bologna, Italy)  
J. A. T. Machado (ISEP-Institute of Engineering of Porto, Porto, Portugal)  
W. M. Macek (Cardinal Stefan Wyszyński University, Warsaw, Poland)  
P. Mahanti (University of New Brunswick, Saint John, Canada)  
G. M. Mahmoud (Assiut University, Assiut, Egypt)  
P. Manneville (Laboratoire d'Hydrodynamique, Ecole Polytechnique, France)  
N. Mastorakis (Techn. Univ. of Sofia, Bulgaria and ASEI Greece)  
A. S. Mikhailov (Fritz Haber Institute of Max Planck Society, Berlin, Germany)  
M. S. M. Noorani (Universiti Kebangsaan Malaysia)  
G. V. Orman (Transilvania University of Brasov, Romania)  
S. Panchev (Bulgarian Academy of Sciences, Bulgaria)  
G. Pedrizzetti (University of Trieste, Trieste, Italy)  
F. Pellicano (Universita di Modena e Reggio Emilia, Italy)  
S. V. Prants (Pacific Oceanological Institute of RAS, Vladivostok, Russia)  
A. G. Ramm (Kansas State University, Kansas, USA)  
G. Rega (University of Rome "La Sapienza", Italy)  
H. Skiadas (Hanover College, Hanover, USA)  
V. Snasel (VSB-Technical University of Ostrava, Czech)  
D. Sotiropoulos (Technical University of Crete, Chania, Crete, Greece)  
B. Spagnolo (University of Palermo, Italy)  
P. D. Spanos (Rice University, Houston, TX, USA)  
J. C. Sprott (University of Wisconsin, Madison, WI, USA)  
S. Thurner (Medical University of Vienna, Austria)  
D. Trigiante (Universit  di Firenze, Firenze, Italy)  
G. Unal (Yeditepe University, Istanbul, Turkey)  
A. Valyaev (Nuclear Safety Institute of RAS, Russia)  
A. Vakakis (National Technical University of Athens, Greece)  
J. P. van der Weele (University of Patras, Greece)  
M. Wiercigroch (University of Aberdeen, Aberdeen, Scotland, UK)

A. Katsirikou, Conference Secretary

# Keynote Talks

## **Professor Marco Amabili**

Department of Mechanical Engineering  
McGill University, Montreal, Canada

[Chaotic Vibrations of Circular Cylindrical Shells: Galerkin versus reduced-order models](#)

## **Professor Jan Awrejcewicz**

Department of Automatics and Biomechanics, Technical University of Lodz, Lodz, Poland

[Deterministic Chaos Machine: Experimental vs. Numerical Investigations](#)

## **Professor Leon D. Iasemidis**

Associate Editor, Int. J. Neural Systems

Director and Founder, The Brain Dynamics Laboratory

The Harrington Department of Bioengineering and Electrical Engineering

Arizona State University, USA

[Chaos, Brain and Epilepsy: A Bioengineering approach](#)

## **Professor Alfred Inselberg**

School of Mathematical Sciences

Tel Aviv University

Tel Aviv, Israel

[Multidimensional Visualization and its Applications](#)

## **Professor Pier A. Mello**

Institute of Physics

Universidad Nacional Autonoma de Mexico, Mexico

[QUANTUM SCATTERING AND TRANSPORT IN CLASSICALLY CHAOTIC CAVITIES:](#)

[An overview of Old and New Results](#)

## **Professor Sergey V. Prants**

Pacific Oceanological Institute of the Russian Academy of Sciences

Vladivostok, Russia

[Quantum chaos with atoms in a laser field](#)

## **Professor Alexander G. Ramm**

Mathematics Department, Kansas State University

Manhattan, KS 66506-2602, USA

<http://www.math.ksu.edu/~ramm>

[Acoustic and electromagnetic wave scattering by many small particles and creating materials with desired properties](#)

## **Professor Giuseppe Rega**

Department of Structural Engineering and Geotechnical Engineering

University of Rome 'La Sapienza', Italy

[Experimental unfolding and theoretical model of the transition to complex dynamics in sagged cables](#)

## **Professor Pol D. Spanos**

Department of Mechanical Engineering and Materials Science

Department of Civil and Environmental Engineering

Rice University, Houston, TX, USA

Editor, Journal of Probabilistic Mechanics and Journal of Nonlinear Mechanics

[Simulation Algorithms for Nonlinear Stochastic Dynamics Problems](#)



## *Contents*

<b>Invited, Special and Contributed Sessions: Abstracts</b>	<b>1 – 100</b>
<b>CATS Workshop: Abstracts</b>	<b>101 – 124</b>
<b>Author Index</b>	<b>125 –</b>





### **Using a Nonnegative Matrix Factorization (NMF) for Clustering Data**

Hussam Dahwa Abdulla, Martin Polovincak, Vaclav Snasel  
Department of Computer Science, VSB – Technical University of Ostrava  
hussamdahwa@hotmail.com, martin.polovincak.feii@vsb.cz, vaclav.snasel@vsb.cz

There are many search engines in the web and when asked, they return a long list of search results, ranked by their relevancies to the given query. Web users have to go through the list and examine the titles and (short) snippets sequentially to identify their required results. In this paper we present how usage of Nonnegative Matrix Factorization (NMF) can be good solution for the search results clustering.

Key Words: Matrix Decomposition, Nonnegative Matrix Factorization (NMF), search results clustering, web mining.

### **Improved $\varepsilon$ -expansion in theory of turbulence Calculation of Kolmogorov constant and skewness factor**

L.Ts. Adzhemyan, M. Hnatic, J. Honkonen  
University of P.J.Safarik, Kosice, Slovak republik  
hnatic@saske.sk

The method for improvement of  $\varepsilon$ -expansion in the theory of developed  $d$ -dimensional turbulence, based on the renormalization of random forcing in stochastic Navier-Stokes equation, has been suggested. This renormalization takes into account additional divergences, which appear as  $d \rightarrow 2$ . The first  $n$  terms of routine  $\varepsilon$ -expansion are correctly reproduced in  $n$ -approximation of perturbation theory, which includes such a renormalization, and in the rest coefficients of this expansion the first  $n$  terms of its Loran series are correctly reproduced with respect to the parameter  $d-2$ .

The Kolmogorov constant and skewness factor calculated in the one-loop approximation are in a tolerable agreement with their most acceptable experimental values.

Key Words: developed turbulence, field-theoretic methods, renormalization group, scaling, Kolmogorov constant, skewness

### **Analysis of multiple solutions in bifurcation diagrams to avoid unexpected dynamics**

Jan-Olov Aidanpää  
Luleå University of Technology, Div Solid Mechanics, Luleå Sweden.  
joa@ltu.se

In mechanical applications it is essential that unexpected dynamics are avoided. The industry wants to build reliable machines that are not sensitive to initial conditions. Therefore, a simple method has been developed to extract all sets of stable bifurcation diagrams. The method gives a designer a good overview of possible dynamics and thereby the possibility to select a safe operating region. The method is described and demonstrated with a rub-impact rotor. The practical usage of this method is to help the designer to determine if parameter ranges exist where coexistent solutions will appear. Thereby one can design the system to work in parameter ranges where only one acceptable solution exists.

Keywords: Multiple solutions, dynamics, rub, impact, bifurcation diagrams.

### **The Influence of Machine Saturation on Bifurcation and Chaos in Multimachine Power Systems**

Majdi M. Alomari and Jian Gue Zhu  
University of Technology, Sydney (UTS), Australia  
majdi.m.alomari@eng.uts.edu.au

A bifurcation theory is applied to the multimachine power system to investigate the effect of iron saturation on the complex dynamics of the system. The second system of the IEEE second

benchmark model of Subsynchronous Resonance (SSR) is considered. The system studied can be mathematically modeled as a set of first order nonlinear ordinary differential equations with ( $\mu=Xc/XL$ ) as a bifurcation parameter. Hence, bifurcation theory can be applied to nonlinear dynamical systems, which can be written as  $dx/dt=F(x;\mu)$ . The results show that the influence of machine saturation expands the unstable region when the system loses stability at the Hopf bifurcation point at a less value of compensation.

Keywords: Machine Saturation, Hopf Bifurcation, Chaos, Subsynchronous Resonance, Damper Windings.

### **Chaotic Vibrations of Circular Cylindrical Shells: Galerkin Versus reduced-order Models**

M. Amabili, M. P. Païdoussis

Department of Mechanical Engineering, McGill University, Montreal, Canada

The response of water-filled, geometrically nonlinear simply supported circular cylindrical shells to harmonic excitation in the spectral neighbourhood of the fundamental natural frequency is investigated. The response is investigated for a fixed excitation frequency by using the excitation amplitude as bifurcation parameter for a wide range of variation. Bifurcation diagrams of Poincaré maps obtained from direct time integration and calculation of the Lyapunov exponents and Lyapunov dimension have been used to study the system. By increasing the excitation amplitude, the response undergoes (i) a period-doubling bifurcation, (ii) subharmonic response, (iii) quasi-periodic response and (iv) chaotic behaviour with up to 16 positive Lyapunov exponents (hyperchaos). The model is based on Donnell's nonlinear shallow-shell theory, and the reference solution is obtained by the Galerkin method. The proper orthogonal decomposition (POD) method is used to extract proper orthogonal modes that describe the system behaviour from time-series response data. These time-series have been obtained via the conventional Galerkin approach (using normal modes as a projection basis) with an accurate model involving 16 degrees of freedom (dofs), validated in previous studies. The POD method, in conjunction with the Galerkin approach, permits building a lower-dimensional model as compared to those obtainable via the conventional Galerkin approach. Periodic and quasi-periodic response around the fundamental resonance for fixed excitation amplitude can be very successfully simulated with a 3-dof reduced-order model. However, in the case of large variations of the excitation, even a 5-dof reduced-order model is not fully accurate.

#### REFERENCES

- 1) M. Amabili, 2008, *Nonlinear Vibrations and Stability of Shells and Plates*, Cambridge University Press, New York, USA.
- 2) M. Amabili, A. Sarkar and M. P. Païdoussis, 2006, *Journal of Sound and Vibration*, Vol. 290, No. 3-5, pp. 736-762. Chaotic vibrations of circular cylindrical shells: Galerkin versus reduced-order models via the proper orthogonal decomposition method.
- 3) M. Amabili and C. Touzé, 2007, *Journal of Fluids and Structures*, Vol. 23, pp. 885-903. Reduced-order models for nonlinear vibrations of fluid-filled circular cylindrical shells: Comparison of POD and asymptotic nonlinear normal modes methods.
- 4) S. A. Zahorian, M. Rothenberg, Principal component analysis for low-redundancy encoding of speech spectra. *Journal of the Acoustical Society of America* 69 (1981) 519-524.
- 5) L. Sirovich, Turbulence and dynamics of coherent structures, Part I: coherent structures. *Quarterly of Applied Mathematics* 45 (1987) 561-571.
- 6) M. F. Azeez, A. F. Vakakis, Proper orthogonal decomposition (POD) of a class of vibroimpact oscillations. *Journal of Sound and Vibration* 240 (2001) 859-889.
- 7) G. Kerschen, B. F. Feeny, J.-C. Golinval, On the exploitation of chaos to build reduced-order models. *Computer Methods in Applied Mechanics and Engineering* 192 (2003) 1785-1795.

### **Chaotic Vibrations of Circular Cylindrical Shells Conveying Flowing Fluid**

M. Amabili, K. Karagiozis, M. P. Païdoussis

Department of Mechanical Engineering, McGill University, Montreal, Canada

Shells containing flowing fluids are widely used in engineering applications, and they are subject to manifold excitations of different kinds, including flow excitations. Usually these shells are made as thin as possible for weight and cost economy; therefore, they are quite fragile, and their response to such excitations is of great interest. The response of a shell conveying fluid to harmonic excitation, in the spectral neighbourhood of one of the lowest natural frequencies, is investigated for different flow velocities. The theoretical model has been developed using the Donnell theory retaining in-plane inertia. Linear potential flow theory is applied to describe the fluid-structure interaction, and the steady viscous effects are added to take into account flow viscosity. For different amplitudes and frequencies of the excitation and for different flow velocities, the following are investigated numerically: (i) periodic response of the system; (ii) unsteady and stochastic motion; (iii) loss of stability by jumps to bifurcated branches. The effect of the flow velocity on the nonlinear periodic response of the system has also been investigated. Poincaré maps, bifurcation diagrams and Lyapunov exponents have been used to study the unsteady and stochastic dynamics of the system. Amplitude-modulated motions, multi-periodic solutions, chaotic responses, cascades of bifurcations as the route to chaos and the so-called "blue sky catastrophe" phenomenon have all been observed for different values of the system parameters.

#### REFERENCES

1. M. Amabili, 2008, *Nonlinear Vibrations and Stability of Shells and Plates*, Cambridge University Press, New York, USA.
2. M. Amabili, F. Pellicano and M. P. Païdoussis, 2000, *Journal of Sound and Vibration*, Vol. 237, No. 4, pp. 641-666. Non-linear dynamics and stability of circular cylindrical shells containing flowing fluid. Part IV: large-amplitude vibrations with flow.
3. M. Amabili, F. Pellicano and M. P. Païdoussis, 2002, *Computers and Structures*, Vol. 80, No. 9-10, pp. 899-906. Non-linear dynamics and stability of circular cylindrical shells conveying flowing fluid.
4. E. J. Doedel, A. R. Champneys, T. F. Fairgrieve, Y. A. Kuznetsov, B. Sandstede and X. Wang 1998 *AUTO 97: Continuation and Bifurcation Software for Ordinary Differential Equations (with HomCont)*. Montreal, Canada: Concordia University.

### **The boundary value problems for spectrally loaded heat operator**

Muvasharkhan J., Amangaliyeva M.M., Akhmanova D.M., Jenaliyev M.T., Ramazanov M.I.,  
Tuimebayeva A.E.

Institute of Mathematics, Almaty, Republic of Kazakhstan

[muvasharkhan@gmail.com](mailto:muvasharkhan@gmail.com)

In this work we continue a investigation of the boundary value problems for spectrally loaded parabolic equations in unbounded regions. The order of the derivative in the loaded summand is equal to that of the differential part of the operator. The space variable loading point moves in an law  $x(t)=t^\omega$ .

Key Words: Spectrally loaded heat operator

### **Phase Synchronization in Systems coupled through a Dynamic Environment**

G. Ambika and V. Resmi

[g.ambika@iiserpune.ac.in](mailto:g.ambika@iiserpune.ac.in)

We present the results of our studies in phase synchronization in systems coupled indirectly through a common but dynamic environment. This is an interesting situation where the environment is kept dynamic by feedback from the systems and the dynamics of the environment drives the systems collectively. Such a situation arises in many biological systems, for example a system of neurons that communicate through a chemical medium. We specifically study two cases, a system of Rossler oscillators and a system of neurons.

Key Words: phase synchronization, environmental coupling, neurons, Rossler oscillators

### **Parametric Characterization of Multifractal Spectra**

G Ambika<sup>1</sup>, K P Hari Krishnan<sup>2</sup>, R Misra<sup>3</sup> & R E Amritkar<sup>4</sup>

<sup>1</sup> Indian Institute of Science Education & Research, <sup>2</sup> The Cochin College, <sup>3</sup> Inter University Centre for Astronomy & Astrophysics, <sup>4</sup> Physical Research Laboratory, India  
g.ambika@iiserpune.ac.in

We propose a fully automated algorithmic scheme to compute the f-alpha spectrum from a time series. We establish that the spectrum can be characterized using three parameters uniquely. Starting from a standard mutiscale cantor set, we evaluate analytically and numerically its f-alpha values and observe that the formalism can give information only upto two sclaes about a mutifractal set. This is verified by taking several examples and real world data sets.

Key Words: mutifractals, cantor set, f-alpha spectrum

### **Chaos in multiplicative systems**

Dorota Aniszewska and Marek Rybaczuk

Institute of Materials Science and Applied Mechanics Wroclaw University of Technology  
[dorota.aniszewska@pwr.wroc.pl](mailto:dorota.aniszewska@pwr.wroc.pl), [marek.rybaczuk@pwr.wroc.pl](mailto:marek.rybaczuk@pwr.wroc.pl)

The goal of the paper is chaos examination in multiplicative systems. The paper collects results of numerical simulations as well as presentation of methods applicable in the case of multiplicative systems. Chaos examination concerns one-dimensional multiplicative version of logistic equation and multi-dimensional nonlinear system described with multiplicative derivatives. The classical Lorenz system transformed into multiplicative version was chosen for analysis of stability and chaotic behaviour.

Keywords: multiplicative calculus, logistic equation, the Lorenz system, Runge-Kutta method, Lyapunov exponent.

### **Correlation dimension of Magnetoencephalographic signals as a marker for brain pathogeny.**

Panagiotis E. Antoniou, Athanasia Kotini, Elina Mavraki, Photios A. Anninos, Haritomeni Piperidou  
Medical School, Democritus University of Thrace, Alexandroupolis, Greece  
[pantonio@med.duth.gr](mailto:pantonio@med.duth.gr)

Non linear signal analysis is a powerful technique that reveals qualitative and quantitative differentiations between different dynamical systems (biological or otherwise). Specifically the correlation dimension of a signal time series can be considered as a direct measure of the underlying dynamical system's complexity. There are indications that the healthy brain, due to the statistical nature of neuronal discharges, is a very high, theoretically infinite complexity system. Thus low dimensionality discovered in the Magnetoencephalographic signals can be construed as a sign of pathogeny.

Presented here is part of an ongoing effort to quantitatively investigate the differentiation of the correlation dimension of Magnetoencephalograms (MEG) received from persons having clinically diagnosed brain pathogeny and normal healthy volunteers.

We present MEG recordings from patients with different diseases of the central nervous system. Specifically we present MEG recordings of patients with malignant CNS lesions, a highly localized and anatomical pathology, and MEG recordings of patients diagnosed with idiopathic generalized epilepsy, a disease without localized lesion. Moreover we studied the MEG signals from healthy volunteers.

A 122-channel SQUID biomagnetometer in an electromagnetically shielded room was used to record the MEG signals and the Grassberger-Procaccia method for the estimation of the correlation dimension was applied on the phase space reconstruction of the recorded signal from each subject.

The results of this study support the hypothesis that low dimensionality, low complexity, of the signal's dynamic is a sign of high organization in the underlying dynamical system, that is, in our case, the brain.

Keywords: Chaos in the Brain, Magnetoencephalography, Non-linear signal processing, Biomedical signals, Correlation dimension.

### **Forecasting chaotic time series by simulating annealing**

Atsalakis George, Tsakalaki Katerina and Skiadas Christos  
Technical University of Crete, Greece  
[atsalak@otenet.gr](mailto:atsalak@otenet.gr) ; [kattsak\\_89@hotmail.com](mailto:kattsak_89@hotmail.com)

This paper examines how simulating annealing is relative to linear and polynomial approximations to forecast a time series that is generated by the chaotic Mackey-Glass differential delay equation. The forecasting horizon is one step ahead. A series of regressions with polynomial approximators and a simulating annealing model is taking place and compare the multiple correlation coefficients. The experimental results confirm that the simulating annealing algorithm performs well as a global search algorithm. Furthermore, it is shown that using the genetic algorithms to determine their values can improve the forecasting effectiveness of the resulting model when applied to a chaotic time series problem.

**Keywords:** simulating annealing forecasting, chaos forecasting, Mackey-Glass forecasting, time series forecasting.

### **Controlling Chaos in Cardiac Arrhythmia**

Samareh Attarsharghi<sup>1</sup>, Mohammad Reza Jahed-Motlagh<sup>2</sup>,  
Nastaran Vasegh<sup>3</sup> and Ali Khaki-Sedigh<sup>4</sup>

<sup>1</sup>Department of Engineering and Technical, Science and Research Branch,  
Islamic Azad University, <sup>2</sup>Computer Engineering Department, Iran University of Science and  
Technology, <sup>3</sup>Faculty of Electrical Engineering , K.N. Toosi University of Technology, <sup>4</sup>Faculty of  
Electrical Engineering , K.N. Toosi University of Technology,  
Tehran, Iran

[sasharghi@gmail.com](mailto:sasharghi@gmail.com), [jahedmr@iust.ac.ir](mailto:jahedmr@iust.ac.ir), [vasegh@eetd.kntu.ac.ir](mailto:vasegh@eetd.kntu.ac.ir), [sedigh@kntu.ac.ir](mailto:sedigh@kntu.ac.ir)

In order to investigate controlling abnormal heart behaviors with chaotic pattern, fixed-points which are interpreted as desired interbeat intervals are imposed on the logistic map via a control law. An adaptive control approach based on delayed feedback control methodology is presented to stabilize the imposed fixed-points. Simulation results are provided to show the effectiveness of the proposed method. Finally advantages of the controller are mentioned.

Keywords: Chaotic behavior, Delayed feedback control, Stabilization, Inerbeat interval.

### **Modeling and Simulation of Self-Organized Criticality in Landslides**

Markos Avlonitis<sup>1</sup> and George Efremidis<sup>2</sup>

<sup>1</sup> Department of Informatics, Ionian University, Corfu, Greece, <sup>2</sup> Sector of Geotechnical Engineering,  
Department of Civil Engineering, University of Thessaly, Volos, Greece,  
[avlon@ionio.gr](mailto:avlon@ionio.gr), [gefrain@civ.uth.gr](mailto:gefrain@civ.uth.gr)

The paper elaborates on an avalanche-like dynamic model for catastrophic landslides introducing the effect of water diffusion along the failure plane. The main idea lies on the assumption that the stochastic nature of water diffusion along the failure plane results in a dynamic decrease in time of the shear strength for the entire rock mass parallel to this plane. To this end, a single stochastic constitutive equation is proposed, modeling external and internal stresses, spatial interactions

between neighborhood sites as well as water diffusion, which are shown to reproduce correctly experimental observations. Indeed, simulations of a discrete automaton were performed, in order to study the model dynamics. It is demonstrated that the model exhibits features of self-organized critical behavior and solves the reported discrepancy between simulations outcomes and experimental data for the corresponding power law exponent.

Keywords: Catastrophic landslides, Water diffusion, Discrete automaton, Self-Organized Criticality.

### **Deterministic Chaos Machine: Experimental vs Numerical Investigations**

Jan Awrejcewicz

Department of Automatics and Biomechanics, Technical University of Lodz, Poland

awrejcew@p.lodz.pl

Deterministic chaos machine consisting of the triple pendulum as well as of driving and measurement subsystems is presented and studied (see [1], [2], [3]). The triple physical pendulum is designed as a system of two symmetrically joint pendulums to eliminate stress caused by torques and/or forces out of the pendulum's plane dynamics. It possesses a module-like structure and a stand being symmetrical steel welded construction. The pendulum-driving subsystem consists of two engines of slow alternating currents and optoelectronic commutation. The engine stator has been designed in such a way that the current intensity in the windings is linearly dependent on the engine torque owing to the removal of the ferromagnetic cores. The LabView software environment is applied. Namely, blocks are linked by lines of various colors and patterns in the environment and represent some predefined application procedures (reading and writing to channel inputs and outputs, numerical analysis, etc.) A series of measured data is stored in the text files and shown in various wave form graphs. In addition, a mathematical model of the experimental rig is derived as a system of three second order strongly nonlinear ODEs. Mathematical modeling includes details, taking into account some characteristic features (for example, real characteristics of joints built by the use of roller bearings) as well as some imperfections (asymmetry of the forcing) of the real system. Parameters of the model are obtained by a combination of the estimation from experimental data and direct measurements of the system's geometric and physical parameters. A few versions of the model of resistance in the joints are tested in the identification process. Good agreement between both numerical simulation results and experimental measurements have been obtained and presented. Some novel features of our real system chaotic dynamics have been reported.

#### References

- [1] Awrejcewicz J., Kudra G., Wasilewski G., Experimental and numerical investigation of chaotic regions in the triple physical pendulum, Special Issue of Nonlinear Dynamics, 50(4), 755-766, 2007.
- [2] Awrejcewicz J., Supeł B., Lamarque C.-H., Kudra G., Wasilewski G., Olejnik P., Numerical and experimental study of regular and chaotic motion of triple physical pendulum, International Journal of Bifurcation and Chaos, 18(10), 2883-2915, 2008.
- [3] Awrejcewicz J., Kudra G., Wasilewski G., Chaotic zones in triple pendulum dynamics observed experimentally and numerically, Applied Mechanics and Materials, 9, 1-17, 2008.

### **Estimations of the periodic regularities in time series of water runoff of Neman River for its long range forecasting**

Alexey V. Babkin

State Hydrological Institute, Russia

Abav@mail.ru

Neman River is one of the largest rivers in Europe. Its length is equal to 937 km. Neman has origin in the Minsk Upland, Belarus, and flows west through a broad, swampy basin. It then turns north and passing through the territories of Lithuania and Russia discharge its water into the Baltic Sea.

The discontinuous time series (TS) of Neman River runoff are available from 1859. Observations are made near Smalininkai, Lithuania. The runoff of the river is chaotic and significantly variable. Its minimum of 1969 was equal to 11,2 km<sup>3</sup>/year, while the maximum of 1916 approaches the value of

25,2 km<sup>3</sup>/year. So, the diapason of the changes of the annual runoff of Neman River is equal to 14 km<sup>3</sup>/year.

The variation of runoff of Neman River impacts to different branches of modern economy, such as fishery, water transport and tourism, industrial and communal water consumption.

The development of the methodology of analysis of TS of Neman River runoff, revealing their regularities for long range forecasting are actual research and practical tasks closely related with the problems of development of the regional economy and integrated water resources management. Long range forecasts should account the hidden periodicities in runoff dynamics.

The present study is aimed for the development of the method of periodicities for the analysis, modeling and forecasting of TS of Neman River runoff. Annual time series were analyzed and modeled in the time interval from the beginning of instrumental observations up to 1995, the training forecasts for 1996 – 2005, and for the intervals of 1996 – 2000 and 2001 – 2005, were computed and tested by the new data. The forecast computed by the method of periodicities was compared with the mean value forecast.

The work was performed with support of grants of President of Russian Federation (МД-3616.2008.5) and RFFI – the Russian Fund for Fundamental Research (07-05-00465).

Key Words: time series analysis, river runoff, periodicities, forecast

#### References

Apollov B.A., Kalinin G.P. and Komarov V.D. The manual for the hydrological forecasts. – Leningrad, Gidrometeoizdat, 1974, 419 pp. (in Russian)

Linnik Iu.V. Method of the least squares. – Moscow, Nauka, 1962, 350 pp. (in Russian)

Babkin A.V. An improved model of the assessment of periodic changes in the level and elements of the water balance of the Caspian Sea. – Meteorology and hydrology, 2005, N11, 63-73 (in Russian).

### **Some Issues and Results on the EnKF and Particle Filters for Meteorological Models**

Christophe Baehr<sup>1,2</sup> and Olivier Pannekoucke<sup>1</sup>

<sup>1</sup> Meteo-France / CNRS, <sup>2</sup> Universite de Toulouse Paul Sabatier Institut de Mathematiques, Toulouse, France

christophe.baehr@meteo.fr, olivier.pannekoucke@meteo.fr

In this paper we examine the links between Ensemble Kalman Filters (EnKF) and Particle Filters (PF). EnKF can be seen as a Mean-Field process with a PF approximation. We explore the problem of dimensionality on a toy model. To by-pass this difficulty, we suggest using Local Particle Filters (LPF) to catch non-linearity and feed larger scale EnKF. To go one step forward we conclude with a real application and present the filtering of perturbed measurements of atmospheric wind in the domain of turbulence. This example is the cornerstone of the LPF for the assimilation of atmospheric turbulent wind. These local representation techniques will be used in further works to assimilate singular data of turbulence linked parameters in non-hydrostatic models.

Keywords: Ensemble Kalman Filter, Particle Filter, Data Assimilation, Mean-Field Process.

### **The Application of Nonlinear Waves Methods to Markov Diffusion Stochastic Processes in Economics, Genetics, Astrophysics, Seismology, Psychology**

A.G. Bagdoyev, Yu.S. Safaryan, D.R. Karapetyan, H.A. Martirosyan, G.S. Mikaelyan

The application of nonlinear waves methods to Markov diffusion stochastic processes in economics, genetics, astrophysics, seismology, psychology is done. The known diffusion equations of Kolmogorov-Fokker-Plank-Einstein-Raleigh are supplemented by addition of nonlinear term, by analogy with wave dynamics, since in vicinity of mean curves of processes parameters, connected

with the wave fronts for the mentioned diffusion equations for probability equations, and taking into account of nonlinearity. The analytic solution of nonlinear equation with shock wave is obtained and applications are carried out to various processes with strong disturbances of parameters.

Key Words: Nonlinear waves, stochastic processes in economics, biology, probabilities.

### **Synthesis of Nonlinear Model Predictive Controllers for Chaotic Systems**

Lianjun Bai, Daniel Coca  
University of Sheffield, Sheffield, UK  
[d.coca@sheffield.ac.uk](mailto:d.coca@sheffield.ac.uk)

This paper proposes a novel nonlinear predictive controller synthesis method for controlling chaotic systems. In this approach the nonlinear multi-step-ahead predictors are identified directly from experimental data so that the model of the chaotic system does not need to be known in advance. The proposed is computationally efficient and can deal effectively with noisy measurements. Numerical simulations are used to demonstrate the performance of the proposed approach.

Key Words: Nonlinear Predictive Control, Chaotic systems, Nonlinear System Identification

### **Local and Global Lyapunov Exponents in a Discrete Mass Waterwheel**

David Becerra Alonso and Valery Tereshko  
School of Computing, University of the West of Scotland, United Kingdom  
David.Becerra.Alonso, [Valery.Tereshko@uws.ac.uk](mailto:Valery.Tereshko@uws.ac.uk)

A generic Jacobian is calculated to obtain the Lyapunov exponents Malkus' system. However complete, the Lyapunov exponents obtained from the Jacobian do not appropriately show the distinction between chaos and order. A further explanation for this is required. We show how the waterwheel equations, chaotic as a whole, can be decomposed into a series of convergent equations. Chaos will then come in from the transition between any two of these convergent equations. We finally use a common numerical method, not based on the Jacobian, to obtain Lyapunov exponents that properly make the distinction between chaos and order.

### **Bounds upon Graviton mass, and making use of the difference between Graviton propagation speed and HFGW transit speed to observe post Newtonian corrections to Gravitational potential fields.**

Andrew Beckwith  
[Andrew.Beckwith@mail.uh.edu](mailto:Andrew.Beckwith@mail.uh.edu)

The author presents a post Newtonian approximation based upon an earlier argument / paper by Clifford Will as to Yukawa revisions of gravitational potentials in part initiated by gravitons with explicit mass dependence in their Compton wave length. The Li- Baker HFGW detector, with its ultra refined capacity to obtain relic HFGW signals is able to experimentally determine for HFGW empirical data sets which could determine upper bounds as to the existence of a graviton mass. Prior work with Clifford Will's idea was stymied by the application to binary stars and other such astro-physical objects with non useful frequencies topping off as up to 100 Hertz, thereby rendering Yukawa modifications of Gravity due to gravitons effectively an experimental curiosity which was not testable with any known physics equipment. The appearance of HFGW data sets as could be measured by the Li Baker detector gives a real chance as to experimentally obtain a measurable upper bound to the Compton wave length of Gravitons, which leads to other tests as to Gravitons existence as a measurable



quantity, contradicting Tony Rothman's (2006) assertion that a detector the size of Jupiter would be needed to obtain measurements of a single graviton.

### **Handle of self-descriptiveness of network cartographical tools**

Stanislav L. Belyakov, Marina L. Belyakova  
Technological Institute of Southern Federal University, Taganrog, Russia  
samoilov@fep.tsure.ru

The task of reception of as much as possible informative working areas of the electronic maps formed by inquiries of network clients with limited resources is considered. An example of the systems solving such task, is the cartographical Internet-services for transportable devices. Models of estimation of selfdescriptiveness at base and applied levels are offered, handle strategies on each of them are described.

Keywords: electronic maps, Internet-services, network clients, estimation models

### **Non Local Fluctuations in the Oscillation Systems**

V.V. Belyi  
sbelyi@izmiran.ru

Any oscillating system is characterized by two main parameters: the proper frequency and the quality factor (Q factor). The latter is inversely proportional to the width of the spectral line of the parameter fluctuations. The higher Q factor, the more sensitive the system is. In thermodynamic equilibrium, fluctuations are determined by the system temperature and the dissipation [1]. In the general case parameters of the systems can be change in both time and space. Inhomogeneities in space and time of these quantities will certainly also contribute to the fluctuations. The fluctuation-dissipation relation has been generalized to the non-equilibrium systems with slowly varying parameters [2]. The important conclusion of this analysis is to reveal that the spectral function of the fluctuations is determined not only by dissipation but also by the derivatives of the dispersion. The non-Joule dispersion contribution is characterized by a new non-local effect originating from an additional phase shift between the force and the response of the system. That phase shift results from the parametric control to the system.

In the context of plasma physics, using the Langevin approach and the time-space multiscale technique, it has been shown that the amplitude and the width of the spectral lines of the electrostatic field fluctuations and the electron form factor are determined not only by the imaginary (dissipative) part of the dielectric susceptibility but also by the derivatives of its real (dispersive) part [3]. As a result of the inhomogeneity, these properties become asymmetric with respect to the inversion of the sign of the frequency. In the kinetic regime, the form factor is more sensitive to space gradients than the spectral function of the electrostatic field fluctuations. This asymmetry of lines can be used as a diagnostic tool to measure local gradients in the plasma. These results are applicable to other oscillation systems and are important for the understanding of various behaviors observed in different field of physics.

1. Callen, H.B., and Welton, T.A., Phys. Rev. 83, 34 (1951).
2. Belyi V.V., Phys. Rev. E, 69, 017104, (2004)
3. Belyi V.V., Phys. Rev. Lett., 88, 255001, (2002)

Key Words: fluctuation-dissipation, non-local fluctuation, oscillations and circuits, Q-factor.

## **Ultrasonic Multiscale Modelling for Material NonDestructive Characterisation**

F. Bettayeb, K. Boussiha  
Research center on welding and control, Algiers, Algeria  
[fairouz\\_bettayeb@email.com](mailto:fairouz_bettayeb@email.com)

Acoustical characterization is an important item in materials testing and takes an increasing place during the fabrication and the "in service inspection" processes. Indeed, ultrasonic techniques have been commonly used in power and petrochemical industries for nearly 50 years and the often used technique is the echo-graphic in which the waves reflected by the material structures are observed and analyzed. Since, the performance of ultrasonic techniques are often affected by the physical structure of the component and by background noise, the effects of aging and environment on failure mechanisms cannot be sufficiently predicted by the traditional methods. However computational modelling of materials behaviour is becoming a reliable tool to emphasize scientific investigations and to match up theoretical and experimental approaches. With the continuous progress in computational power new ultrasonic testing systems are expected to be discovered and implemented. This requires not only development of improved processing techniques but also a better understanding of material structure. These conditions implicate multiple length scales analysis and multiple implementation steps, which are available only by means of simulation models. Therefore, increasing efforts are focused on ultrasonic multiscale modelling methods for signal interpretation; the multi-resolution models are the mainly investigated approaches. In this work a multi-resolution analysis is accomplished and an enhanced energetic smoothing filtering algorithm is proposed for an advanced material behavior characterization.

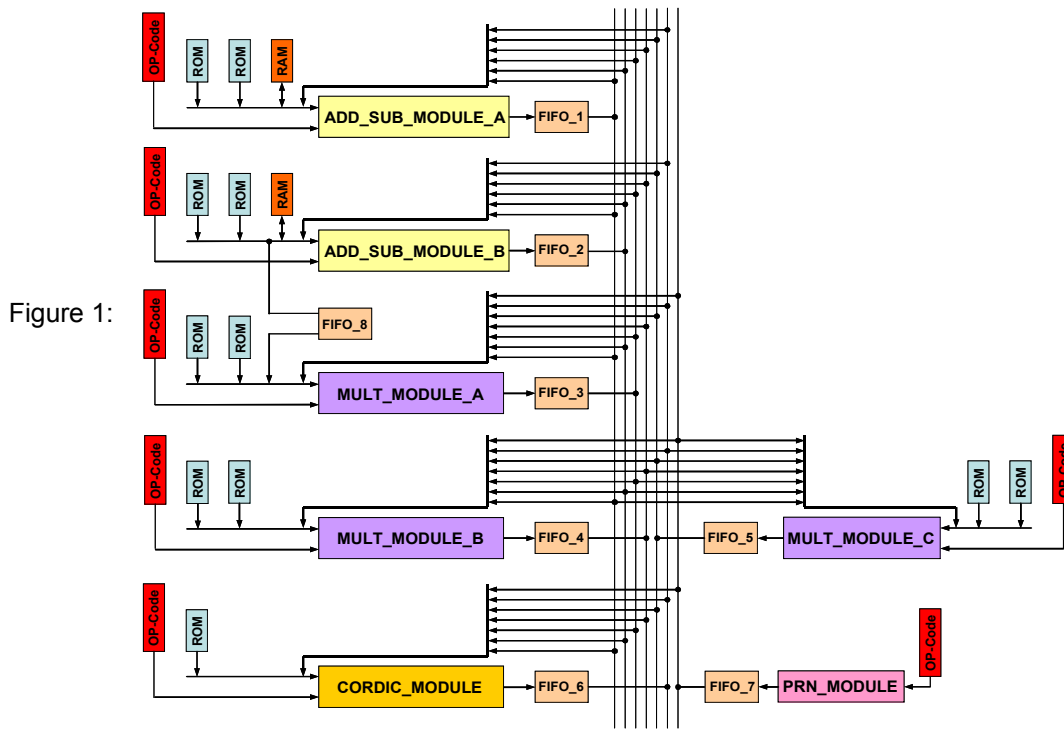
## **Architecture of a Digital Neuron-Core for real-time Computation**

Marcel Beuler and Werner Bonath  
University of Applied Sciences Giessen-Friedberg, Germany  
[bonath@ieee.org](mailto:bonath@ieee.org), [marcel.beuler@web.de](mailto:marcel.beuler@web.de)

The Hodgkin-Huxley-Equations allow detailed simulations of neurons in analogy to electrical nonlinear networks. Due to the complex numerics the software-based simulation is quite timeconsuming and therefore exist several approaches to model those equations with analogue or digital electronic circuitry.

A digital architecture will be presented, which is implemented in state-of-the-art programmable logic and which allows fast and accurate computation of the Huber-Braun-Model. The digital neuron core simulates the membrane potential of 40 neurons in one neuron cycle. That means computing about 2500 arithmetical operations including mathematical functions in a step size of 100  $\mu$ s. The model equations are implemented on a Virtex-4-FPGA by a slow frequency of 10 MHz for hardware verification in real-time, on the condition of constant injection currents for depolarizing the membrane potential for each neuron.

The developed architecture is shown in Figure 1. To overcome numerical problems, we chose a 32-bit floating-point data format. By a step size of 100  $\mu$ s and a frequency of 10 MHz we have 1000 clock cycles to compute all model equations during a neuron cycle. At this point a network topology and the depolarizing of the membrane potential by postsynaptic potentials are excluded to reduce complexity. We assuming 200 clock cycles for these operations, so 800 clock cycles are still available for computing the equations of as many neurons as possible.



Architecture of a neuron core

A neuron core consists of 6 arithmetical units and an addition unit as a source of uniform distributed pseudo random numbers. Each unit has its own Code-memory for individual programming, a FIFO to store the results of operations and own digital memory. To realize the required mathematical functions in a uniform architecture, the CORDIC algorithm in a 32-bit floating-point environment and intensive pipelining is used. The presented architecture can be seen as the condition of implementing a network topology in the next turn of development a digital neuron processor for the desired model.

### Geodesic Holonomy Attractor between Surfaces of Different Curvature Signs relevant to Spin Transport

Bernd Binder  
 Quanics, 88679 Salem, Germany  
[binder@quanics.com](mailto:binder@quanics.com)

We will consider nonlinear holonomy effects -especially the spin dissipation dynamics- arising in the transport of a linear rotator between metric spaces with different curvature (positive, zero, negative). The extra 3D spin vector current induced by curvature and curvature change (measurable as precession) provides for a holonomic attractor called "Magic Angle Precession" (MAP) that could be relevant to 3D geodesic flows in classical mechanics, quantum physics, and quantum gravity based on chaotic dissipation. Limitations and instabilities of the spin current exchange are assigned to bifurcations at high precession loads as the driving gauge potential. In the classical range the chaotic dynamics can be verified with a mechanical toy gyroscope with built-in spin-precession coupling that could also be modeled by a Chua-type electronic circuit. Transporting vector currents composed by spin and precession is treated by Schwarz-Christoffel triangle maps with constant Schwarzian

derivative and hypergeometric monodromy. In closed loops or periodic grids with alternating curvature the MAP attractor corresponds to a quantum state allowing for a lossless spin current transport without reflection. The Schrodinger hypergeometric quantum mechanical solution corresponds to Poschl-Teller type equations with factorization and ladder operators. By pull-back we get the generalized Gauss linking number density differential form.

Keywords: holonomy, chaotic precession, geometric phase, hypergeometric, curvature, Berry, Chua, quantum gravity, Schrodinger, Poschl - Teller, Legendre, Gegenbauer, Gauss, linking number, spin, magic angle spinning.

### **The neural networks application for estimation of wheels braking actual parameters for an airplane on the runway covered with precipitations**

A.Ya. Bondarets, O.D. Kreerenko  
Beriev Aircraft Company, Taganrog, Russia  
[olgadm@yandex.ru](mailto:olgadm@yandex.ru)

The experience of neural network application for determination of airplane's wheels drag actual coefficient on the runway covered with precipitations is introduced. DCSL (Dynamic Cell Structure) neural network from "Adaptive Neural Network Library" was selected as a tool of identification. The task is solved in Matlab Simulink environment. The program includes math model of aircraft motion along runway. Available aerodynamic and altitude-airspeed performances of engines are used. Runway surface gradients (slopes), which correspond to the experimental data, are taken into account. The data from airplane runs during flight tests in actual conditions are used to create a samples for neural networks training. The obtained by identification wheels drag parameters (braking, rolling resistance and contamination drag) and the convergence between the results received in test modeling and the experimental data are shown.

Keywords: Adaptive Neural Network, Math model of aircraft motion along runway, Identification, Runway surface gradients, Flight tests, Braking resistance, Rolling resistance.

### **Deterministic and Noise Induced Chaos in Neuronal Impulse Patterns**

Hans A. Braun and Svetlana Postnova  
Institute of Physiology, Philipps University of Marburg, Germany  
[braun@staff.uni-marburg.de](mailto:braun@staff.uni-marburg.de)

We have used a Hodgkin-Huxley type neuronal model to examine cooperative effects between nonlinear dynamics and noise. The model neuron is designed for the simulation of physiologically relevant impulse patterns according to experimental recordings from diverse types of neurons in the peripheral and central nervous system. It consists of two sets of simplified de- and repolarizing conductances. These are operating at different activation levels and time-scales thereby constituting a fast subsystem for spike generation and a slow subsystem for subthreshold oscillations. These two subsystems are coupled via the membrane potential as common variable.

Such a neuron can be tuned to different dynamic states thereby exhibiting a rich variety of physiologically relevant impulse patterns. These include single-spike (tonic) discharges of different types, impulse groups (bursts) of varying duration and period and several ranges of chaotic dynamics, the broadest appearing in between the regimes of burst discharges and pacemaker-like tonic firing, including a homoclinic bifurcation.

To account for physiologically more realistic simulations it is necessary to consider that biological systems, especially neurons, are notoriously noisy. Accordingly, we have applied noise in different forms: current noise and conductance noise, white noise and correlated noise. In all cases, the impulse pattern can be significantly changed. Distinct noise effects, expectedly, can be seen at the bifurcations. However, there are significant differences also in comparison of the noise effects on different activity pattern.

While the bursting regime reveals to be comparably robust against stochastic disturbances, the deterministically chaotic structure is covered with only small noise intensities. Remarkably, most drastic noise effects appear in the tonic firing regimes. With application of noise, a deterministically unknown pattern is introduced which is generated by a mixture of subthreshold and spike generating oscillations. Moreover, the pace-maker like tonic firing regime exhibits clear signs of unstable periodic orbits indicating an extension of chaotic dynamics into this deterministically periodic regime. These are the regimes where also the most significant differences between different noise implementations can be observed. Conductance noise as well as colored noise with a sufficiently high intensity introduces irregular burst in the previously chaotic and tonic firing regime.

All the noise sensitive regimes reflect dynamic states of high physiological relevance, for peripheral sensory encoding as well as for neuronal information in the brain. This which strongly suggest further attempts towards a more thorough understanding of the underlying dynamics.

Supported by the European Union through the Network of Excellence BioSim, contract No LSHB-CT-2004-005137.

### **Effect of temperature on the structure of the expression of the motor system fatigue**

Marius Brazaitis, Albertas Skurvydas

Lithuanian Academy of Physical Education, Department of Applied Physiology and Physiotherapy  
kku712@yahoo.com

As far as we know this is the first study in the world in such unique conditions (heated vs. normal vs. cooled), investigating the fatigue of motor system using not only usual (deterministic), but also deterministic chaos techniques. Besides, it was determined, that the changes in the expression of motor system fatigue depend on the specificity of muscle activation (voluntary vs. electrostimulation), stimulation frequency to the muscle (low vs. high), fatigue location (central vs. peripheral), determination of registered value (stability vs. dynamics), type of muscle contraction (repeated vs. sustained), fatigue phase (beginning vs. middle vs. end) and the adaptation condition of motor system (heating vs. acclimation). It shows that the fatigue development of motor system is a complex and dynamic process. In other words, expression of the dynamics of fatigue has its own structure.

Keywords: Motor control, force output structure, temperature

### **Complex dynamics in an asset pricing model with updating wealth**

Serena Brianzoni, Cristiana Mammana, Elisabetta Michetti

Dipartimento di Istituzioni Economiche e Finanziarie, Università degli Studi di Macerata (Italy)

Many studies on present discounted value asset pricing model with heterogeneous agents have been developed afterwards the work of Brock and Hommes (1998). A common feature of this kind of models is the independence of the optimal demand for the risky asset from agents' wealth, as a result of the assumption of Constant Absolute Risk Aversion utility function. As stated by many recent studies, this assumption is unrealistic, see e.g. Levy et al. (2000) and Campbell and Viceira (2002).

In particular, part of the literature has been focused on the study of the evolution of agents' wealth and its effect on price dynamics, by assuming that investors' optimal demand for the risky asset depends on wealth as a result of a Constant Relative Risk Aversion utility function (see Chiarella and He (2001), Chiarella and He (2002) and Chiarella et al. (2006)). Following this research line, we develop an asset pricing model with heterogeneous beliefs and wealth dynamics considering two types of agents. In particular, we enable agents to switch among different predictors and to bring their own wealth from a group to another one. Furthermore we assume homogeneity between agents within the same group and heterogeneity between agents belonging to different groups, in the sense that all agents belonging to the same group agree to share their wealth whenever an agent gets in the group (or leaves it). As a consequence the wealth of each group is updated at each time and changes dynamically. We assume that the price adjustments are operated by a market maker, as in Chiarella et al. (2006). We derive the resulting deterministic nonlinear dynamic system and analyze the model in order to investigate complicated dynamics and to consider the effects on wealth distribution among agents.

#### References

- Brock, W.A., Hommes, C.H., 1998. Heterogeneous beliefs and routes to chaos in a simple asset pricing model. *Journal of Economic Dynamics and Control*, 22, 1235-1274.
- Campbell, J. Y., Viceira, L. M., 2002. *Strategic asset allocation: portfolio choice for long-term investors*. Clarendon Lectures in Economics. Oxford University Press, Oxford.
- Chiarella, C., Dieci, R., Gardini, L., 2006. Asset price and wealth dynamics in a financial market with heterogeneous agents. *Journal of Economic Dynamics and Control*, 30, 1755-1786.
- Chiarella, C., He, X., 2001. Asset price and wealth dynamics under heterogeneous expectations. *Quantitative Finance*, 1 (5), 509-526.
- Chiarella, C., He, X., 2002. An adaptive model on asset pricing and wealth dynamics with heterogeneous trading strategies. In *Computing in Economics and Finance 2002*, 135, Society for Computational Economics.
- Levy, M., Levy, H., Solomon, S., 2000. *Microscopic simulation of financial markets - from investor behavior to market phenomena*. Academic Press, Sydney.

### **Dynamics of gear drive systems with impacts: ways leading to chaos**

Miroslav Byrtus and Vladimir Zeman

University of West Bohemia, Department of Mechanics, Czech Republic

[mbyrtus@kme.zcu.cz](mailto:mbyrtus@kme.zcu.cz)

This paper contains a brief overview of mathematical modelling and dynamic analysis of gear drives including gearing and bearing couplings with nonlinearities. The general mathematical model of nonlinear gear drive vibration is derived by modal synthesis method with degrees of freedom number reduction. The couplings nonlinearities, mainly the gear mesh interruption, affects the behaviour of the systems especially in resonant states and during low external applied torque. Chosen results gained on different test and real gear drives show the influence of coupling nonlinearities on complex gear drive behaviour with respect to chosen operation parameters.

Keywords: nonlinear dynamics, modal synthesis method, gear drive, gearing coupling, bearing coupling.

### **Contraction-Theoretic Observers for Lorenz-95 systems**

Han-Lim Choi<sup>1</sup> and Jean-Jacques E. Slotine<sup>2</sup>

<sup>1</sup> Dept. Aeronautics and Astronautics, <sup>2</sup> Dept. Mechanical Engineering and Information Sciences, MIT  
hanlimc@mit.edu, jjs@mit.edu

This work presents analysis and design of nonlinear observers for the Lorenz-95 chaos model by employing contraction theory. Contraction theory has been an emerging theoretical framework to analyze the stability of nonlinear systems, and especially, synchronization of networked dynamical systems. This study designs hybrid observers that account for asymmetry in the topology of observation networks: continuous measurements are taken for some subset of the state space, while only (periodic) discrete measurements are available for the other subset of the state space. This hybrid architecture models the adaptive sampling problem in the context of numerical weather prediction, which determines supplementary sensing locations to aid the routine observation network. Contraction-theoretic analysis of the presented observers identifies observability characteristics of the Lorenz-95 model.

KeyWords: Contraction theory, Network synchronization, Lorenz-95 model, Hybrid observer.

### **Neuro-Fuzzy Nonlinear Dynamical System Approximations using High Order Neural Networks**

Manolis A. Christodoulou\*, Dimitris C. Theodoridis\*\*, Yiannis A. Boutalis\*\*

\*Department of Electronic and Computer Engineering, Technical University of Crete, Chania, Crete,

\*\*Department of Electrical and Computer Engineering, Democritus University of Thrace Xanthi,  
GREECE

[manolis@ece.tuc.gr](mailto:manolis@ece.tuc.gr), [dtheodo@ee.duth.gr](mailto:dtheodo@ee.duth.gr), [ybout@ee.duth.gr](mailto:ybout@ee.duth.gr)

A new definition of Adaptive Neuro Fuzzy Systems is presented in this paper for the identification of unknown nonlinear dynamical systems. The proposed scheme uses the concept of Adaptive Fuzzy Systems (AFS) operating in conjunction with High Order Neural Network Functions (F-HONNFs). Since the plant is considered unknown, we first propose its approximation by a special form of an adaptive fuzzy system and in the sequel the fuzzy rules are approximated by appropriate HONNFs. Thus the identification scheme leads up to a Recurrent High Order Neural Network, which however takes into account the fuzzy output partitions of the initial AFS. The proposed scheme does not require a-priori experts' information on the number and type of input variable membership functions making it less vulnerable to initial design assumptions. Weight updating laws for the involved HONNFs are provided, which guarantee that the identification error reaches zero exponentially fast. Simulations illustrate the potency of the method and comparisons with well known benchmarks are given.

### **Weight Tracking in Nonlinear System Identification via Fuzzy High Order Neural Network Function Approximation**

Manolis A. Christodoulou\*, Dimitris C. Theodoridis\*\*, Yiannis A. Boutalis\*\*

\*Department of Electronic and Computer Engineering, Technical University of Crete, Chania, Crete,

\*\*Department of Electrical and Computer Engineering, Democritus University of Thrace Xanthi,  
GREECE

[manolis@ece.tuc.gr](mailto:manolis@ece.tuc.gr), [dtheodo@ee.duth.gr](mailto:dtheodo@ee.duth.gr), [ybout@ee.duth.gr](mailto:ybout@ee.duth.gr)

The weight tracking in the identification of varying unknown nonlinear systems is examined in this paper. The unknown nonlinear system is represented and identified by an Adaptive Dynamic Fuzzy Systems (ADFS), which operates in conjunction with High Order Neural Network Functions (HONNFs) and takes the form of a Fuzzy Recurrent High Order Neural Network (F-RHONN). Weight updating laws for the involved HONNFs are given, which guarantee that the identification error reaches zero exponentially fast. The proposed scheme has the ability to track very fast any change in the unknown nonlinear system, that can be reflected in weight changes of its F-RHONN representation. Simulations illustrate the potency of the method especially in tracking the changes made in the unknown system.

## **Possibilities of Incertitude Reflecting and Modeling in Economic Decision Process**

Cristina Coculescu, Radu Despa, Ovidiu Folcut  
IT, Statistics and Mathematics Department  
Romanian-American University, Bucharest, Romania  
[cristina\\_coculescu@yahoo.com](mailto:cristina_coculescu@yahoo.com)

Most of phenomena are developed with an amount of conditions which is equivalent to the existence of several possible states of nature, whose possibilities of realization aren't known as a rule. For this case, actual decision theories have put in the concept of incertitude as an unavoidable condition of the decision process which basically characterizes human being.

Incertitude, function of its sources, exists in process having role of conditions (decision in incertitude cases), established both by outside environment and by intrinsic character of decision (decision incertitude), helped by human factor (the actors of decision process). Therefore, incertitude can produce a series of psycho-managerial problems. Whose solving is so than can clearly change the decisional process itself, wherein real decision men adopt strategies of decision different from those suppose by the analytic model.

Incertitude can act in decisional process in sure conditions as initial incertitude but each phase of process is finalized in a sure process and starting incertitude is absorbed through cognitive processes. In this case, through taking decision, the incertitude has wholly cancelled and even it remains more a certain quantity of incertitude, it is no more important.

But in real cases, incertitude isn't as a rule wholly integrated in before-decision phases but persists. Thus, it becomes an important parameter of decision process, interacting with the other parameters of it.

In this work we purpose to analyze the kinds of incertitude reflection in the phases of economic decisional process for finding possibilities of its modeling, thus offering for decision man right instruments of analyze and option in incertitude cases.

Keywords: decision theory, risk, incertitude, tendency optimality strategy, strategy of the satisfactory.

## **Chaos in the Duffing's type system with fractional-order term**

Livija Cveticanin  
Faculty of Technical Sciences, Novi Sad, Vojvodina, Serbia  
[cveticanin@uns.ac.rs](mailto:cveticanin@uns.ac.rs)

In this paper the qualitative analysis of the Duffing's type dynamic system with fractional-order term is considered. The unperturbed system has three fixed points: two centers and a saddle point. The homoclinic orbit which connects a fixed point with itself and the corresponding stable and unstable manifolds are given in the closed analytical form. Melnikov's procedure for defining the criteria for transversal intersection of the stable and unstable manifolds is extended for the systems with fractional order deflection function. The critical parameter values for chaos are obtained analytically and proved numerically using the Lyapunov exponents. The bifurcation diagrams are plotted for various values of fractional-order and the transition to chaos by period doubling is shown. The phase plane diagrams and the Poincare maps for certain fractional orders are obtained. The 'Pyragas method' is adopted for chaos control in the system. The transformation from chaos to periodic motion is considered.

Key Words: chaos, fractional-order term, Duffing's equation, Melnikov's method

## **Effect of Delays on S-I Epidemic Model**

Prasenjit Das and Ying-Hen Hsieh  
Department of Public Health and Biostatistics Center, Taichung, Taiwan China  
[jit\\_das2000@yahoo.com](mailto:jit_das2000@yahoo.com)

We propose a Susceptible-Infective (S-I) model with two time delays  $\tau_1$  and  $\tau_2$  representing a period of temporary immunity of newborns and a disease incubation period, respectively. For the full model with two discrete time delays, stability behavior of the trivial equilibrium is investigated. For the stability of endemic equilibrium point, only the case  $\tau_1 = \tau_2$  is analyzed in detail. Conditions for supercritical and subcritical Hopf bifurcation are also derived. Results are verified through computer simulations with biological interpretations given.

Key Words: Time delay, Hopf Bifurcation, Periodic solutions



### **Chaotic Mixing in the system Earth: mixing Granitic and Basaltic Liquids**

Cristina De Campos <sup>1</sup>, Werner Ertel-Ingrisch <sup>1</sup>, Diego Perugini <sup>2</sup>, Donald B. Dingwell <sup>1</sup>, and Giampero Poli <sup>2</sup>

<sup>1</sup> Earth and Environ. Sci., LMU – Univ. of Munich, Munich, Germany; <sup>2</sup> Dept. of Earth Sciences, Univ. of Perugia, Perugia, Italy.

[campos@min.uni-muenchen.de](mailto:campos@min.uni-muenchen.de); [ertel@min.uni-muenchen.de](mailto:ertel@min.uni-muenchen.de); [diegop@unipg.it](mailto:diegop@unipg.it);

A widely debated question in Geosciences is whether and how viscous magmas with extreme viscosity contrast may mix in nature. Chaotic mixing in magma chambers is known to play a central role not only in determining the timing and dynamics of modern volcanic eruptions but should be equally of relevance for the evolutionary history of our planet. Earlier studies already evidenced that chaotic dynamics can control magma mixing processes in nature [1] e.g., in magma chambers. To date applied studies on chaotic mixing in geological systems are based on model systems at room temperature and numerical simulations.

Here we report the first experimental study of chaotic mixing in molten silicates of geological relevance at high temperature (at 1400°C). For this, a special device has been designed and built according to the journal-bearing geometry for viscous fluids for the study of slow flows [2].

The experiments were performed using synthetic end-members of a) haplogranite [SiO<sub>2</sub> (71.6), Al<sub>2</sub>O<sub>3</sub> (12.4), Na<sub>2</sub>O (7.0), K<sub>2</sub>O (9.0) (wt.% in brackets)] and b) haplobasalt [SiO<sub>2</sub> (48.6), Al<sub>2</sub>O<sub>3</sub> (16.3), CaO (23.8), MgO (11.4)]. The haplogranitic starting composition was doped with trace amounts of Rb, Sr, Ba, Zr, and REE oxides.

An initial experimental campaign was performed at 1400 °C with total run duration of 110 min., with spindle and crucible run in alternating directions. The experiment was terminated by stopping the stirring protocol and cooling the sample to room temperature inside the furnace. A glass cylinder was cored from the used Pt crucible, and sectioned in 5 mm sections along the long axis. Obtained sections were prepared for electron microprobe and laser-ablation ICP-MS analyses.

Optical and microchemical studies revealed crystal-free filaments and vortex structures of intermediary compositions, changing with depth, in complex chaotic patterns. Despite the intricacy of the multicomponent system studied in this work, experimental flow patterns are in good agreement with mathematical models, being therefore suitable for further projections on element mobility.

The results of the chemical analyses of the obtained glass sections will be discussed in context of the efficiency of the interplay between convection and diffusion under chaotic dynamics, in respect to enhancing mixing in multicomponent silicate melts.

Keywords: Chaotic advection-diffusion experiments, multicomponent silicate melts, high temperature

#### **References**

- [1] Perugini D., Petrelli M. and Poli G., 2006. Diffusive Fractionation of Trace Elements by Chaotic Mixing of Magmas. *Earth and Planetary Sciences Letters*, 234: 669-680.  
[2] Swanson, P. D. and Ottino, J.M., 1990. A comparative computational and experimental study of chaotic mixing of viscous fluids, *J. Fluid Mech.*, 213, 227-249.

### **Fractal Dimensions Effects in Biology Resulting from a Phenomenological Univesalities Approach**

Pier Paolo Delsanto and Antonio Gliozzi  
Politecnico di Torino, Torino, Italy  
[pier.delsanto@polito.it](mailto:pier.delsanto@polito.it)

Phenomenological Univesalities represent a new tool for the classification and interpretation of observed or experimental data in the context of cross-disciplinary research. Also they can act as a B“magnifying glassB” to finetune the analysis and to quantify the difference among similarly looking datasets. In particular, the class U2 is of special relevance, since it includes, as subcases, all growth models proposed to date. In this presentation we show that it may be applied, in a simple fashion, to a variety of problems of interest in biology, medicine and other fields. The results demonstrate the predictive power of the approach and foretell the emergence, in several contexts, of fractal dimensioned variables with interesting consequences and applications.

Key Words: Phenomenological Univesalities, Fractal dimensions, Growth models

#### References:

- P. P. Delsanto, ed., *Universality of Nonclassical Nonlinearity with applications to NDE and Ultrasonics* (Springer, 2007).
- P. Castorina, P.P. Delsanto, and C. Guiot, A classification scheme for phenomenological universalities in growth problems in physics and other sciences, *Phys. Rev. Lett.* 96, 188701 (2006).
- Delsanto PP, C Guiot and Gliozzi AS. Scaling, growth and cyclicity in biology: a new computational approach, *Theor. Biol. Med. Model.* 2008, 5:5.
- Gliozzi AS, Guiot C, Delsanto PPD. A new computational tool for the phenomenological analysis of multipassage tumor growth curves. To appear in *PLoS One*.
- P.P. Delsanto et al., Scaling laws and fractality in the framework of a phenomenological approach, *Chaos, Solitons and Fractals*, in press (2009)

#### **Bubbling in Delay-Coupled Lasers**

O. D’Huys<sup>1</sup>, V. Flunkert<sup>2</sup>, J. Danckaert<sup>1,3</sup>, I. Fischer<sup>4</sup>, E. Schöll<sup>2</sup>

<sup>1</sup>. Dept. of Physics (DNTK), Vrije Universiteit Brussel, Belgium, <sup>2</sup>. Institut für Theoretische Physik, Berlin, Germany, <sup>3</sup>. Dept. of Applied Physics and Photonics (TONA), Vrije Universiteit Brussel, Belgium, <sup>4</sup>. School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, Scotland, UK

We study numerically and analytically the influence of noise on the synchronisation of two chaotic elements which are delay-coupled via an active or a passive relay. We decompose the dynamics in a symmetric part, which determines the synchronised dynamics, and an antisymmetric part, which relates to the stability of the synchronised solution. Depending on the coupling parameters the system can exhibit bubbling, (i.e., noise-induced desynchronisation), or on-off intermittency. We apply this analysis to semiconductor lasers, where we associate the desynchronisation dynamics in the coherence collapse and low frequency fluctuation regimes with the transverse instability of some of the compound cavity's antimodes. Finally, we demonstrate how, by proper tuning of an active relay, bubbling can be suppressed.

Keywords: synchronisation, chaos, delay, laser dynamics, bubbling

#### **Simulation of Multinomial Models for Oligopolistic Competition**

Yiannis Dimotikalis

Dept. of Finance & Insurance

Technological Education Institute of Crete

Aghios Nikolaos, 72100 CRETE, GREECE

[jdimit@finance.teicrete.gr](mailto:jdimit@finance.teicrete.gr)

In this paper a multivariate model family derived from the Binomial Model known as Logistic is presented and exhibited. The relation of the model with other well known models as the Lotka-Volterra system of equations and Bass model analysed and used to extend the proposed models. The suitability of the model for modeling the competition in an oligopoly market is presented and discussed by computer simulation. Also the chaotic behavior of the model is demonstrated.

Key Words: Logistic Model, Bass Model, Lotka-Volterra system, Chaos, Multivariate Analysis, Oligopoly

#### **Hick Samuelson Keynes dynamic economic model with discrete time and consumer sentiment**

Loretti I. Dobrescu, Mihaela Neamtuy, Dumitru Oprisz

University of Venice, Department of Economics, Italy, West University of Timisoara, Department of Economic Informatics,

Mathematics and Statistics, Romania, West University of Timisoara, Department of Applied Mathematics, Romania

lorettiisabella.dobrescu@unipd.it, [mihaela.neamtu@fse.uvt.ro](mailto:mihaela.neamtu@fse.uvt.ro), oprisz@math.uvt.ro

The paper describes the Hick Samuelson Keynes dynamical economic model with discrete time and consumer sentiment. We seek to demonstrate that consumer sentiment may create fluctuations in the economical activities. The model possesses a flip bifurcation and a Neimark-Sacker bifurcation, after which the stable state is replaced by a (quasi-) periodic motion.

Key Words: consumer sentiment, Hick Samuelson Keynes models, Neimark-Sacker, flip bifurcation, Lyapunov exponent.

### On the entropy flows to disorder

C.T.J. Dodson

School of Mathematics, University of Manchester, UK

ctdodson@manchester.ac.uk

Gamma distributions, which contain the exponential as a special case, have a distinguished place in the representation of near-Poisson randomness for statistical processes; typically, they represent distributions of spacings between events or voids among objects. Here we look at the properties of the Shannon entropy function and calculate its corresponding flow curves, relating them to examples of constrained degeneration from ordered processes. We consider univariate and bivariate gamma, and Weibull distributions since these also include exponential distributions.

Keywords: Shannon entropy, integral curves, gamma distribution, bivariate gamma, McKay distribution, Weibull

### Square-well Fluid as the Reference System in Variational Calculations for Liquid Metals

N.E. Dubinin, V.V. Filippov, N.A. Vatolin

Institute of Metallurgy of the Ural Division of the R A S, Ekaterinburg, Russia

ned67@mail.ru

The variational method based on the Gibbs-Bogoljubov inequality is widely used for thermodynamic calculations of liquid metals. As a rule, the hard-sphere (HS) reference system is used for this purpose. There are a number of attempts to use other reference systems: the one-component-plasma system [1], the charged-hard-sphere system [2], and the hard-sphere Yukawa one [3]. Here, we perform variational calculations with the square-well (SW) reference system. The analytical expression for the SW structure factor is taken in the framework of the random phase approximation. The Helmholtz free energy is minimised with respect to the core diameter, the SW width, and the SW depth. This approach is applied to the liquid Na and liquid K at 373K. The Animalu-Heine model pseudopotential and the Vashishta-Singwi exchange-correlation function are used. Obtained results are compared with results of works [1-3] and with our HS-reference-system results.

References:

[1] K.K. Mon, R. Gann and D. Stroud. Thermodynamics of liquid metals: The hard-sphere versus one-component-plasma reference systems. *Phys. Rev. A.*, 24:2145, 1981

[2] S.K. Lai. Use of the charged-hard-sphere reference system in variational thermodynamic calculations. *Phys. Rev. A.*, 31:3886, 1985

[3] C. Hausleitner and J. Hafner. Soft-sphere reference system in thermodynamic variational calculations. I: Liquid simple metals. *J. Phys. F: Met.Phys.*, 18:1013, 1988

Key Words: Square-well model, Random phase approximation, Variational method, Liquid metal, Thermodynamic properties

### Numerical Investigation of Semiconductor Ring Lasers With Two External Cavities

I. V. Ermakov,<sup>a,b</sup> G. Van der Sandea,<sup>b</sup> L. Gelens,<sup>a</sup> A. Scirè,<sup>b</sup> P. Colet,<sup>b</sup> C. R. Mirasso,<sup>b</sup> V.Z. Tronciu,<sup>c</sup> and J. Danckaert,<sup>a,d</sup>

<sup>a</sup>Dept. of Applied Physics and Photonics, Vrije Universiteit Brussel, Belgium

<sup>b</sup>Instituto de Física Interdisciplinar y Sistemas Complejos, Palma de Mallorca, Spain

<sup>c</sup>Weierstrass Institute for Applied Analysis and Stochastics, Berlin, Germany

<sup>d</sup>Dept. of Physics, Vrije Universiteit Brussel, Belgium

iermakov@tona.vub.ac.be

We report results on the numerical analysis of the behaviour of a semiconductor ring laser under the influence of feedback from two external cavities. Double feedback arises naturally in a semiconductor ring laser, e.g. at the end facets of an outcoupling waveguide. We find that, under certain conditions, the system displays quasi-periodic and chaotic behavior.

Key Words semiconductor ring lasers, delayed optical feedback

## **Modeling and Optimization of Production-Distribution Plan in Supply Chains**

Behnam Fahimnia, Lee Luong, Romeo Marian  
School of Advanced Manufacturing and Mechanical Engineering, University of South Australia,  
Adelaide, Australia  
[behnam.fahimnia@unisa.edu.au](mailto:behnam.fahimnia@unisa.edu.au)

Supply chain (SC) is the network of organizations, people, activities, information and resources involved in the physical flow of products from suppliers to the end-users. Supply Chain Management (SCM) is, therefore, the process of integrating and utilizing suppliers, manufacturers, distribution centers, and retailers; so that products are produced and delivered to the end-users at the right quantities and at the right time, while minimizing costs and satisfying customer requirements.

The overall performance of a supply-chain (SC) is influenced significantly by the decisions taken in its production-distribution plan. A production-distribution plan integrates the decisions in production, transport and warehousing as well as inventory management. Hence, one key issue in the performance evaluation of a Supply Network (SN) is the modeling and optimization of production-distribution plan considering its actual complexity.

This paper firstly develops a mixed integer formulation for a two-echelon supply network that extends the previous production-distribution models through the integration of Aggregate Production Plan and Distribution Plan as well as considering the real-world variables and constraints. Secondly, A Genetic Algorithm is proposed for the optimization of the developed model. Thirdly, the methodology will be applied to solve real-world problem incorporating multiple time periods, multiple products, multiple manufacturing plants, multiple warehouses and multiple end-users. The validation of this model will be finally studied for the presented case study.

Key Words: Supply Chain, Genetic Algorithms, Optimization

### **Fractal functional filtering and regularization**

R. Fernandez-Pascual<sup>1</sup> and M.D. Ruiz-Medina<sup>2</sup>

<sup>1</sup> Department of Statistics and Operation Research, University of Jaen, Spain, <sup>2</sup> Department of Statistics and Operation Research, University of Granada, Facultad de Ciencias, Spain  
[rpascual@ujaen.es](mailto:rpascual@ujaen.es), [mruiz@ugr.es](mailto:mruiz@ugr.es)

Pseudodifferential models have been widely applied in the description of biological systems. This paper studies the filtering and prediction problems associated with functional observation models. The functional sample information is given by a temporal sequence of spatial realizations of a process, solution to a spatiotemporal pseudodifferential equation, affected by additive strong Hilbertian white noise.

The robustness of the functional estimator depends on the spatial fractality levels of the spatial observation noise and the local regularity of the process of interest. The stability of these problems is also affected by the self-similarity of the initial condition.

The simulation study developed for illustration of the methodology shows the effect of the local singularity (fractality), introduced by the observation noise, on the quality of the functional estimations, as well as the effect of the self-similarity of the random initial condition, when the density of the spatial locations increases.

Keywords: Fractality, functional spatio-temporal estimation, pseudodifferential evolution models.

Acknowledgments: This work has been supported in part by projects MTM2005-08597, MTM2008-03903 of the DGI, MEC and P05-FQM-00990, P06-FQM-02271 of CICE.

### **On the Role of Subthreshold Currents in a Mammalian Cold Receptor Model**

Christian Finke and Ulrike Feudel  
Institute for Chemistry and Biology of the Marine Environment  
Carl von Ossietzky University of Oldenburg, Germany  
[christian.finke@uni-oldenburg.de](mailto:christian.finke@uni-oldenburg.de), [u.feudel@icbm.de](mailto:u.feudel@icbm.de)

Information transfer between neurons is at least partly encoded in the frequency of spikes or burst discharges as well as in the temporal spike patterns. It is known that mammalian cold receptors exhibit a variety of different spike patterns depending on temperature, which is one of the possible stimuli of these cells. The characteristic changes of spike patterns with respect to the variation of temperature can be described by the Huber/Braun model, which mimics the neuron dynamics as an interplay of

fast and slow ion currents. While the slow currents yield subthreshold oscillations, the fast subsystem seems to be responsible for the spiking mechanism.

The amplitude of subthreshold oscillations in this model neuron might be altered by external stimuli like hormones or neurotransmitters. To study the role of the subthreshold oscillations we have introduced a parameter which manipulates the impact of the subthreshold currents on the dynamics of the membrane potential. The neuron then undergoes a series of systematic changes in the course of scaling down the amplitude of subthreshold oscillations until it settles at a fixed point. It can be concluded from the analysis of the emerging dynamics that amplitude scaling serves as an important ingredient in the perception of temperature in mammals.

Furthermore, our study shows that the key feature for non-trivial dynamics is the highly nonlinear coupling of the slow, subthreshold currents to the fast, spike-generating currents in the model. If the fast subsystem is subjected to a periodic external forcing current of the same amplitude and frequency as supplied by the subthreshold currents, the dynamic behaviour becomes merely trivial.

In the light of these results, it seems likely that an extension of the common interpretation of the mechanism of spike generation and the spiking patterns is necessary. The highly nonlinear feedbacks between the slow and fast subsystems of the cold receptor model should be emphasized more. The explanation for the spiking mechanism can not be based solely on the idea of spikes being triggered by the amplitude of slow oscillations alone.

### **Complex multilocus population dynamics under mixed reproduction systems**

Zeev M. Frenkel, Valery M. Kirzhner, and Abraham B. Korol

Institute of Evolution and Department of Evolutionary and Environmental Biology, University of Haifa, Israel

korol@research.haifa.ac.il

Here we analyze the effect of deviation from pure sexual reproduction (panmixia) on complex dynamics of multilocus genetic systems subjected to cyclical selection. A rich spectrum of complex dynamic patterns is displayed by this model. It appears that complex dynamics can be very robust to variation of mating parameters and recombination rate. We demonstrate that sex and recombination do not usually simplify the population dynamics of multilocus genetic systems, despite previous generalizations based on single-locus models with selection caused by antagonistic species interaction.

Keywords: complex population dynamics, stability of complex dynamics, evolution of reproduction type

### **Functional wavelet-thresholding-based long-range dependence parameter estimation with missing data**

Maria Pilar Frias<sup>1</sup> and Maria Dolores Ruiz-Medina<sup>2</sup>

<sup>1</sup> University of Jaen, <sup>2</sup> University of Granada, Spain

[mpfrias@ujaen.es](mailto:mpfrias@ujaen.es), [mruiz@ugr.es](mailto:mruiz@ugr.es)

Semiparametric estimators of temporal and spatial long-range dependence parameters are formulated from spectral functional data. The case where such data are affected by additive measurement noise is studied. Specifically, wavelet thresholding techniques are applied to the spectral curves, for removing the noise. Compactly supported wavelets in a neighborhood of zero frequency are considered in the implementation of such techniques. Linear regression is then applied to the log-directional wavelet thresholded transform of the temporal and spatial spectral curves to obtain an approximation of the fractal and strong-dependence parameters. A simulation study is developed to investigate the bias and efficiency of the computational methods proposed for functional parameter estimation of fractal and strong-dependent processes.

Keywords: Fractal spectral processes, long-range dependence parameters, spatiotemporal parametric models, spectral functional data, wavelet transform.

## Stochastic photon-correlation effects and quantum chaos in atomic and nuclear systems

Alexander V. Glushkov

Odessa University, Odessa (Odessos), Ukraine, Russian Academy of Sciences, Troitsk, Russia  
[glushkov@paco.net](mailto:glushkov@paco.net)

Deformation and shift of the atomic emission and absorption lines in a strong laser field, definition of a laser radiation quality effect on atomic characteristics are the most actual problems of atomic optics to be still solved. At present time, a progress is achieved to describe behaviour of an atom in a harmonic emission field. But in the realistic laser field the corresponding processes in significant degree differ from ones in the harmonic field and manifest unusual behaviour. The widespread approaches to solving considered tasks are as follows: the Green function method, the density - matrix formalism (the stochastic equation of motion for density - matrix operator and its correlation functions). The laser model considered is that of an ideal single-mode laser operating high above threshold, with constant field amplitude and undergoing phase-frequency fluctuations similar to Brownian motion. As correlation time of the frequency fluctuations increases from zero to infinity, the laser line shape changes from Lorentzian to Gaussian in a continuous way. For intermediate and strong fields, an averaged intensity of fluorescence in the case of a resonant broadband Lorentzian line shape is higher than that in the case of the Gaussian line shape with the same bandwidth and total power. This is in contrast to the weak-field case where the higher peak power of the Gaussian line shape makes it more effective than the Lorentzian line shape. In the case of a non-zero frequency correlation time (non-Lorentzian line shape) the intensity of fluorescence undergoes non-Markovian fluctuations. Regarding the spectrum of resonance fluorescence it is shown that as the line shape is varied from Lorentzian to Gaussian the following changes take place: i). in the case of off-resonance excitation, the asymmetry of the spectrum decreases; ii). in the case of resonance excitation, the centred peak to side-peak height ratio for the triplet structure increases. We will use the consistent QED method, which bases on the S-matrix Gell-Mann and Low formalism, for the studying interaction of atomic and molecular systems with the realistic laser field [1]. The radiative emission and absorption atomic lines are studied and described by their moments of different orders  $m(n)$ . The moments are strongly dependent upon the laser pulse quality: intensity and mode constitution. In particular, the  $k$ -photon absorption line centre shift in the transition  $q-p$  can not be obtained from the corresponding expression for the "1"-photon absorption by the replacement of  $w-w/k$  and introduction of the multiplier  $1/k$  ( $w$  - the central laser emission frequency). The cases of a single-, multi-mode, coherent, stochastic laser pulse shape are in details studied. The significant role of the stochasticity and photon-correlation effects is analyzed. Some calculation results of multi-photon resonance and ionization profile in H, Mg, Cs, Kr, and other atoms are presented. For example, studying highly lying states and ATI from the Mg ground state to states with  $J=2$  with taking into account ionization to the  $3s_{kd}$  and  $3p_{kp}$  opened channels showed availability of non-regular clusters of strongly interacting resonances (satisfying to Wigner distribution) and revealed a quantum chaos effect (quantum entanglement). The same program is realizing for nuclei in a super strong laser field, providing opening the field of nuclear quantum optics. The direct interaction of super intense laser fields in the optical frequency domain with nuclei is studied and the AC Stark effect for nuclei is described within the operator perturbation theory [1] and the relativistic mean-field (RMF) model for the ground-state calculation of the nucleus [2]. We find that AC-Stark shifts of the same order as in typical quantum optical systems relative to the respective transition frequencies are feasible with state-of-the-art or near-future laser field intensities.

References:

- [1]. A.V.Glushkov, L.N. Ivanov, *Phys.Lett.A*.170 :33-36, 1992; *J.Phys.B* 26: L376-386, 1993; A.V Glushkov et al, *Europ.Phys.Journ.* 160 : 195-206, 2008; *Phys.Scripta* T134, 5-10 (2009); *Int.J.Quant.Chem.* 99:887-893, 933-939, 2004 ; 104, 512-517, 562-569 (2005).  
[2]. A.V.Glushkov, L.N. Ivanov, Preprint ISAN, N-3AS, Moscow-Troitsk (1992); T.J. Burvenichm J.Evers, C.H.Keitel, *Phys.Rev.Lett.* 96 : 142501, 2006); *Phys. Rev. C.* 74 : 044601, 2007.

### Non-linear prediction method in short-range forecast of atmospheric pollutants:

#### Low-dimensional chaos

Alexander V. Glushkov<sup>1,2</sup>, Valery Khokhlov<sup>1</sup>, Nikolay Serbov<sup>1</sup>,  
Andrey A. Svinarenko<sup>1</sup> and Yuliya Ya. Bunyakova<sup>1</sup>

<sup>1</sup>Odessa University, Odessa (Odessos), Ukraine, <sup>2</sup>Russian Academy of Sciences, Troitsk, Russia  
[glushkov@paco.net](mailto:glushkov@paco.net)

It's known that a chaos is alternative of randomness and occurs in very simple deterministic systems. Although chaos theory places fundamental limitations for long-range prediction (c.f.[1,2]), it can be used for short-range prediction since ex facte random data can contain simple deterministic relationships

with only a few degrees of freedom. We shall (i) study the concentration of atmospheric constituents in Gdanck region to select only those measurements, which are defined as chaotic, and (ii) build non-linear prediction model for selected time series. In our study, nitrogen dioxide (NO<sub>2</sub>) and sulphurous anhydride (SO<sub>2</sub>) concentration data observed at the sites of Gdansk region during 2003 year are used. There are ten sites in the region, but time series are continuous at 2 ones only, Sopot (site 6) & Gdynia (site 9). To reconstruct an attractor, the time delay and embedding dimension are needed. The former is determined by the methods of autocorrelation function and average mutual information, and the latter is calculated by means of correlation dimension method and algorithm of false nearest neighbours. It's shown that low-dimensional chaos exists in the time series under investigation. The spectrum of Lyapunov exponents (LE) is reconstructed as well as both Kaplan-Yorke dimension and Kolmogorov entropy that inversely proportional to the predictability limit are calculated. Our results show that these time series are resulted from the low-dimensional chaos. In spite of the fact that the embedding dimensions for each time series are identical ( $d_N = 6$ ), this outcome is not regularity. Also, the correlation dimensions were calculated using the algorithm of Grassberger and Procaccia [8]. It is noteworthy that the nearest integer above the saturation value provides the minimum or optimum embedding dimension for reconstructing the phase-space or the number of variables necessary to model the dynamics of the system. This concept can be applied to the dynamics of NO<sub>2</sub> time series, since the embedding dimension determined by both the correlation dimension method and the algorithm of false nearest neighbours are identical. The number of variables necessary to model the system dynamics equals six. From the other hand, the analysis of correlation dimension provides only the number of variables, but not their physical meaning.

- [3] H. Abarbanel, R. Brown, J. Sidorowich, L. Tsimring, *Rev. Mod. Phys.* 65:1331-1392, 1993; P. Grassberger, I. Procaccia, *Physica D* 9:189-208, 1983; M.B. Kennel, R. Brown, H. Abarbanel, *Phys. Rev. A* 45: 3403-3411, 1992.
- [2] A. Glushkov, V. Khokhlov, N. Loboda, et al, *Nonlin. Proc. in Geophysics*. 11: 285-293, 2004.; *Atm. Research* (Elsevier). 77:100-113, 2005; *Stoch Environ. Res Risk Assess.* (Springer) 22:777-788, 2008; *Atm. Environment* (Elsevier) 42: 1213-1220, 2008.

### **Impact of Choice of Ensemble on Long-range Forecasting of Monsoon Rainfall**

P Goswami and K C Gouda

CSIR Centre for Mathematical Modelling and Computer Simulation  
Wind tunnel Road, Bangalore – 560037, India

For short or even medium-range forecasting, a primary source of dispersion in the forecasts is the inherent uncertainties in the initial fields. Ensemble averaging of forecasts from different initial conditions provides an efficient way of assessing and handling uncertainties in the forecasts due to inherent uncertainties in the initial conditions. An ensemble forecasting, however, should be able to (non linearly) filter errors for it to be considered good, or useful for forecasting. A critical issue in ensemble forecasting is thus how to create a good ensemble, that is, how to create a set of initial states that would result in a better forecast. A number of techniques and methodologies have evolved since early nineties to generate perturbations for creating an ensemble, especially for short-range forecasting. However, it is now well known that changes in initial conditions can give rise to significant changes in the forecasts even at long range; however, the methodology for generating ensemble for long range forecasting has been less explored so far. The procedure for generating an ensemble of forecasts has to be based on careful consideration. In particular, the ensemble initial states should optimally sample the space of initial states. In case of the Indian summer monsoon, it is characterized by a number of intraseasonal oscillations (ISO) whose phases can significantly affect the monsoon and which can be adequately sampled only using initial states spread over time scales comparable to characteristic time scales of these ISO. We have explored whether use of initial states spread over a longer period (such as April 1-May 1) results in better ensemble average for long-range forecasting of Indian summer monsoon than that from an ensemble of closely packed states with shorter lead. We adopt an optimized configuration for long-range forecasting of monsoon using a variable resolution general circulation model, which can provide higher resolution over a selected area (zoom). The lower boundary forcing (SST) is prescribed as climatological monthly mean to examine our hypothesis primarily in terms of atmospheric internal dynamics. We then compare 5-members wide-lead (April 1-May 1) ensemble average forecasts with 5-member compact-lead (April 27-May 1) ensemble average forecasts for 24 (1980-2003) hindcasts. Our results show that the skill with the wide-lead ensemble average is superior to that with the compact-lead ensemble.

## **Linear Communication Channel Based on Chaos Synchronization**

Victor Grigoras<sup>1</sup>, Carmen Grigoras<sup>2</sup>

<sup>1</sup>Faculty of Electronics, Telecommunications and Information Technology, 'Gh. Asachi' Technical University, Iasi, Romania

<sup>2</sup>Faculty of Medical Bioengineering, University of Medicine and Pharmacy, "Gr.T. Popa", Iasi, Romania, Romanian Academy – Iasi Branch, Institute of Computer Science  
grigoras@etc.tuiasi.ro

This paper presents the possibility of designing a linear communication channel by modulating chaotic analog systems. After presenting the general setup, conditions for correct demodulation and linear dynamic input-output behavior are demonstrated. For a linear dynamic relation between the modulating and demodulated signals, channel equalization is used to achieve wider bandwidth transmission. The presented case studies, regarding the Lorenz and Chen systems, highlight the applicability of the proposed method for high speed digital communication. The overall performance of the resulting communication system is analyzed in terms of speed, security and occupied frequency bandwidth. The concluding remarks point towards some directions in further research.

Keywords: Chaos synchronization, Channel equalization, Lorenz system, Chen System.

## **Turbulent effects in Flux-dominated Solar dynamo models**

G. Guerrero, E. M. de Gouveia Dal Pino & M. Dikpati

IAG-USP, Sao Paulo, Brazil

[guerrero@astro.iag.usp.br](mailto:guerrero@astro.iag.usp.br)

The Babcock-Leighton Solar dynamo models have shown to be relatively successful in reproducing the main features of the solar cycle. In this class of models, the source of the poloidal field is the emergence of bipolar magnetic regions (BMR's) and their further diffusive decay. Meridional flow plays also an important role because it transports the low latitude dipolar field towards the poles, and then to the inner layers in order to close the dynamo loop. This mechanism to produce poloidal field differs from the turbulent  $\alpha$  effect, which it is believed to be quenched, under some conditions, in the presence of strong toroidal fields. However there are another turbulent effects operating in the interior of the convective zone that could have important consequences in the dynamo process. In this work we explore the introduction of the turbulent magnetic pumping and the  $\eta$ -quenching in a Babcock-Leighton dynamo model. We find that the former is important in the transport of the toroidal fields, being in some cases more important than the meridional flow in setting the correct period of the cycle. It could also help to produce solutions with the observed dipolar parity, suggesting that the parity problem is related to the quadrupolar imprint of the meridional flow on the poloidal component of the magnetic field. The turbulent pumping positively contributes to wash out this imprint. For the quenching effect, we solve an algebraic function for  $\eta$  by which it is strongly suppressed when the magnetic field is large, we find the formation of long-lived small intense toroidal magnetic structures. Since the period of the cycle increases when the efficiency of the quenching is larger, we explore whether it is possible to have large values of the magnetic diffusivity in the convection zone and still keep the dynamo in the flux-transport regime, however we observe that for values of  $\eta$  above  $2e11 \text{ cm}^2 / \text{s}$ , the model drifts to the diffusion regime.

## **Positive Entropy of a Coupled Lattice System Related with Belusov-Zhabotinskii Reaction**

J. L. Garcia Guirao, M. Lampart

Department of Applied Mathematics, TU Ostrava, Czech Republic

[marek.lampart@vsb.cz](mailto:marek.lampart@vsb.cz)

In this paper we present a lattice dynamical system stated by K. Kaneko in [Phys. Rev. Lett., 65, 1391-1394, 1990] which is related to the Belusov-Zhabotinskii reaction. We prove that this CML (Coupled Map Lattice) system has positive topological entropy for zero coupling constant.  
Key Words: coupled map lattice, positive topological entropy



### **Nonlinear Head-Neck Dynamics at Small Amplitude Perturbations**

Senih Gurses

Middle East Technical University, Ankara 06531, Turkey

[senih@metu.edu.tr](mailto:senih@metu.edu.tr)

It has been previously reported that head-neck neuromechanical system demonstrates nonlinear characteristics in its response to small amplitude perturbations by looking at the sign of the largest Lyapunov exponent of the system dynamics and the correlation dimension estimates computed at the Poincaré sections [9,21]. Twelve healthy young adults seated on a linear sled randomly received anterior-posterior sinusoidal translations with  $\pm 15$  mm and  $\pm 25$  mm peak displacements at 0.81, 1.76 and 2.25 Hz. Head angular position data was used to reconstruct the system dynamics in  $m$ -dimensional embedded phase space. Correlation dimension estimates ( $D_k$ ) from head angular displacement data have been computed by using the method of time delays ( $\tau$ ). The optimum  $\tau$  for expanding the reconstruction of the attractor has been found by using the average displacement method [10]. Head-neck dynamics has been verified to involve at least two degrees of freedom in the range of stimulations experimented but subjects, demonstrating three degrees of freedom head-neck dynamics especially by increasing the amplitude of perturbation also existed. Furthermore, a knee-like behavior has been observed at the  $\log C(r)$  versus  $\log r$  plots, which is manifested by increasing the perturbation amplitude. The nonlinear behavior observed at the plots has been interpreted as the existence of not-coupled dynamics slightly interacting [11].

Keywords: Head oscillations, Correlation dimension, Time delays, Knee-like behavior

### **Maxwell-Bloch Equations as Predator-Prey System**

A.S.Hacinliyan<sup>1,2</sup>, E.E.Akkaya<sup>1</sup>, I.Kusbeyzi<sup>2,3</sup>, O.O.Aybar<sup>2,3</sup>

<sup>1</sup>Yeditepe University, Istanbul, Turkey, Department of Physics

[erguneray.akkaya@std.yeditepe.edu.tr](mailto:erguneray.akkaya@std.yeditepe.edu.tr), [ahacinliyan@yeditepe.edu.tr](mailto:ahacinliyan@yeditepe.edu.tr)

<sup>2</sup>Yeditepe University, Istanbul, Turkey, Department of Information Systems and Technologies

<sup>3</sup>Gebze Institute of Technology, Kocaeli, Turkey, Departments of Mathematics

[ikusbeyzi@yeditepe.edu.tr](mailto:ikusbeyzi@yeditepe.edu.tr), [oaybar@yeditepe.edu.tr](mailto:oaybar@yeditepe.edu.tr)

Regions of the full parameter space for which chaotic behavior in laser models based on the Maxwell-Bloch equation occurs are studied. Under reasonable conditions, the system has been reduced to a simpler system resembling the Lotka Volterra system, the bifurcation properties have been examined. Key Words: Maxwell-Bloch equations, Hopf Bifurcation, Chaotic behaviour, Optical Nonlinearity.

### **Analysis of chaotic vibration of a nonlinear seven degrees-of-freedom full vehicle model**

H. Hajkarami, H. Samandari, S. Ziaei-Rad

Department of Mechanical Engineering, Isfahan University of Technology, Isfahan, Iran

In this paper, the dynamic behavior of a nonlinear seven degrees-of-freedom ground vehicle model is examined.

The nonlinearity occurs due to suspension dampers and springs. The disturbances from the road are assumed to be sinusoid and the time delay between the disturbances is also considered. Numerical results show that the responses of the vehicle model could be chaotic. Using bifurcation phenomenon, the chaotic motion is detected and confirmed with the Poincare maps. The results can be applicable in dynamic design of a vehicle.

Keywords: Nonlinear dynamics; Chaos; Bifurcation; Poincaré map

### **Elimination of cardiac chaos by low-volt defibrillation using three electrodes**

Monica Hanslien and Ola Skavhaug

Simula Research Laboratory, LYSAKER, NORWAY

[monicaha@simula.no](mailto:monicaha@simula.no)

Disorganized electrophysiological patterns are commonly observed in the human heart. Atrial flutter and fibrillation are the most frequent rhythm disorders, with possibly severe complications unless treated medically. High-voltage shocks are known to terminate cardiac chaos effectively, but are too painful for use when such rhythm disorders occur in the atria. Recent in-lab experiments on animal hearts show that atrial flutter and fibrillation may be wiped out by low-voltage shocks through three,

instead of the normal two, electrodes. In this paper the effect of the additional electrode is tested through numerical simulations of atrial tissue that undergoes atrial flutter which frequently degenerates into chaotic patterns. In our simulations we use the Courtemanche model, coupled to the bidomain equations of cardiac electrical activity to simulate a re-entrant wave. The simulations are performed on a ring of atrial tissue, including blood cavity and the torso in 2D. We demonstrate that the shock strength necessary for termination of re-entry is considerably reduced with the additional electrode.

Key Words: simulations, low-vold defibrillation, three electrodes

### **Chaos in mixing vessels**

Pavel Hasal<sup>1</sup> and Ivan Fort<sup>2</sup>

<sup>1</sup> Institute of Chemical Technology, Prague Department of Chemical Engineering, <sup>2</sup> Czech Technical University, Department of Process Engineering, Czech Republic  
Pavel.Hasal@vscht.cz, Ivan.Fort@fs.cvut.cz

Experimental time series from two geometrically similar mixing vessels are decomposed by Singular Value Decomposition. Low frequency components are identified and extracted and their attractors are reconstructed and the attractor invariants are evaluated in a dependence on operational conditions and fluid properties. Regions with distinct dynamical behaviours are identified within the vessels. The correlation dimension of the attractors is suitable for analysis of transitions between different flow patterns and of different low-frequency flows resulting from these transitions. The maximum Lyapunov exponent can be used to identify regions with dispersive dynamics within the tank.

Keywords: Stirred tank, macro-instability, chaos, attractor, embedding dimension, chaotic invariants.

### **Chaotic Vibration of the First Mode of a Nonlinear Viscoelastic Beam under Moving Mass Excitation**

Arash Hatami, Aria Alasty and Hassan Salarieh

Sharif University of Technology, Mechanical Engineering Department, Tehran, Iran,  
[a\\_hatami@alum.sharif.edu](mailto:a_hatami@alum.sharif.edu), [aalasti@sharif.edu](mailto:aalasti@sharif.edu), [salarieh@sharif.edu](mailto:salarieh@sharif.edu)

This paper presents chaotic behavior of a nonlinear viscoelastic beam under a moving mass interaction. Considering the stretching effect which is modeled by the Lagrangian strain theory and using linear Kelvin-Voigt model to constitute viscoelastic behavior of the beam, the governing equations of transverse vibration is derived. Then Galerkin truncation is applied to find the ordinary differential equation of the first mode vibration of the beam. Solving the single-mode governing equation of the beam indicates that different nonlinear phenomena from regular to chaotic responses appear in the beam vibrations for different values of moving mass. Chaotic behavior of the beam is numerically examined through Poincare map and calculating the Lyapunov exponent of the system time series.

Keywords: Chaos, Viscoelastic beam, Moving mass, Nonlinear vibration

### **The onset of chaos in quantum phase transitions**

WD Heiss

Department of Physics, University Stellenbosch, Stellenbosch, South Africa  
[dieter@physics.sun.ac.za](mailto:dieter@physics.sun.ac.za)

The transitional region of quantum phase transitions is particularly susceptible to the onset of chaos. The study of the Lipkin model serves to demonstrate this point. The behaviour of exceptional points (singularities of the spectrum) play a particular role in the understanding of this phenomenon.

Key Words: chaos and phase transitions

### **Chaos in Traffic Analysed by a Distributed Network of Sensors**

Graeme Hil, Neil Thorpe, Margaret C. Bell  
Newcastle University, Newcastle Upon Tyne, UK  
[G.A.Hill@ncl.ac.uk](mailto:G.A.Hill@ncl.ac.uk)

Traditionally chaotic patterns in traffic have either been investigated through modelling or experimentally captured with a sparse number of sensors, of varying types. Within this paper we detail the effect of using a large number (50+) of wirelessly connected sensors, in two different locations, to capture traffic patterns. Analysis of the data is completed off-line but the possibilities for real time data analysis through the use of a real time database plus a data warehouse is considered. With this data it is hoped to more readily understand how distributed networks break down when they transfer from free flow to congestion and how E-Science may help us understand this.  
Key Words: Traffic, Distributed Sensors, E-Science

### **Mutual implication relationship among complete chaotic maps that preserve a same invariant density**

Huang Weihong  
Nanyang Technological University, Division of Economics, Singapore  
[awhhuang@ntu.edu.sg](mailto:awhhuang@ntu.edu.sg)

An implication relationship among the class of multi-branches complete chaotic maps that preserve a specified invariant density is revealed. Such relationship helps to construct a whole family of complete chaotic maps that preserve not only the same invariant measure but also the same degree of chaos in terms of Lyapunov component.

Key Words: chaotic systems, invariant measure, invariant density, complete chaotic map, fully-chaotic, inverse Frobenius-perron problem

### **Chaos, Brain and Epilepsy: A Bioengineering Approach**

Leon D. Iasemidis  
The Brain Dynamics Laboratory The Harrington Department of Bioengineering and Electrical Engineering Arizona State University Tempe, USA

The normal state of the brain exhibits chaos in the spatial and temporal domain. Electroencephalographic (EEG) recordings from the surface (scalp EEG) and depth (intracranial EEG) of the human and animal brain are characterized by spatio-temporal chaos. Over the last 20 years, analysis of measures of chaos (Lyapunov exponents, Kolmogorov entropy etc.) from continuous (time resolution of msec), long-term (days) EEG over multiple brain sites (space) has revealed similarities with dynamical phenomena (e.g., chaos synchronization, hysteresis) exhibited before and after phase transitions of complex nonlinear systems. Novel concepts, like "dynamical resetting" and "feedback decoupling" control of the dynamics of the brain, have also been recently developed, especially in connection with epilepsy. Epilepsy is very prevalent (afflicts 1% of the population and is second only to stroke), debilitating and at times devastating (status epilepticus is a life-threatening condition) neurological disorder. The pathology of dynamics in the epileptic brain is characterized by an intense and long-term synchronization of chaos at normal brain sites with the chaos at the epileptogenic focus (foci). This pathology is reset by seizures themselves or by a successful external intervention (e.g. anti-epileptic drugs or deep brain stimulation). Examples of the underlying concepts from animal and simulation models, as well as from patients with epilepsy, will be presented. It will be shown that the impact of these findings on the understanding of the mechanisms of epileptogenesis may constitute the basis for a) improvement of the diagnosis and prognosis of epilepsy patients, and b) design and development of much needed new and effective therapies (e.g., brain pacemakers) for epilepsy and other brain dynamical disorders. It is expected that this line of research, being mathematically general enough and having produced significant results in the most complex living system, the brain, could also assist with the prediction and control of catastrophic transitions in networks of other complex biological and physical systems.

Key Words: Spatio-temporal chaos, Spatial synchronization, Prediction and control of epileptic seizures, Brain resetting

## Long time Simulations of Astrophysical Jets Energy Structure and Quasi-periodic ejection

Ahmed Ibrahim and Kazunari Shibata

Department of Astronomy and Meteorology, Faculty of Science, Al-Azhar U., Cairo, Egypt,  
[ahmednobi2000@yahoo.com](mailto:ahmednobi2000@yahoo.com)

We have performed self-consistent 2.5-dimensional nonsteady MHD numerical simulations of jet formation as long as possible, including the dynamics of accretion disks. Although the previous nonsteady MHD simulations for astrophysical jets revealed that the characteristics of nonsteady jets are similar to those of steady jets, the calculation time of these simulations is very short compared with the time scale of observed jets. Thus we have investigated long term evolutions of mass outflow rate, poynting flux, kinetic energy flux, enthalpy flux and the energy of the toroidal magnetic field. We found that average poynting flux is dominant over both kinetic energy flux and enthalpy flux especially when initial magnetic field is strong. The radial dependences of different energies reveal that the main source of collimation comes from the pinching by toroidal field. We found that the ejection of jet is quasi-periodic and the periodicity of the jet can be related to the time needed for the initial magnetic field to be twisted to generate toroidal field. Key Words: MHD simulations, astrophysical jets

## Chaotic phenomenon in a multi-wave ionization of non- Rydberg atoms

Anna V. Ignatenko

Odessa University, Odessa (Odessos), Ukraine  
[quantign@mail.ru](mailto:quantign@mail.ru)

In last years a phenomenon of multiwave ionization and photoionization of atomic systems in low-frequency electromagnetic fields attracts a great interest [1,2]. Above many reasons very essential moment is connected with a possibility of realizing quantum chaos phenomenon in a system. Earlier it was shown that an ionization process for highly excited H atom states by a strong low frequency electromagnetic field is realized through a mechanism of diffusion on atomic states which are strongly perturbed by a field. An important feature of process is in a stochastic character of electron vibrations. In order to describe a stochastic dynamics of hydrogen atom, several models were developed. The most simplified model uses diffusion like equation [2]. More sophisticated numerical calculations are presented in refs. [2]. Experimental observation of chaotic effect was carried out for the H atom from the state with ground quantum number  $n=60$  in a field of frequency  $\omega=9,9$  GGz. In series of papers by Casati et al [3] a dynamical chaos effect for hydrogen atom in a field was at first correctly described by the non-linear classic mechanics methods. If a hydrogen atom in a field problem is studied in many details, the analogous problem for multi-electron highly excited atoms is far from their adequate solution. In this aspect an especial interest attracts studying the highly excited dynamic Stark resonant states for alkali elements atoms in a electromagnetic field. This problem is also stimulated by experimental discoveries of the near threshold resonances in the photo ionization cross sections for hydrogen and alkali atoms in a electric field [4]. Here we study a phenomenon of multiwave ionization of non-hydrogenic Rydberg atoms on example of alkali atoms. All results are obtained by using quasi-stationary, quasi-energy states method and the model potential one [5].

### References:

- [1] M. W. Noel, M. W. Griffith, T. F. Gallagher, *Phys. Rev. A* **62**:063401, 2000.
- [2] A. Krug, A. Buchleitner, *Phys. Rev. Lett.* **86**:3538-3541, 2001; A. Krug, A. Buchleitner, *Europhys. Lett.* **49**:176-180, 2000.
- [3] F. Benvenuto, G. Casati, D.L. Shepelyansky, *Z.Phys.B.* **94**:481-486, 1996; G. Casati, I. Guarneri, G. Mantica, *Phys.Rev.A.* **50**:5018-5024, 1994.
- [4] A.V. Glushkov, .Proc. Int. Conference on Quantum Chaos: Theory and Application, Cocoyoc, Mexico (2001), p.40.
- [5] A.V. Glushkov, L.N. Ivanov, *J.Phys.B:At.Mol.Opt.Phys.* **26**:L379-388, 1993; A. Glushkov, S. Ambrosov, A. Ignatenko, D. Korchevsky *Int.J.Quant.Chem.* **99**:8889-896 (2004).

### **Multidimensional Visualization and its Applications**

Alfred Inselberg

School of Mathematical Sciences, Tel Aviv University, Israel

[aaisreal@math.tau.ac.il](mailto:aaisreal@math.tau.ac.il)

With Parallel Coordinates the perceptual barrier imposed by our 3-dimensional habitation is breached enabling the unambiguous visualization of multidimensional problems and multivariate relations. For  $RN$  points are mapped into planar polygonal lines (see representation of vertices in Fig. 3) and hypersurfaces into  $(N - 1)$  distinct planar regions. The methodology is developed intuitively from its foundations to recent result like the visualization of proximity for families of “close” lines & hyperplanes; a central problem in many applications. Properties of hypersurfaces are detected from their representation. Convexity in *any dimension* or non-convex features like bumps, dimples, coiling, non-orientability can be recognized from one orientation, unlike standard 3D surface representations. Concepts and applications are illustrated interactively. The parallel coordinates methodology has been applied to collision avoidance algorithms for air traffic control (3 USA patents), computer vision (USA patent), data mining (USA patent) for data exploration and automatic classification, optimization, process control and elsewhere.

KEYWORDS: Multidimensional Visualization, Parallel Coordinates, Visual & Automatic Data Mining, Multidimensional Problems

### **Detecting weak phase locking in ill-defined attractors**

Hengtai Jan, Ming-Chung Ho, and I-Min Jiang

National Sun Yat-sen University, Kaohsiung, Taiwan

[zarda@ms8.url.com.tw](mailto:zarda@ms8.url.com.tw)

The present analysis methods for detecting phase synchronization are unable to apply on a chaotic system with complex phase skeleton. The novel quantitative analysis for a chaotic system with ill-defined attractors, which is locked weakly by a prescribed periodic signal, was constructed via stroboscopic method. The onset coupling strength of weak phase locking in this analysis result do well match the critical coupling strength as the originally null Lyapunov exponent becomes negative. The detail structure of phase locking intensity is described by Arnold tongue diagram.

Key Words: Chaotic synchronization, CHUA'S oscillators,

### **Front dynamics with delays in a bistable system of the reaction-diffusion type: role of symmetry of the rate function**

V. Jasaitis, F. Ivanauskas

Faculty of Mathematics and Informatics, Vilnius University, Vilnius, Lithuania

[valdas.jasaitis@gmail.com](mailto:valdas.jasaitis@gmail.com)

The retardation effects in dynamics of the ac driven fronts joining two stable states of the different stability in a bistable system of the reaction-diffusion type are studied by use of the piece wise linear rate (reaction) function of the flexible symmetry. We investigate the front dynamics numerically and, partially, also analytically. By tuning the adjustable parameters of the rate function we investigate whether the retardation effects in front dynamics are sensitive to the symmetry of the rate function, i.e., how the lag time between the ac drive and the moment velocity of the ac driven front depends on the adjustable parameters of the rate function. By considering the response of the self-ordered front to the step-like ac force we find that the numerically found speed function follows the analytic approximation in the case of the asymmetric piecewise-linear rate function. Another aspect of front dynamics studied in our report is the influence of delays on the ratchet-like transport of the ac driven fronts generated by the rate functions of the different symmetry. By using the oscillatory (single-harmonic) force of zero time average we find the dependency between the mean drift velocity of the ac driven bistable front and the frequency of the driving force is sensitive to the symmetry of the rate function. Moreover characteristics of the mean drift velocity versus the strength (amplitude) of the driving force being derived by the computer simulations is very close to that being derived within the quasi-stationary regime of the ac drive.

Keywords: nonlinear dissipative systems, self-ordered fronts, ratchet-like transport, partial differential equations.

## Identifying Chaotic and Quasiperiodic Time-Series Candidates for Efficient Nonlinear Projective Noise Reduction

N. Jevtic <sup>[a,b]</sup>, J.S. Schweitzer <sup>[b]</sup>

<sup>[a]</sup> Physics and ET, Bloomsburg University, <sup>[b]</sup> Physics Department, University of Connecticut

One of the principal problems in identifying chaos using nonlinear time-series analysis of real-world data is additive noise. A straightforward procedure in traditional phase-space is introduced that can be used to identify data sets amenable to nonlinear projective noise reduction. This methodology can be used both as a tool for identifying candidates for noise reduction and, and with some adaptation, for “zeroth order” noise quantification. Results for simulation data are compared with that for a quasiperiodic measured time series to illustrate when series can benefit most from nonlinear projective noise reduction.

## Asynchronous chaos-based DS-CDMA over multi-path channels: Analytical bit error rate

Georges Kaddoum, Pascal Charge, Daniel Roviras, and Daniele Fournier-Prunaret

IRIT/ENSEEIH, Toulouse, France

[gkaddoum@enseeiht.fr](mailto:gkaddoum@enseeiht.fr)

This paper presents a new approach to compute the analytical bit error rate (BER) for multi-user chaos-based DS-CDMA. A stationary multi-path channel with constant gain is considered. The studied system is an uplink chaos-based DS-CDMA system, where all users transmit their signals over the same multi-path channel. The emission time between the different users and the base station is random. In order to outperform the current system performance, a simple RAKE receiver structure is considered. Perfect estimation of the channel coefficients with the associated delays and chaos synchronization is assumed.

A widely used assumption is initially considered in order to compute the BER for chaos-based communication systems. This assumption is known as the "Gaussian approximation" Tam *et al.* (2004), and considers the sum of dependent variables at the output of the correlator as a Gaussian variable. This assumption suffers from low precision for a small spreading factor [Tam *et al.* (2004)] because the chaotic signals are generated from a deterministic generator. From the non-periodic nature of a chaotic sequence, the energies of the transmitted bits can not be considered as constant. In this paper, the interest is to compute the performance of chaos-based DS-CDMA system in a better way. The main idea is to use the probability density function (pdf) of the chaotic bit energy.

To get an analytical expression for the BER it is necessary first to have an analytical expression for the pdf of the bit energy and secondly to compute a suitable integral of it to yield the BER. An analytical expression for the pdf is difficult to derive because chaotic samples are not statistically independent, rather they are functionally dependent. Another solution is proposed which is based on intensive work that has been done on the analytical expression of BER in the context of mobile radio channels. It can be obtained if the root square of the energy distribution follows one of the known Rayleigh, Nakagami or Rice distribution laws. Thus to investigate this aspect, the root square bit energy is simulated to obtain its distribution in histogram form, and using the chi-square test, the Rice distribution is found to be the most appropriate one of the three. This solution will lead to an analytical BER expression which is derived in terms of the root square energy distribution, the number of paths, the noise variances, and the number of users. The results are illustrated by theoretical calculations and simulations which point out the accuracy of the approach.

Keywords: Chaos-based DS-CDMA, asynchronous multi-user, bit energy distribution, Rice distribution, multi-user interference, self interference, bit error rate.

## Reference

Tam, W. M., Lau, F. C. M., Tse, C. K. and Lawrance, A. J. "Exact analytical bit error rate for multiple access chaos-based communication systems". *IEEE Trans. Circuits and Systems*, 9, 473-481, 2004.

### **Chaotic Mode-locking of Chirped-pulse Oscillators**

Vladimir L. Kalashnikov  
Institut für Photonik, Wien, Austria  
kalashnikov@tuwien.ac.at

Chaotic mode-locking of chirped-pulse oscillator has been analyzed on the basis of generalized nonlinear cubic-quintic complex Ginzburg-Landau equation.

It has been shown, that the chirped solitary pulse can be stabilized against the vacuum excitation, if the fourth-order dispersion is nonzero and positive. However, the pulse evolves chaotically, if the dispersion reaches some threshold value.

Keywords: Chirped-solitary pulse, Pulse propagation and temporal solitons, Mode-locked lasers.

### **Modeling and Verifying an Innovative Biomass-based Thermal Energy System**

Athanasios Kalpakas, John Fasoulas and George Rovithakis  
Aristotle University of Thessaloniki, Faculty of Engineering,  
Dept. of Electrical and Computer Engineering  
Thessaloniki, Greece

[kalpakas@ee.auth.gr](mailto:kalpakas@ee.auth.gr), [jfasoula@ee.auth.gr](mailto:jfasoula@ee.auth.gr), [robi@eng.auth.gr](mailto:robi@eng.auth.gr)

Biomass exploitation systems are able to supply heat, steam and electricity for home or industrial users. However, modern utilization methods of biomass do not deal with the problem globally but usually get confined to empirical and non-optimal approaches. The innovative energy production unit which is designed and implemented in this paper suggests a universal processing and exploitation strategy using several different types of biomass while aiming at an effective combustion with minimum losses. System identification and modeling of the combustion process is implemented using a simplified linear model which can adequately describe the above process and lay strong foundations for a prospective robust control.

Keywords: thermal systems, combustion modeling, energy systems simulation

### **Basins of Convergence in the Restricted Five-Body Problem of Ollöngren**

Tilemahos J. Kalvouridis<sup>1</sup> and Meropi Paraskevopoulou<sup>2</sup>  
National Technical University of Athens, Department of Mechanics, Athens, Greece  
<sup>1</sup>[tkalvouridis@gmail.com](mailto:tkalvouridis@gmail.com), <sup>2</sup>[m\\_paraskevopoulou2005@yahoo.com](mailto:m_paraskevopoulou2005@yahoo.com)

The paper deals with the chaotic and deterministic character of the basins of convergence in the restricted five-body problem of Ollöngren. The parametric evolution of these regions as well as of the equilibrium locations of the small body is also investigated and some useful remarks concerning this dynamical aspect of the problem are made.

Keywords: Chaotic and deterministic basins of convergence, Newton's method for nonlinear algebraic equations, restricted five-body problem of Ollöngren, numerical determination of equilibrium positions

### **Computing the Dominant Subgroups of the Full Non-rigid Group of Hexamethylethane**

Majid Karami<sup>1</sup> and Ali Moghani<sup>2</sup>

<sup>1</sup>Department of Mathematics, Islamic Azad university, South branch Tehran, <sup>2</sup>Department of Color Physics, Institute for Colorants Paint and Coating (ICPC), Tehran, Iran.  
[m-karami@azad.ac.ir](mailto:m-karami@azad.ac.ir)

Recently, the full non-rigid (f-NRG) group of hexamethylethane has been introduced by Darafsheh and et al (J. Chem. Phys.). The f-NRG of hexamethethane is isomorphic to the semidirect product of six copies of the cyclic group of order 3 by the dihedral group of order 12 (with order 8748). The dominant subgroups of finite group has been proposed by S. Fujita who applied his results in this area of research to enumerate isomers of molecules. In this paper, via GAP program all the dominant subgroups of the above molecule are computed.

Keywords: Full non-rigid group, Symmetry, Dominant subgroup, hexamethethane.

## **Sensitivity to parameter variation of time-delay feedback Chua's circuit**

Trabelsi Karim, Ben Jemaa Zouhair and Belghith Safya  
Ecole nationale d'ingénieurs de Tunis (ENIT), University El Manar. Tunis, Tunisia.  
Karim.Trabelsi@enig.rnu.tn

Many parameter estimation based proposed attacks of chaotic secure communication system have been proposed in literature; the more sensitive to parameter variation the chaotic system is, the more robust to attacks it is.

The aim of this paper is to prove that it is possible to increase the degree of the sensitivity to parameter variation of time delay chaotic systems; by introducing a time delay feedback. We considered classical Chua's circuit and time delay version of this circuit; in the two cases we analysed the resemblance between two solutions corresponding to two slightly different parameters. This resemblance is measured by computing the intercorrelation between the solutions. We found that by choosing the parameters of the time delay feedback it possible to increase the sensitivity to parameters of time delay feedback system with respect to standard one.

Keywords: Chaos, Delay-systems, Sensitivity to parameter.

## **Chaos in Semiconductor Laser Amplifiers**

Abid Karim  
Bahria University (Karachi Campus), Karachi, Pakistan  
[abid@bimcs.edu.pk](mailto:abid@bimcs.edu.pk)

Semiconductor laser amplifiers have been studied extensively due to their potential use in future optical communication systems and optoelectronic integrated circuits (OEICs) [1-2]. However, when a pre-biased SLA is subjected to external optical signals (as in optical communication systems and in OEICs), local carrier density within the active layer of SLA decreases while the refractive index increases accordingly. This results in non-linear behaviour of the device. The non-linear phenomena in a SLA (Fabry-Perot or travelling-wave) may introduce periodic pulsation (or self-sustained pulsation (SSP)), sub-harmonic generation, period doubling, period quadrupling and period tripling; all leading to chaos as a result of time dependant instabilities within the gain medium [3-6]. Chaotic dynamics and SSP have gained considerable importance due to the following reasons:

1. Non-linearities in amplifiers introduce additional cross talk and noise [7] which are the main obstacles to the application of semiconductor lasers in ultra-high frequency regime. They are undesirable in optical communication systems and in OEICs and therefore must be eliminated.
2. Non-linear behaviour and chaotic dynamics of laser based optical systems are the subject of intensive theoretical and experimental investigations because a better understanding of non-linear dynamics allows us to avoid these non-linearities and chaos [8].
3. It has potential applications in the fields of encrypted, synchronised, secure and high speed communication [9-10], linewidth enhancement [11] and ultra-fast and short pulse generating systems [12].

Normally, in a semiconductor laser based system, nonlinearities are not expected due to the fast intraband relaxation rate, but can be achieved by introducing some external effects, such as;

- (a) Modulation of the pumping currents [13-14].
- (b) Feedback by an external cavity [15].
- (c) Injection of external optical signals [16].

In all three approaches, the essential requirement is the existence of two frequencies [17], which characterise the non-linear dynamics of the device. Individually, they assume only one degree of freedom. However, if a source laser and a SLA are coupled to each other, then the injection of the input signal can generate considerable amount of non-linearity in an optical system [18]. In this paper, non-linear dynamics of a semiconductor laser amplifier, subjected to an external input radiation are investigated experimentally by generating self-sustained pulsation. Period doubling route to chaos is demonstrated for the first time. Co-existence of multiple wavelengths satisfying the cavity resonance of the SLA is thought to be the main reason behind the appearance of this behaviour.

Key Words: Semiconductor laser amplifiers, SSP, Chaos, Frustrated instabilities, Coherence collapse



## REFERENCES

1. T. Mukai, Y. Yamamoto, T. Limura, Semiconductor and Semimetal, Ed. W. T. Tsang, Academic Press, New York, vol. E, 265 (1985).
2. Special issue on optical amplifiers, Ed. Y. Yamamoto, T. Mukai, Opt. and Quantum Electron. vol. 21 (1989).
3. H. F. Liu, W. F. Ngai, IEEE J. of Quantum Electron. 29, 1668 (1993).
4. Y. H. Kao, N. M. Wang, H. M. Chem, IEEE J. of Quantum Electron., 30, 1732 (1994).
5. Bennett, S., Snowden, C. M., Iezekiel, S., IEEE J. of Quantum Electron., 33, 2076 (1997).
6. Special issue on Fundamental nonlinear dynamics of semiconductor lasers, J. of the European Opt. Society Part B: Quantum and Semiclassical Optics, vol. 5 (October 1997).
7. A. Argyris, K.E. Chlouverakis, A. Bogris, D. Syvridis, Photonics Tech. Lett. 19, 1667 (2007).
8. J. Ohtsubo, Optical Rev. 6, 1 (1999).
9. P. Colet, R. Roy, Opt. Lett. 19, 2056 (1994).
10. J. P. Goedgebuer, L. Larger, H. Porte, Phys. Rev. Lett. 80, 2249 (1998).
11. C. H. Henry, IEEE J. Lightwave Technol. LT-4, 288 (1986).
12. H. Kawaguchi, H Appl. Phys. Lett. 45, 1264 (1994).
13. J. Sacher, D. Baums, P. Pankinn, W. Elsasser, E. O. Gobel, Phys. Rev. A, 45, 1893 (1992).
14. Y. C. Chen, H. G. Winful J. M. Liu, Appl. Phys. Lett. 47, 208 (1985).
15. J. Mork, Mark, J. B. Tromberg, Phys. Rev. Lett. 65, 1999 (1990).
16. T. B. Simpson, J. M. Liu, A. Gavrielides, V. Kovanis, P. M. Alsing, Phys. Rev. A, 51, 4181 (1995).
17. H. G. Winful, Y. C. Chen, J. M. Liu, Appl. Phys. Lett. 48, 616 (1986).
18. Karim, A., Proceedings of the Romanian Academy, Series-A, 9, 01 (2008).

### **Full-Wave Analysis of a Frequency Selective Surfaces with Fractal-Type Elements**

A.O.Kasyanov, V.A.Obukhovets  
Taganrog Institute of Technology Southern Federal University  
Taganrog, Russia  
[vao@tsure.ru](mailto:vao@tsure.ru)

It is shown the possibility of development of multifrequency frequency selective surfaces (FSS) by means of complicating of the shape of elements, for example, using elements with composite fractal shape. In the paper the method of integral equations is applied for the analysis of scattering characteristic of these gratings. In the paper the possibility of applying of FFS with elements of the composite shape at development of multifrequency FSS with reduced angular sensitivity on the basis of numerical experiment is shown. The obtained results can be used for choosing the most rational version of element shape of FSS at a solution of some problems in antenna engineering.

### **Kolmogorov-Sinai entropy from the ordinal viewpoint**

Karsten Keller, Mathieu Sinn  
Institute of Mathematics, University of Luebeck, Germany  
[keller@math.uni-luebeck.de](mailto:keller@math.uni-luebeck.de)

Much of the structure of time-discrete multidimensional dynamical system is already determined by its ordinal structure. In order to explain this phenomenon more precisely, we show that multidimensional ordinal patterns, which describe the up and down in the components of the orbits of a map, are in a certain sense generating for a large class of Borel measurable maps. On this base we give statements relating the Kolmogorov-Sinai entropy to a multivariate generalization of the permutation entropy introduced by Bandt and Pompe.

Key Words: Kolmogorov-Sinai entropy, ordinal pattern, permutation entropy

## Atomic parity non-conservation in atoms and dynamical enhancement of weak interaction: Quantum chaos

Olga Yu. Khetselius<sup>1</sup>

<sup>1</sup>Odessa University, Odessa (Odessos), Ukraine  
[nuclei08@mail.ru](mailto:nuclei08@mail.ru)

During the past decade, first of all the optical experiments to detect atomic parity non-conservation (PNC) have progressed to the point where PNC amplitudes can be measured with accuracy on the level of a few percents in certain heavy atoms [1,2]. Promising idea (Forston) is to apply the techniques of laser cooling and ion trapping to measurement of the PNC in  $6s^2S_{1/2}-5d^2D_{3/2}$  transition of the singly ionized barium. To provide an adequate treating these experiments in terms of the standard model for a electro-weak interaction, comparison of the measured amplitudes with theoretically defined ones is required. In the quantum many-body systems with dense spectra of excited states weak perturbation can be significantly enhanced. We consider an enhancement of the PNC effects in heavy atoms and neutron-nucleus reactions. Using the PNC effects one can study quantum chaos in many-body systems, nuclear fission, distribution of neutrons in nuclei etc [1-3]. Nowadays the PNC in atomic systems has a potential to probe a new physics beyond the standard model. We systematically apply the formalism of the relativistic many-body perturbation theory [2] to precise studying PNC effect in heavy atoms (nuclei) with account for the relativistic, nuclear and radiation corrections. Earlier an efficiency of this approach has been demonstrated in the precise calculation of the hyperfine structure constants, E1, M1 transition probabilities for heavy atoms and heavy ions [3]. We present the preliminary calculation results for energy levels, hyperfine structure intervals, E1-,M1-transitions amplitudes in heavy atoms of  $^{133}\text{Cs}$ ,  $^{137}\text{Ba}^+$ ,  $^{207}\text{Pb}$ ,  $^{119}\text{Sn}$ . For comparison the analogous data (e.g.[1,2]) by Dzuba et al (Novosibirsk), Bouchiat et al (Paris), by Johnson et al (Indiana), by Johnson-Sapirstein-Blundell (Notre Dame) are presented. Comparison of calculated transition amplitudes with the measurement by Noeker et al gives the following data of weak nuclear charge  $Q_w$  and the Weinberg angle  $\vartheta_w$ .

References:

- [1] V.V.Flaumbaum, *Phys.Scripta* T46:198-207, 1993; W. Johnson, J. Sapirstein, S. Blundell, *Phys. Scripta* T46:184-192, 1993); V. Dzuba, V.Flambaum, M. Safronova, *Phys. Rev. A* 73:022112,2006; B.Sahoo, B. Das, et al, *Phys. Rev.A* 75:032507, 2007.
- [2] A.V.Glushkov, O. Khetselius, et al, *Nucl. Phys.A734S:21-26*, 2004; *Frontiers in Quant. Systems in Chem. and Phys.* (Berlin, Springer) 18:521-558, 2008; *Recent Adv. in Theory of Phys. and Chem. Systems* (Berlin, Springer) 15:285-300, 2006.
- [3] O.Yu.Khetselius, *Phys. Scripta* T134, 2009; *Int. J. Quant.Chem.* 109:N10, 2009.

## Dynamics of multi-layers neural networks on the basis of photon echo: Effects of chaos and stochastic resonance

Olga Khetselius<sup>1</sup>, A.V. Glushkov<sup>1,2</sup>, L.Lovett<sup>3</sup> and V.Buyadzhi<sup>1</sup>

<sup>1</sup>Odessa University, Odessa (Odessos), Ukraine, <sup>2</sup>Russian Academy of Sciences, Troitsk, Russia, <sup>3</sup> UK National Acad.of Sciences and Bookdata Co., London, UK  
[nuclei08@mail.ru](mailto:nuclei08@mail.ru)

In our work we carry out new quantum models for dynamics of the optical neural networks on the basis of the photon echo and study the features of the optical bi-stability manifestation, resonance-stochastic effects in two-level atomic ensembles [1] and provide the PC computer realization of the models with the aim of computer modelling the neural networks dynamics [2]. We proposed a new quantum model of optical photon echo neural networks, provided by hyperfine structure of states of the two-level atomic ensembles. The results of the computer experiments on dynamics of neural networks with input rectangular pulse are presented. On the basis of the object oriented programming we carried out the numerical realization of the new model and performed the computer simulation experiments in order to study the optimal

information possibilities of photon echo neural network in tasks of the images and complex signals detection and estimate a possibility of the resonance stochastic effects manifestation. In particular, the input signal is modelled by the sin, cos, soliton-like, rectangular pulses. Besides, it has been considered a case of the noise input signal sequence. It is shown that for definite value of the additive

noise intensity  $D$  ( $D = 0,0001-0,004$ ) a tutoring process of the neural network is very effective and the signal reproduction is an optimal (the optimal value  $D = 0,0017$ ). A coherence of input and output is optimal under definite level of noise. So, it is shown that it is possible a realization of the stochastic resonance regime in a photon echo neural networks system.

#### References

- [1] A. Glushkov, et al, Recent Adv. in Theory of Phys.and Chem. Systems (Springer) 15:285-308, 2006.
- [2] A.V. Glushkov et al, Dynamics of neural networks on basis of photon echo and its computer program realization, Odessa: TEC, 2004; 300p.

#### **Chaos from the Observer's Mathematics point of view**

Boris Khots, Dmitriy Khots  
Compressor Controls Corporation, Des Moines, Iowa, USA  
[bkhots@cccglobal.com](mailto:bkhots@cccglobal.com)

This work considers Chaos aspects in a setting of arithmetic provided by Observer's Mathematics (see [www.mathrelativity.com](http://www.mathrelativity.com)). We prove that Euclidean Geometry works in sufficiently small neighborhood of the given line, but when we enlarge the neighborhood, non-euclidean Geometry takes over. We give an analog of Lorentz transform. We prove that the physical speed is a random variable, cannot exceed some constant, and this constant doesn't depend on an inertial coordinate system. Certain results and communications pertaining to these theorems are provided.

2000 MSC: 81Q50, 37D45

Key Words: Observer, Chaos, arithmetic, derivative, Lorentz

#### **Evaluation for Threat of Debris Flows: Virtual Nature Systems Approach**

Valeriy I. Klenov  
Private, Moscow, Russia  
[klenovvaleriy@mail.ru](mailto:klenovvaleriy@mail.ru)

Virtual Nature Systems (VNS) are enlivening computer doubles for the Actual Nature Systems (ANS), with properties of the Open Non-Equilibrium Nature Systems (ONES). The ability of multi-purpose VNS is to evaluate Geodynamics for any area (one or several river basins). This ability requires for preliminary validation of the VNS by existing data on exogenous and endogenous external influences. Instead for assessment of the Risk as statistic criteria, the VNS evaluates the Threat by VNS training on concrete area. Evaluation for debris flows threats over any hazardous area require for continual monitoring for external factors. Summary and current mapping of the threats is in result.

Keywords: Virtual Nature System, External factors, Debris flows, River basins, Calibration, Risk, Threat, Monitoring, Systems analysis.

#### **Markovian forecast of extreme events by methods of symbolic dynamics**

I.Knyazeva, N.Makarenko  
Pulkovo Observatory of Russian Academy of Sciences, St.Petersburg, Russia  
[iknyazeva@gmail.com](mailto:iknyazeva@gmail.com)

The records in time series which are upper than the some level or threshold are called extreme events. Usually threshold is chosen in such a way that these extreme values belongs to tail of the distribution function. The task of extreme events predictions appears in different fields, for example in geophysics. There were two approaches considered. First of them is based on selection of a certain threshold value, which is considered as extreme event. We applied symbolic dynamics techniques to obtain an empirical measure. The extreme events we coded as ones, other records is zero. As a result we received a consecution of symbols. From this symbolic representation of the time series we construct the words or patterns of symbols with fixed length. The frequency distribution of such words could be seen as empirical estimation of measure. In the most interesting cases a multifractal analysis

showed that the measure has multifractal properties. So it could be modeled with a Recurrent Iterated Function System with probabilities. Such system represents random dynamical system. Its trajectories lie on the attractor which has a unique ergodic measure. So, the coefficients and the probabilities could be found by solving the inverse problem in fractal theory. We used "collage-distance" as an objective function of the problem. In such a way we generated theoretical measure and used it for the prediction. The predictor was implemented in a form of Markovian chain. The second approach is based on patterns of order. This approach could be applied in the cases when we could not define a fixed threshold for time series. We divided whole time series into the short samples with a fixed length. The sequence of counts in each word was encoded in accordance to the relation of strict order. The prediction was based on using matrix of transitional probabilities between different words. Numerical results of real data prediction were received for both methods and they showed that such approaches are very perspective

Keywords: Symbolic dynamic, time series forecasting, multifractals, IFS.

### **New model of nonlinear oscillations generators**

Alexander A. Kolesnikov

Technological Institute of Southern Federal University, Synergetics and Control Processes  
Department, Taganrog, Russia  
anatoly.kolesnikov@gmail.com

In modern nonlinear dynamics the most fundamental problem is complex control problem of regular and chaotic oscillation processes in systems of various natures. This problem becomes one of the source for development of nonlinear dynamics and synergetics, i.e. science about processes of self-organization in complex system.

We explore synergetic approach to synthesis of self-oscillated systems based on famous method of analytical design of aggregated regulators [1, 2]. This approach provides analytical definition of feedbacks that form desired structure of nonlinear oscillation processes. Developed new types of nonlinear oscillations generators cover as particular cases as model of well-known generators: Poincare, van der Pole, Rayleigh and so on.

### **Nonlinear system's synthesis – the central problem of modern science and technology: synergetics conception. Part I: General Statements (plenary report)**

Anatoly A. Kolesnikov

Technological Institute of Southern Federal University, Synergetics and Control Processes  
Department, Taganrog, RUSSIA  
anatoly.kolesnikov@gmail.com

Our environment, such as natural, social, economics and engineering ones are the world of complex supersystems of various natures. These systems are collection of various subsystems providing defined functions and interconnected by processes of forced dynamics interaction and exchange of power, matter and information. These supersystems are nonlinear, multidimensional and multilinked. And in these systems are complex transients and has place of critical and chaotic modes. Problems of system synthesis, i.e. finding of common objective laws of control processes in a such dynamics system are much actual, complicated and, in many respects, practically inaccessible for present control theory.

In the report we consider fundamental basis of nonlinear theory of system's synthesis based on synergetics approach in modern control theory as well as its application [1, 2].

The report consists of three parts: Part I General Statements; Part II Strategies of Synergetics control; Part III Synergetics synthesis of nonlinear systems with state observers.

Keywords: synergetics, system's synthesis, invariants, nonlinear systems, regulator's design, chaotic disturbances

**Nonlinear system's synthesis – the central problem of modern science and technology:  
synergetics conception. Part II: Strategies of Synergetics control  
(plenary report)**

Anatoly A. Kolesnikov

Technological Institute of Southern Federal University, Synergetics and Control Processes  
Department, Taganrog, Russia  
anatoly.kolesnikov@gmail.com

Our environment, such as natural, social, economics and engineering ones are the world of complex supersystems of various natures. These systems are collection of various subsystems providing defined functions and interconnected by processes of forced dynamics interaction and exchange of power, matter and information. These supersystems are nonlinear, multidimensional and multilinked. And in these systems are complex transients and has place of critical and chaotic modes. Problems of system synthesis, i.e. finding of common objective laws of control processes in a such dynamics system are much actual, complicated and, in many respects, practically inaccessible for present control theory.

In the report we consider fundamental basis of nonlinear theory of system's synthesis based on synergetics approach in modern control theory as well as its application [1, 2].

The report consists of three parts: Part I General Statements; Part II Strategies of Synergetics control; Part III Synergetics synthesis of nonlinear systems with state observers.

Keywords: synergetics, system's synthesis, invariants, nonlinear systems, regulator's design, chaotic disturbances

**Nonlinear system's synthesis – the central problem of modern science and technology:  
synergetics conception. Part III: Synergetics synthesis of nonlinear systems with state  
observers**

**(plenary report)**

Anatoly A. Kolesnikov

Technological Institute of Southern Federal University, Synergetics and Control Processes  
Department, Taganrog, Russia  
anatoly.kolesnikov@gmail.com

Our environment, such as natural, social, economics and engineering ones are the world of complex supersystems of various natures. These systems are collection of various subsystems providing defined functions and interconnected by processes of forced dynamics interaction and exchange of power, matter and information. These supersystems are nonlinear, multidimensional and multilinked. And in these systems are complex transients and has place of critical and chaotic modes. Problems of system synthesis, i.e. finding of common objective laws of control processes in a such dynamics system are much actual, complicated and, in many respects, practically inaccessible for present control theory.

In the report we consider fundamental basis of nonlinear theory of system's synthesis based on synergetics approach in modern control theory as well as its application [1, 2].

The report consists of three parts: Part I General Statements; Part II Strategies of Synergetics control; Part III Synergetics synthesis of nonlinear systems with state observers.

Keywords: synergetics, system's synthesis, invariants, nonlinear systems, regulator's design, chaotic disturbances, invariants, observer

### **Synergetic approach to traditional control laws multi-machine power system modification**

Anatoly A. Kolesnikov, Andrew A. Kuzmenko

Technological Institute of Southern Federal University, Synergetics and Control Processes Department,  
Taganrog, Russia  
anatoly.kolesnikov@gmail.com

Traditional algorithms for control power system that were proposed more the half a century ago are applied in our days. We propose principally new synergetics laws for frequency and power сцтєкщд for power station units and unit groups. This approach requires development of technique for application. Moreover, directed implementation of synergetics control laws require global rebuilding of existing patters of power units control. The simplest way of synergetics algorithms implementation is using of hierarchical principal of control system building. So synergetics control laws we rate as dynamical desired values for ordinary algorithms or as correcting signals [1].

Keywords: power system, synergetics control, regulator, modiflicated control law.

### **Bibliography**

1. Kolesnikov A., Kuzmenko A., *at all.* Synergetics Methods of Complex Systems Control: Power Systems. Moscow: URSS, 2006.

### **Synergetics synthesis of amphibian control under heavy sea**

Anatoly A. Kolesnikov, Phuong Nguyen

Technological Institute of Southern Federal University, Synergetics and Control Processes Department,  
Taganrog, Russia  
anatoly.kolesnikov@gmail.com

One of aircraft automatic control applied problem is vontrol system synthesis for aircraft take-off and landing (splash-down) under heavy sea. So there are the problem of structural adaptation of aircraft actuators and wing's mechanization system to corresponding flight mode. Engineering solutions providing basing and maintenance of aircraft at water surface actually define an image – its aerodynamics layout. So the key problem is to synthesize control laws providing minimization of environment resistant while balancing an aircraft at take-off and landing.

We present the method of synergetics synthesis or analytical design of interrelated control laws for aircraft motion. This laws account aircraft dynamical properties as nonlinear mechanical plant at heavy sea conditions.

### **The problem of social self-organization of modern risk society: Social invariants -attractors**

Tatiana A. Kolesnikova, Natalya A. Kolesnikova

Russian railways company, Moscow, Russia

anatoly.kolesnikov@gmail.com

We explore the key problem of modern science considering social self-organization of postindustrial risk society. The problem is to find optimal correlation between processes of self-organization of civil society and state administrating. We propose using of social attractors in order to solve the problem that will attract processes in corresponding social system.

By exploring Russia we propose social invariants, i.e. attractors, based on "golden section" that reflect optimal correlation between number of poor and rich population by the view of harmonization of social differential society control.

Moreover, we propose universal law of harmonic labour payoff based on golden section approach and providing harmonization in corresponding social system.

### **Controlled chaos for secure communications**

Anton F. Kononov, Anastasia S. Kapustina  
Technological Institute of Southern Federal University, Synergetics and Control Processes Department,  
Taganrog, Russia  
[anatoly.kolesnikov@gmail.com](mailto:anatoly.kolesnikov@gmail.com)

We explore synergetics approach to communication system synthesis based on phenomena of chaotic synchronization. There are many opportunities for mixing informational signal into chaotic carrier. But reconstruction of informational signal after passing thru effective communication channel becomes difficult by various distortions and by adding of noise component to chaotic carrier. In order to solve the problem on information reconstruction at receiver side we propose method of synchronization for receiver and transmitter generators based on superposition of its image points in pseudo phase space. And we observe informational signal at the output of receiver generator control system. Proposed approach is an robust one to some kinds of distortions and additive noise acting to chaotic carrier.

### **Spatiotemporal-Chaotic Sequences for Asynchronous DS-UWB Communication System**

Ali Kotti, Safya Belghith, Zouhair Ben Jemaa,  
LABORATOIRE SYSCOM ENIT, TUNISIE  
[ali.kotti@enit.rnu.tn](mailto:ali.kotti@enit.rnu.tn), [safya.belghith@enit.rnu.tn](mailto:safya.belghith@enit.rnu.tn), [Zouhair.benjemaa@enit.rnu.tn](mailto:Zouhair.benjemaa@enit.rnu.tn)

In previous works, the performance of DS-UWB (Direct Sequence-Ultra Wide Band) systems in a multiuser scenario with binary pulseamplitude modulation have been studied. In most of these works, tradional spread spectrum sequences such as independent identically distributed (i.i.d) random sequences and Gold sequences have been considered. Since these sequences are limited in term of correlation properties several researchers were interested in using chaotic sequences generated by non linear systems. In this paper, we propose a new family of spatiotemporal chaotic codes to be used in asynchronous DS-UWB systems and investigate an analysis of Multi-User Interference (MUI) term for this new family and the two classical i.i.d and Gold families. Then, the Bit Error Rate (BER) is computed to evaluate the performance of conventional receiver in both cases AWGN and mulyi-path channel to confirm the results found about MUI.

### **Dynamic Stability Loss of Closed Circled Cylindrical Shells Estimation Using Wavelets**

V.A. Krysko<sup>1</sup>, J. Awrejcewicz<sup>2</sup>, M. Zhigalov<sup>1</sup>, V. Soldatov<sup>1</sup>, E.S. Kuznetsova<sup>1</sup>, S. Mitskevich<sup>1</sup>  
<sup>1</sup>Saratov State Technical University, Department of Mathematics and Modeling, Saratov, Russia, <sup>2</sup>Technical University of Lodz, Department of Automatics and Biomechanics, Lodz, Poland  
[tak@san.ru](mailto:tak@san.ru), [awrejcew@p.lodz.pl](mailto:awrejcew@p.lodz.pl)

In this work dynamic stability loss of closed cylindrical shells is studied. The hybrid type PDEs governing cylindrical shells dynamics and regarding deflection (Airy's) function and stresses are first derived. Then they are reduced to ODEs and algebraic equations (AE) applying the Bubnov-Galerkin high order approximations method. Dynamic stability loss of the cylindrical shells subject to sign-changeable loading using wavelets is investigated. In addition, the convergence of the Bubnov-Galerkin method and results validation are addressed.

Keywords: chaos, closed cylindrical shells, wavelets, nonlinear dynamics, dynamic stability loss.

### **Complex Networks in Climate Dynamics**

J. Kurths, J. Donges, N. Marwan, and Y. Zou

Potsdam Institute for Climate Impact Research, P.O. Box 601203, 14412 Potsdam, Germany

Complex network theory provides a powerful framework to statistically investigate the topology of local and non-local interrelationships, in particular teleconnections in the climate system. We extract such a complex network from global climate data sets (AOGCM and reanalysis data sets) by using nonlinear mutual information and betweenness centrality. It is shown that this approach offers new perspectives on nonlinear mechanisms in the climate systems which is of high relevance for forecasts.

#### References

Arenas, A., Diaz-Guilera, A., Kurths, J., Moreno, Y., Zhou, C. (2008) Synchronization in complex networks, Phys. Rep. 469, 93.153.

Donges, J., Zou, Y., Marwan, N., Kurths, J. (2009) The backbone of climate networks (subm.).

### **Complicated behavior of dynamical systems. Mathematical methods and computer experiments.**

Kuznetsov N.V., Leonov G.A., and Seledzhi S.M.

St.Petersburg State University, St.Petersburg, Russia

leonov@math.spbu.ru

It is shown that the most suitable definition of chaos in dynamical systems is instability by Zhukovsky. There are considered computer experiments and analytical proofs are corresponding to this definition. Also it is shown that the Filter Hypothesis is untrue.

Keywords: Zhukovsky stability, Harmonic linearization.

### **Frequency and Spatial Features of Waves Scattering on Fractals**

A.V. Laktyunkin, A.A. Potapov

V.A. Kotelnikov Institute of Radio Engineering and Electronics RAS, Moscow, Russia,

[laktyun@rambler.ru](mailto:laktyun@rambler.ru), [potapov@mail.cplire.ru](mailto:potapov@mail.cplire.ru)

Now there are two general approaches of scattering on the statistically rough surface: method of small perturbation and Kirchhoff approach. These methods relate to the two extreme cases of very small flat irregularities or smooth and large irregularities respectively. We use fractal model which has many advantages. Electrical field dependencies on fractal dimension  $D$  are presented. Investigation of the coherence function with accounting of surfaces fractality has been started.

**Keywords:** Fractals, Radio waves scattering, Scattering indicatrixes, Coherence function.



**Balance and Structure of the Galaxy, with Antimatter and Dark Matter, Through Thermodynamics of the Cosmic Rays (Oral Contribution)**

Maurice LALOU  
CNRS/IN2P3, Paris LPNHE, FRANCE  
Maurice.Laloum@lpnhE.in2p3.fr

Various outstanding paradoxes in the mechanical balance of the Galaxy are highlighted. Their utmost relevance demands a coherent and likely explanation. We propose a unique and synthetic interpretation, including a cosmological theory of the origin of the observed cosmic rays, especially at the highest energies known. It involves MATTER-ANTIMATTER ANNIHILATION in the median plane of the Milky Way, as a source of "DARK MATTER". Accordingly, we discuss the structure and balance of the Galaxy, seen as made of two parallel disks of matter versus antimatter dominance, and opposed by the repulsion of an annihilation gas, settled in the equator disk. The admitted suppression of antimatter in the Universe, just after the "big-bang", is questioned. By the way, ULTRA-RELATIVISTIC THERMODYNAMICS of cosmic rays are settled : they fully confirm our theory, with several stringent tests, further. Pointedly, the now classical energy behaviour of the incident flux of energetic cosmic rays is easily derived as a power law, quite with expected exponents of -2.5 and -3, possibly (main dependence, including the first knee). Ultra-high energies, besides, are easily attainable, with no necessary restriction of the "GZK" kind, for instance. Beyond  $10^{20}$  eV, rather, a new break is still made feasible.

**COSMOLOGICAL DARK ENERGY THROUGH NEUTRINO OSCILLATIONS, AND QUANTUM MECHANICS. (Oral Contribution)**

Maurice LALOU  
CNRS/IN2P3, Paris LPNHE, FRANCE  
Maurice.Laloum@lpnhE.in2p3.fr

We argue that the present classical formalism of neutrino oscillations is just approximate (cf. PDG 2006), thus requiring various second-order corrections : internal kinetic dispersion from internal mass dispersion ; curing Lorentz invariance violation between different MASS EIGENSTATES, in transitions of the kind  $m_1=m_2$ , through energy shifts  $(m_2^2-m_1^2)/(2p)$ , made salient in phase factors ; so, necessary transfers of quadri-momentum with any medium, even "vacuum" ; so, evidence of ethereal "DARK ENERGY" of purely weak essence, within "vacuum" oscillations ; actual violation of some deeply rooted principles of "quantum mechanics" (corpuscular elementarity, orthogonality of eigenstates amplitudes, Wigner's rules of superselection, Heisenberg's relations of uncertainty) ; strict non-hermiticity of the Hamiltonian operator, involving FINITE PROPER LIFETIMES ; neutrino mass matrices duly of the "CKM" type, as for quarks ; "UBIQUITY" concept and existence of "PROBABILITY WAVES", instead of matter waves, giving serious credibility to the paradoxical lemma of intense radiation from the vicinity of so-called "black holes" and "pulsars" (so, faking genuine "white wells"). Spontaneous individual birth of zero-mass neutrinos (not by pairs, from Lorentz invariance !), might explain the paradoxical excess of "dark energy" over "dark mass", overwhelming at cosmological scales.

**Dynamics of a bouncing ball**

Shiuan-Ni Liang and Boon Leong Lan  
School of Engineering, Monash University, Selangor, Malaysia

The dynamics of a bouncing ball undergoing repeated inelastic impacts with a table oscillating vertically in a sinusoidal fashion is studied using Newtonian mechanics and general relativistic mechanics. An exact mapping describes the bouncing ball dynamics in each theory. We show that, contrary to conventional expectation, the trajectories predicted by Newtonian mechanics and general relativistic mechanics from the same parameters and initial conditions for the ball bouncing at *low speed* in a *weak* gravitational field can rapidly disagree completely. The bouncing ball system could be realized experimentally to test which of the two different predicted trajectories is correct.

## The application of multivariate analysis tools for non-invasive performance analysis of atmospheric pressure plasma

V J Law<sup>1</sup>, J Tynan<sup>2</sup>, G Byrne<sup>2</sup>, D P Dowling<sup>2</sup>, and S Daniels<sup>1</sup>

<sup>1</sup>Dublin City University, National Center of Plasma Science and Technology, <sup>2</sup>School of Electrical, Electronic and Mechanical Engineering, UCD, Ireland  
[vic.law@dcu.ie](mailto:vic.law@dcu.ie)

This paper describes the development and use of real-time non-invasive Multivariate analysis tools for the performance monitoring of atmospheric pressure plasma. The MVA tools (acoustic spectrogram analysis, principal component analysis and non-parametric analysis) are embedded within a LabVIEW software program. The software program is used to probe a parallel-plate atmospheric pressure process system. It is found that the acoustic frequency spectrum distribution provides a signature of the plasma mode of operation. The signatures are modeled as overtones of the fundamental drive frequency and combination signals (intermodulation distortion). Within these spectrums syncopated patterns are observed. The acoustic signatures are correlated with changing electrical parameters. Using appropriate scaling factors, PCA of the current and voltage waveform are used to generate data set clusters that are deterministic of the acoustic signals. Non-parametric cluster analysis is used to identify and classify the modes.

Keywords: Multivariate analysis, frequency analysis, principal component analysis, and non-parametric cluster analysis, atmospheric pressure plasma, acoustic emission and electrical waveform identification.

## Experimental and numerical investigation of graphs with and without time reversal symmetry

Michał Ławniczak, Oleh Hul, Szymon Bauch, and Leszek Sirko  
Institute of Physics, Polish Academy of Sciences

Quantum graphs are excellent paradigms of quantum chaos and are widely investigated theoretically and numerically [1]. Experimentally, quantum graphs are simulated by microwave graphs (networks) consisting of joints and microwave cables [2-3]. This is possible due to an equivalency of the one-dimensional Schrödinger equation describing a quantum system and the telegraph equation describing an ideal microwave network.

We present the results of experimental and numerical study of distributions of the reflection coefficient  $P(R)$

and the enhancement factor [4]:  $W_{S,\beta} = \frac{\sqrt{\text{var}(S^{aa})\text{var}(S^{bb})}}{\text{var}(S^{ab})}$  for irregular fully connected hexagon

microwave and quantum graphs in the presence of absorption.

The distribution  $P(R)$  was obtained from the measurements and numerical calculations of the scattering matrix  $S$ . To determine the enhancement factor  $W_{S,\beta}$  we measured the matrix  $S$  for the microwave graphs with time reversal symmetry (TRS), which statistical properties of eigenfrequencies can be described by Gaussian Orthogonal Ensemble (GOE), and for the graphs with broken time reversal symmetry described by Gaussian Unitary Ensemble (GUE). The measurements were performed as a function of absorption, which was varied by microwave attenuators.

This work was supported by the Ministry of Science and Higher Education grant No. N202 099 31/0746.

### References

- [1] T. Kottos, U. Smilansky, Phys. Rev. Lett. 79, 4794 (1999).
- [2] O. Hul, S. Bauch, P. Pakoński, N. Savytskyy, K. Życzkowski, L. Sirko, Phys. Rev. E 69, 056205 (2004).
- [3] M. Ławniczak, O. Hul, S. Bauch, P. Seba, and L. Sirko, Phys. Rev. E 77, 056210 (2008).
- [4] D. V. Savin, Y. V. Fyodorov, H.-J. Sommers, Acta Phys. Pol. 109, 53 (2006)

## **Chaos Communication: An Overview of Exact, Optimum and Approximate Results Using Statistical Theory**

Anthony J. Lawrance  
Department of Statistics, University of Warwick, UK  
a.j.lawrance@warwick.ac.uk

This paper overviews exact and optimum results for a type chaos shift-keying (CSK) system, in particular, for the antipodal system in which a bit is transmitted by modulating a chaotic segment and decoded by use of the corresponding unmodulated segment, the so-called reference segment. Both single- and multiple- user versions with both known- and transmitted- reference segments are considered, the so-called coherent and non-coherent cases. There are two main themes in the paper – the use of statistical likelihood theory leads to optimum or improved decoders – the bit error performance of decoders can be obtained exactly for chaotic segments which are generated by chaotic maps with explicit convolution forms. As a first use of statistical theory, it will be shown that in the simplest of single-user CSK systems, the correlation decoder is actually the optimal likelihood decoder. An argument is then given [Lawrance et al. (2003)] to yield an exact expression for its bit error rate and it is shown how to calculate from it with spreading sequences generated by chaotic maps which have explicit convolutions. The theory leads to a lower bound result which was the original inexact result obtained by Gaussian approximation, and cited by Kolumban et al. (2002) and many others. The exact bit error result is extended to when there is a type of alternating jamming or interference and the role of a key quantity termed the jamming factor (JF) is emphasized. Attention then moves to coherent multiple-user CSK systems, motivated by the extensive approximate Gaussian results in Lau et al. (2003), Tam et al. (2007), and to their optimal decoding following the likelihood route [Lawrance et al. (2008)]. In this way a generalized correlation decoder is derived, generalized in the sense that it employs the autocorrelations of the spreading segment. Exact BER results are obtained and exemplified by calculations using logistic map and Bernoulli map spreading. These are compared with those from the correlation decoder and shown to be particularly superior at the desirable high SNR levels. The structure of the results indicates the roles of SNR and a quantity defined as the spreading to interference ratio (SIR) in determining the BER of such systems; comparisons are also made to the form of Gaussian results. To conclude, some of the earlier correlation decoder results are extended and compared to non-coherent systems in terms of BER, both in the single- and multiple-user cases. Comments concerning the improved design of noncoherent systems, following Yao et al. (2006), and areas awaiting investigation, conclude the presentation.

**Keywords:** Communication systems, Chaos shift keying, Correlation decoding, Likelihood-based decoding, Exact calculation of bit error rate, Gaussian approximations, Statistical theory

### References

- Kolumban, G., Kennedy, P., Jako, Z. and Kis, G., "Chaotic communications with correlator receivers: theory and performance limits," *Proceedings of the IEEE*, 50, 711-732, 2002.
- Lau, F.C.M. and Tse, C.K., *Chaos-based Digital Communications Systems*. Heidelberg: Springer Verlag, 2003.
- Lawrance, A.J. and Ohama, G., "Exact calculation of bit error rates in communication systems with chaotic modulation," *IEEE Trans. Circuits Systems I: Fund. Theory Appl.*, 50, 1391-1400, 2003.
- Lawrance, A.J. and Yao, J., "Likelihood-based demodulation in multi-user chaos shiftkeying communication," *Circuits, Systems and Signal Processing*, 27, 000-000, 2008.
- Tam, W.M., Lau, F.C.M. and Tse, C.K., *Digital Communications with Chaos*. Oxford: Elsevier, 2007.
- Yao, J. and Lawrance, A.J., "Performance analysis and optimization of multi-user differential chaos shift-keying communication systems," *IEEE Transactions on Circuits and Systems-1: Regular Pap*

## Noise and Chaos in Brain Dynamics

Hans Liljenstrom

Dept. of Energy and Technology, SLU, Uppsala and Agora for Biosystems, Sigtuna, Sweden

[hans.liljenstrom@et.slu.se](mailto:hans.liljenstrom@et.slu.se)

The human brain is a complex system whose activity is reflected by a highly complex neurodynamics. This dynamics is characterized at a macroscopic level by oscillations, chaos and fluctuations, apparent in EEG and depending on underlying neural processes, external stimuli and various neuromodulatory mechanisms. The different organisational scales of the brain, from ion channels to neurons to networks, are coupled via specific processes, each with a characteristic time scale.

We use computational models of different brain structures, both from paleocortex and neocortex, to investigate how cortical neurodynamics may depend on structural properties, such as connectivity and neuronal types, and on intrinsic and external signals and fluctuations. In particular, we study the underlying mechanisms for phase transitions in cortical neurodynamics of hippocampus, and the olfactory and visual cortices.

With the aid of our computational methods, we address questions such as: How can the nervous system shift its neurodynamical states quickly, as a response to external or internal stimuli? How can arousal and attention modulate the cortical neurodynamics, and lead to a more efficient information processing? What is the dependence on various intrinsic parameters, such as neuronal types, excitability, connectivity, and ion channel densities? What is the relation between microscopic and macroscopic processes? How does the brain respond to artificial inputs, such as anesthetics, or electric pulses, as used in e.g. electroconvulsive therapy (ECT)?

Our results are suggestive for the neural mechanisms underlying EEG, as well as for the dynamical effects of anaesthetics and ECT on human EEG. We demonstrate some plausible relations between structure, dynamics and function of cortical structures, and also suggest mechanisms and processes involved in phase transitions of cortical neurodynamics. By regulating the network dynamics, shifting between a noisy or chaotic-like dynamics and a more regular oscillatory behavior, functions such as learning and memory can become more efficient. Further, for certain optimal noise levels, system performance can be maximized, analogous to stochastic resonance phenomena. We finally discuss the relevance of these results to clinical and experimental neuroscience.

### Quantum stochastic modeling of energy transfer and an account of the rotational and V-T relaxation effect in multi-photon excitation and dissociation of molecules

Andrey V. Loboda<sup>1</sup>

<sup>1</sup>Odessa University, Odessa (Odessos), Ukraine

[andmolec@mail.ru](mailto:andmolec@mail.ru)

Phenomenological approach to description uncollisional excitation of number of molecules ( $\text{CF}_3\text{I}$ ,  $\text{SF}_6$ ,  $\text{OsO}_4$  etc.) has been realized in papers of Letokhov, Stown et al [1]. At the same time a problem of correct influence of collisions on dynamics of multi-photon processes, selectivity of dissociation, absorption and energy transfer etc. requires a further studying. In this paper within new stochastic, quantum kinetics model it is studied a link between the integral characteristics of the multi-photon excitation and dissociation with parameters of relaxation in a medium of the buffer gas ( $N_2$ ). It is calculated the output of multi-photon dissociation and absorbed energy for molecules of  $^{12}\text{CF}_3\text{Br}$ ,  $^{13}\text{CF}_3\text{Br}$ . We describe a process of excitation into continuum within generalized kinetical equations model [2]. A key moment is connected with account of the stochastic diffusion mechanism in quasi-continuum. To describe an excitation on the lowest discrete levels it is used a modified model of Letokhov et al. Within it, the lowest levels system is described by two velocities: radiative velocity of excitation of some separated levels, which is proportional to pressure, and the rotational relaxation velocity. We calculate a dependence of the absorbed energy  $^{13}\epsilon$  and dissociation output  $^{12}\beta$ ,  $^{13}\beta$  upon a summarized pressure  $p_{\Sigma} = p(N_2) + p(\text{CF}_3\text{Br})$  [ $p(\text{CF}_3\text{Br}) = 0,5 \text{ Torr}$ ] for a number of laser lines of the  $\text{CO}_2$  laser (1048,66; 1043,16; 1035,47  $\text{cm}^{-1}$ ). It is carried out an analysis of absorption by molecules in the quasi continuum, molecules on the lowest levels, contribution of the V-T relaxation. It is shown that in the pressure interval  $p < 50\text{-}100 \text{ Torr}$  a dissociation output is mainly determined by influence of the rotational relaxation and the V-T relaxation is not significant. Above 200 Torr the dissociation output is mainly determined by concurrence of two processes: the V-T relaxation and involving the molecules from the lowest levels Stochastic model block is manifested in more correct description of the excitation dynamics in the

quasi continuum.

#### References

- [1] V.S. Letokhov, *Nonlinear Selective Photoprocesses in Atoms and Molecules*.- Moscow, 1993.
- [2] A.V.Glushkov, S.V.Malinovskaya et al, *Int. Journ.Quant.Chem.* 104:512-517 , 2005.

### **Quantum computation of populations dynamics of the resonant levels for atomic ensembles in a laser pulse: optical bi-stability effect**

A.V. Loboda<sup>1</sup>, A. Fedchuk<sup>1</sup>, N.V. Mudraya<sup>1</sup>, T.Perelygina<sup>1</sup>  
<sup>1</sup>Odessa University, Odessa (Odessos), Ukraine  
[andmolec@mail.ru](mailto:andmolec@mail.ru)

Present paper has for an object (i) to carry out numerical quantum computation of a temporal dynamics of populations' differences at the resonant levels of atoms and nuclei in a large-density medium in a non-rectangular form laser pulse and (ii) to determine possibilities that features of the effect of internal optical bi-stability at the adiabatically slow modification of effective field intensity appear in the sought dynamics. It is known that the dipole-dipole interaction of atoms in dense resonant mediums causes the internal optical bi-stability at the adiabatically slow modification of radiation intensity. The experimental discovery of bistable co-operative luminescence in some crystals showed that an ensemble of resonant atoms with high density can manifest the effect of optical bi-stability in the field of strong laser emission. The Z-shaped effect is actually caused by the first-type phase transfer. On basis of the modified Bloch equations, we simulate numerically a temporal dynamics of populations differences at the resonant levels of atoms in the field of pulse with the non-rectangular cosh form. Furthermore, we compare our outcomes with the similar results, where there are considered the interaction between the ensemble of high-density atoms and the rectangularly- and sinusoidally-shaped pulses. The modified Bloch equations describe the interaction of resonance radiation with the ensemble of two-level atoms taking into account the dipole-dipole interaction of atoms [1,2]. A fundamental aspect lies in the advanced possibility that features of the effect of internal optical bi-stability at the adiabatically slow modification of effective filed intensity for pulse of the cosh form, in contrast to the pulses of rectangular form, appear in the temporal dynamics of populations differences at the resonant levels of atoms.

#### References

- [1] A.V. Glushkov, L.N. Ivanov, *Phys. Lett. A.* 170: 33-36, 1992.
- [2] A.V.Glushkov, S.V.Malinovskaya et al, *Int. Journ.Quant.Chem.* 104:512-517 , 2005.
- [3] A.V.Glushkov, A.V.Loboda, V.N. Khokhlov, G.P.Prepelitsa, *Laser and Fiber-Optical Networks Modeling (IEEE)* 428-430, (2006).

### **Wavefunction approach to Wigner–Fokker–Planck hydrodynamics by dissipation-based logarithmic Schrodinger models**

Jose Luis Lopez and Jesus Montejo Gamez  
Departamento de Matemática Aplicada Universidad de Granada,  
[jllopez@ugr.es](mailto:jllopez@ugr.es), [jmontejo@ugr.es](mailto:jmontejo@ugr.es)

In this contribution we are concerned with the modeling of quantum diffusion and dissipation in the Schrodinger picture. We start with the Wigner–Fokker–Planck (WFP) equation describing interactions of a quantum particle with a thermal bath in thermodynamic equilibrium. Considering the balance of its hydrodynamic moments and imposing some physically plausible closure relations we are led to a family of nonlinear, logarithmic Schrödinger equations (of Doebner-Goldin type) depending on a parametric potential  $U$  which to a certain extent quantifies the degree of mixture (entanglement) of the quantum states caused by the evolution under the WFP equation.

We analyze several properties of our family of Schrödinger equations attending to the choice of  $U$  (which may be modeled via Hartree-Fock type nonlinearities) for some simple cases: the free particle and the quantum harmonic oscillator. Furthermore, we are intended to model the propagation of mixed states in the Schrödinger picture as well as to observe environmental-induced decoherence from an analytical (density matrix operator methods) and numerical point of view.

Keywords: Quantum hydrodynamics, Dissipative phenomena, Nonlinear Schrodinger equations, Wigner–Fokker–Planck equation.

## **The Bayesian approach to modeling random dynamical systems from observed time series**

Loskutov E.M., Molkov Ya.I., Mukhin D.N., Feigin A.M.  
Institute of Applied Physics of RAS, Nizhny Novgorod, Russia  
[loskutov@appl.sci-nnov.ru](mailto:loskutov@appl.sci-nnov.ru)

Construction of parametrized models (global reconstruction) of deterministic dynamical systems from time series has been broadly discussed in the literature for the recent 20 years. A mathematical apparatus substantiating such a possibility has been developed. Different methods of constructing models of evolution operators have been proposed; basic limitations have been understood and formulated. In particular, the authors of some works demonstrated that these approaches can be used for prediction of changes in the qualitative behavior of a weakly nonautonomous system for times longer than the duration of the observed time series.

In the current work we formulate a consistent Bayesian approach to modeling stochastic (random) dynamical systems by time series and implement it by means of artificial neural networks. A feasibility of this approach for both, creating models adequately reproducing the observed stationary regime of system evolution and predicting changes in qualitative behavior of a weakly nonautonomous stochastic system is demonstrated on model examples. It is shown that some basic limitations arising in the case of deterministic systems may be reduced substantially for stochastic systems. In particular, we demonstrate a successful prognosis of complication of systemB's behavior as compared to the observed one, which is impossible in principle for deterministic dynamical systems.

Key Words: random dynamical systems, prognosis of qualitative behaviour

## **Interaction Study SnO<sub>2</sub> & WO<sub>2</sub> Nanofilm and Ethanol in the Gas Phase: Mont Carlo & Langevin Dynamic Simulation**

L. Mahdavian  
Department of Chemistry, Islamic Azad University, Doroud. Iran  
[leila\\_mahdavian@yahoo.com](mailto:leila_mahdavian@yahoo.com)

Nanostructured semiconductor metal oxides have played a central role in the gas sensing research filed, because of their high sensitivity, selectivity and low respond time. SnO<sub>2</sub> sensors have shown high sensitivity to low concentrations of ethanol at moderate temperature. Tin dioxide is the most used material for gas sensing because its three-dimensional nanofilms and properties are related to the large surface exposed to gas adsorption. We propose the use of SnO<sub>2</sub> nanofilms in interaction with ethanol so used different percents SnO<sub>2</sub> and WO<sub>2</sub> in adsorption ethanol by nanofilms. The total energy, potential energy and Kinetic energy calculated for interaction between nanofilms and ethanol at different concentrations in 300K. The calculations achieved by methods of Langevin Dynamic and Mont Carlo simulation. The total energy decreased with addition tungsten percent in nanofilm and increased with enhance ethanol molecules that interactions between them are endothermic.

Key Words: Tin dioxide, tungsten dioxide, nanofilm, Ethanol, Langevin Dynamic and Mont Carlo Simulation.

### **Innovations in synergetics of socio-humanitarian processes**

Marina Maksimova

Southern Federal University, Department of Philosophy, Rostov-on-Don, Russia  
aspera-86@mail.ru

Scope of the research – philosophical aspects of cross-disciplinary science synergetics where the practical interest lies in the opportunity of extrapolation of classical synergetic principles into the sphere of social knowledge.

The analysis made has revealed a number of concepts which have developed modern philosophical and synergetic approach to queries of world vision including cosmogony, beauty and order. The concept of the fractality of the universally recognized golden ratio beauty standard and synergetic nature of the beautiful, concept of social synergetics as postmodern philosophy where attractor is limiting state of the system, limit of mankind evolvement motion to which is nonlinear and per se infinite as endeavor to a universal ideal, concept of synergetic management theory where attractor as a determining essence can be provided with properties which help the system self-organize according to the goals set.

The results of the analysis indicate that the notion of the attractor as invariant diversity, consequence of self-organization process can be made explicit in the most diverse way in consequence of its multidimensional ambiguous nature. This gives the foundation for further development of synergetic approach to philosophy and lets present the attractor as robust philosophical category. In particular this approach is used by the author in cosmogonical concept based upon popular Bible version of Genesis origin interpreted from the point of view of basic synergetic ideas. Attractor as a philosophical category appears as fertile ground for humanitarian researches, for example, allows to assume that synergetic system model is a complex nonlinear process of essence appropriation in the scale of the universe.

### **Sub-critical transitions in coupled map lattices**

P. Manneville and L.A. Zepeda Nunez

Hydrodynamics Laboratory, Ecole Polytechnique, France  
[paul.manneville@polytechnique.edu](mailto:paul.manneville@polytechnique.edu)

Sub-critical transitions between two collective regimes with different periods have been observed in a 4-dimensional hypercubic lattice of coupled logistic maps. Intermittent switching between the two regimes takes place in the upper part of the bifurcation diagram while systematic decay with exponentially distributed transient lifetimes is observed in the lowest part of the coexistence region. Statistical findings can be interpreted in terms of macroscopic quantities (measuring global properties) escaping from potential wells in the presence of noise induced by chaos in the microscopic dynamics (local variables).

Keywords: Coupled Map Lattices, Sub-critical transition, Escape from attractors.

### **Point cloud modeling using fractal interpolation**

Polychronis Manousopoulos, Vassileios Drakopoulos, and Theoharis Theoharis  
Department of Informatics and Telecommunications, University of Athens, Greece.  
{polyman, vasilios, [theotheo](mailto:theotheo@di.uoa.gr)}@di.uoa.gr

Point clouds have been increasingly popular in modeling three dimensional objects, especially objects digitized by 3D scanners. A point cloud often contains a huge amount of information; millions of points, along with additional data such as normal vectors or colour, arise in many practical applications. Therefore, various techniques have been developed for representing point clouds in a compressed form. In this paper, we introduce a new method for representing point clouds using fractal interpolation techniques. Experiments indicate that the proposed method achieves competitive results, yielding considerable compression ratios.

Keywords: point clouds, fractal interpolation, iterated function systems.

## Identifying Fixed Points of Henon Map Using Artificial Neural Networks

Athanasios Margaris and Miltiadis Adamopoulos

University of Macedonia , Department of Applied Informatics, Thessaloniki, Greece  
amarg@uom.gr, miltos@uom.gr

The objective of this work is to present the application of back propagation neural networks for the experimental identification of fixed points of chaotic maps. The results presented here, are associated with the Henon map but the same algorithm can be applied without modification for the estimation of the fixed points of any chaotic attractor. The type of neural network presented in this paper, is a powerful general purpose neural network architecture, capable of solving nonlinear algebraic systems with an arbitrary complexity. The next sections describe the main theory associated with this field, the structure of the neural networks used for this purpose as well as the experimental results for the case of the Henon map.

Keywords: chaotic maps, fixed points, nonlinear equations, neural networks.

## The Taxation and the Attitude towards Risk

Daniela Marinescu, Dumitru Marin, Ioana Ramniceanu

Academy of Economic Studies, Bucharest, Romania

danielamarinescu@hotmail.com, daniela.marinescu@csie.ase.ro, dumitrumarin@hotmail.com,  
dumitru.marin@csie.ase.ro,  
ioana.ramniceanu@hotmail.com

In this paper we will analyze the behavior of an economic agent that has an initial endowment  $s_0$

and who wants to invest in active with or without risk. The rate of return is given by a random variable  $\tilde{e}$  with finite mean and variance.

The attitude towards risk is a Von Neumann Morgenstern function.

We will determine the optimal portfolio maximizing the expected utility of the final available amount with respect to the percent invested in risky active  $x$ , from the initial endowment  $s_0$ .

We will analyze the case when there is a tax with the ratio  $t$  for the final available amount and so:

$$S^a(e) = (1-t)S(e)$$

The influence of the modification of the taxation ratio on the invested amount in the risky active is given by:

$$\frac{dx}{dt} = \frac{x}{1-t} + \frac{1+r}{1-r} \cdot \frac{E\left\{U''\left(S^a(\tilde{e})(\tilde{e}-r)\right)\right\}}{E\left\{U''\left(S^a(\tilde{e})(\tilde{e}-r)^2\right)\right\}}$$

The sign of the derivative  $\frac{dx}{dt}$  is influenced by the monotonicity of the absolute risk aversion index,

$$r_a(\cdot) = -\frac{U''(\cdot)}{U'(\cdot)}.$$

We will derive the substitution and income effects and we will show how these effects influence the sign of the derivative  $\frac{dx}{dt}$ .

Finally, we will analyze the case when the Government subsidize the losses using a tax given by

$$t_r\left(S(\tilde{e}) - S_0\right).$$



Using the monotonicity of the relative risk aversion index  $r_r(s) = -s \frac{U''(s)}{U'(s)}$  we will determine the sign of the derivative:

$$\frac{dx}{dt_r} = \frac{x}{1-t_r} + \frac{r}{1-t_r} \cdot \frac{E\left\{U''\left(S^a\left(\tilde{e}\right)\left(\tilde{e}-r\right)\right)\right\}}{E\left\{U''\left(S^a\left(\tilde{e}\right)\left(\tilde{e}-r\right)^2\right)\right\}}.$$

### Modeling and Analysis of Life Table Data

George Matalliotakis<sup>1</sup> and Charilaos Skiadas<sup>2</sup>

<sup>1</sup>Data Analysis and Forecasting Laboratory, Technical University of Crete, 73100 Chania, Crete, Greece, [matal@ermes.tuc.gr](mailto:matal@ermes.tuc.gr)

<sup>2</sup>Hanover College, Indiana, USA

In this paper we analyze mortality data. An analysis of the mortality curves follows, and comments about their shape, their course during time and differences between males and females are studied. Finally, we use the mortality data fit for comparison of different ways of modelling the Life Table Data. The parameters of the models presented are estimated by means of a curve fitting algorithm. The study shows that we can improve our analysis of life table data and especially by using a dynamic model based on stochastic modeling and especially the first exit time theory.

**Keywords:** Dynamic model, Probability density function, Life table data, Mirror-Gompertz, Weibull.

### Synchronization of stick-slip acoustic emission caused by small influences

Teimuraz N. Matcharashvili, Tamaz L. Chelidze, Natasha N. Zhukova, Eketerine V. Mepharidze  
M. Nodia Institute of Geophysics, Tbilisi, Georgia  
[matcharashvili@gtu.ge](mailto:matcharashvili@gtu.ge)

We investigated dynamics of acoustic emission, accompanying stick-slip motion of sample rocks and influence of small external impacts on its features. For that, laboratory spring-slider system has been developed enabling registration of acoustic emission (AE) related to stick-slip at different sliding regime and relative external forcing. Series of time intervals between consecutive waveforms of AE and its maximums have been analyzed. To create these time series, experimental recordings were conditioned, wave trains separated and onsets of the AE detected. For quantitative evaluation of changes in dynamics of acoustic wave generation, nonlinear recurrence quantitative analysis (RQA) and phase synchronization testing procedures have been used. Analysis was carried out for three sliding regimes as well as weak normal forcing up to 30 % relative to applied dragging force. It was shown, that extent of deterministic structure in dynamics of acoustic wave generation depends on movement regime. Moreover, external forcing up to 25% relative to dragging force may synchronize phase of stick-slip motion, what leads to increase of extent of order in dynamics of AE.

**Keywords:** Synchronization, Stick-slip, Acoustic emission, Nonlinear dynamics, Recurrent analysis.

**QUANTUM SCATTERING AND TRANSPORT IN CLASSICALLY CHAOTIC CAVITIES:  
An overview of Old and New Results**

Pier A. Mello<sup>1</sup>, Victor A. Gopar<sup>2</sup>, and J. A. Mendez-Bermudez<sup>3</sup>

<sup>1</sup> Instituto de Física, Universidad Nacional Autónoma de México, México, <sup>2</sup> Departamento de Física Teórica and Instituto de Biocomputación y Física de Sistemas Complejos Universidad de Zaragoza, Spain, <sup>3</sup> Instituto de Física, Universidad Autónoma de Puebla, México  
mello@fisica.unam.mx, [gopar@unizar.es](mailto:gopar@unizar.es), antonio.ifuap@gmail.com

We develop a statistical theory that describes quantum-mechanical scattering of a particle by a cavity when the geometry is such that the classical dynamics is chaotic. This picture is relevant to a variety of physical systems, ranging from atomic nuclei to mesoscopic systems and microwave cavities; the main application to be discussed in this contribution is to electronic transport through mesoscopic ballistic structures or quantum dots. The theory describes the regime in which there are two distinct time scales, associated with a prompt and an equilibrated response, and is cast in terms of the matrix of scattering amplitudes  $S$ . We construct the ensemble of  $S$  matrices using a maximum-entropy approach which incorporates the requirements of flux conservation, causality and ergodicity, and the system-specific average of  $S$  which quantifies the effect of prompt processes.

The resulting ensemble, known as Poisson's kernel, is meant to describe those situations in which any other information is irrelevant. The results of this formulation have been compared with the numerical solution of the Schrödinger equation for cavities in which the assumptions of the theory hold. The model has a remarkable predictive power: it describes statistical properties of the quantum conductance of quantum dots, like its average, its fluctuations, and its full distribution in several cases. We also discuss situations that have been found recently, in which the notion of stationarity and ergodicity is not fulfilled, and yet Poisson's kernel gives a good description of the data. At the present moment we are unable to give an explanation of this fact. Keywords: Quantum Chaotic Scattering, Statistical  $S$  matrix, Mesoscopic Physics, Information Theory, Maximum Entropy.

**Early Nonlinear Modelling in Economic Analysis:  
The Hicks Model for Greece Revisited**

Panayotis G. Michaelides, Athena Belegri-Roboli and Gerasimos Arapis  
National Technical University of Athens, Greece  
School of Applied Mathematics and Physics  
Department of Humanities, Social Sciences and Law  
Laboratory of Theoretical and Applied Economics  
[pmichael@central.ntua.gr](mailto:pmichael@central.ntua.gr)

The present paper discusses the transition from linear modelling to the first nonlinear models in economic analysis. In this vein, an important contribution was J. Hicks's *A Contribution to the Theory of the Trade Cycle* where he developed his own endogenous model of the cycle. Hicks thought that fluctuations in investment, – caused by nonlinear changes in autonomous investment and the acceleration principle governing induced investment – led to an adjustment process taking place throughout many periods. In this paper we introduce some modifications regarding the econometric estimation of Hicks's nonlinear model and an empirical application for Greece (1960-2007) takes place demonstrating the almost ideal fit of the model.

Keywords: Linear, Nonlinear, dynamics, Hicks, economics.

### **Parametric excitation of a longwave Marangoni convection**

Alexander B. Mikishev<sup>1</sup>, Alexander A. Nepomnyashchy<sup>1</sup> and Boris L. Smorodin<sup>2</sup>

<sup>1</sup>Department of Mathematics, Technion - Israel Institute of Technology, Haifa, Israel. amik@tx.technion.ac.il

<sup>2</sup>Department of Phase Transitions Physics, Perm State University, Perm, Russia

The development of long-wave Marangoni instability under the action of a heat flux modulated in time is studied. The critical Marangoni number for the deformational instability is obtained as a function of frequency.

Keywords: Instabilities, Marangoni convection, thin films

### **Function cascade synchronization scheme with fully unknown parameters for chaotic and hyperchaotic systems**

Ming-Chung Ho, Ming-Chi Lu, Chia-Ju Liu, Chia-Yi Chou

National Kaohsiung Normal University, Kaohsiung, Taiwan

[t1603@nknucc.nknu.edu.tw](mailto:t1603@nknucc.nknu.edu.tw)

This study presents a function cascade synchronization scheme. With the chosen error functions which are nonlinear mostly, we achieve the function cascade synchronization for two chaotic and two hyperchaotic systems with fully unknown parameters. Although the function cascade synchronization methods [Applied Mathematics and Computation 2008;197:96-110] [Communications in Nonlinear Science and Numerical Simulation 2008;13:2246-2255] had been proposed, either the parameters were partially uncertain or the choice of controllers was illogical because the uncertain parameters were involved in them. In theory, the controllers must not include uncertain parameters. In this work, we choose the adaptive controllers excluding all the uncertain parameters, and successfully achieve the function cascade synchronization for chaotic and hyperchaotic systems with fully unknown parameters. The proposed synchronization approach is simple but theoretically rigorous.

All of the obtained results are proven by using the well-known Lyapunov stability theorem. Based on the Lyapunov stability theory, the adaptive controllers following the corresponding parameter update law are designed to achieve the function cascade synchronization for the chaotic Lorenz system, Rossler system, the hyperchaotic Chen system, and Lorenz-Stenflo system with fully unknown parameters. Numerical simulations are performed to demonstrate the effectiveness and feasibility of the proposed control scheme.

Key Words: Function cascade synchronization; Lyapunov stability theory; fully unknown parameters

### **Color Reconstruction and Image Segmentation by Logic Theory via Variant Operator**

Ali Moghani

Department of Color Physics, Institute for Colorants Paint and Coating (ICPC), Tehran, Iran.

[moghani@icrc.ac.ir](mailto:moghani@icrc.ac.ir)

The proposed model introduces an improvement over some other basic color classification techniques which are considered more challenging to color segmentation methods. In color vision systems require a first step of classifying pixels in a given image into a discrete set of color classes. In this paper we describe a human perception based approach to pixel color segmentation which applied in color reconstruction by numerical method associated with graph-theoretic image processing algorithm typically in grayscale.

Fuzzy sets defined on the Hue, Saturation and Value components of the HSV color space, provide a fuzzy logic model that aims to follow the human intuition of color classification.

Keywords: Color reconstruction, Image segmentation, Fuzzy logic, HSV color space.

## **Coupling Processes in the Lower and Middle Atmosphere**

K. Mohanakumar

Department of Atmospheric Sciences  
Cochin University of Science and Technology  
Fine Arts Avenue, Cochin 682016, India  
Email: kmk@cusat.ac.in

Atmospheric gravity waves and planetary waves play a major role in coupling the circulation in the middle atmosphere (defined as that region between the tropopause and 100 km) with that in the troposphere. The present work reviews the history of the study of middle atmospheric dynamics and its coupling with the lower atmosphere. Observational evidences for the broad spectrum of motions in the middle atmosphere are presented. These include zonal mean motions, planetary waves (both extra-tropical and tropical), tides, gravity waves, synoptic scale motions, and turbulence. The current state of comprehensive, three-dimensional, time-dependent modeling of the circulation in the middle and lower atmosphere from a meteorologist's perspective are reviewed. The present knowledge of the sources and sinks for these motions, as well as the wave propagation properties of the middle atmosphere are discussed. Momentum transport by equatorially-generated waves appears to be particularly important in producing the QBO and SAO in the stratosphere and mesosphere, although which waves are responsible is not well understood. Momentum transport by the diurnal tide maximizes at the equator and its dissipation in the lower thermosphere will produce indirect circulations which will transport neutral and ionized constituents both vertically and to higher latitudes. The developments of new observational techniques for giving improved data on the dynamics of the middle atmosphere are also presented.

## **Modelling of high-dimension dynamics by random dynamical systems**

D. Mukhin, A. Feigin, Ya. Molkov, E. Loskutov

Institute of Applied Physics of RAS, Nizhny Novgorod, Russia  
mukhin@appl.sci-nnov.ru

The majority of natural systems are known to be open, i.e., subject to numerous external forcings; these forcings can be modeled by random dynamical systems (RDS). The RDS present a necessary and important step towards reconstructing the observed systems when their adequate first-principle mathematical models are either unknown or subjected to further verification. Note that, even for deterministic systems, the construction of a deterministic model from the observed TS and use of this model for prediction has quite a number of principal restrictions. First, according to the Takens' theorem, the reconstruction of a phase trajectory is possible in a phase space of sufficiently high dimension  $d_E > 2d_S + 1$ , where  $d_S$  is the phase space dimension of the system that has generated the initial TS. This means that a deterministic dynamical system

(DDS) describes correctly behavior of the reconstructed system in the subspace of dimension  $d_S$  that is much smaller than the dimension of the phase space  $d_E$  of the model. Consequently, the model is not adequate for the system at relatively small changes of control parameters. The second restriction is the limitation on prior information. To confirm determinism of the observed system one has to ensure that the attractor reconstructed by the TS has a finite dimension and to find the smallest embedding dimension for this attractor. The available methods of determining such dimensions are inapplicable for analysis of the TS generated by real systems. Reconstruction in the form of RDS (stochastic model) removes these restrictions, thus making the proposed approach more universal. A basic idea underlying the stochastic approach is that the robust dynamic properties of the system evolution can be described by a few equations, while other features may be considered as a stochastic disturbance. A principal new step here is inclusion of parameterized stochastic perturbation in the model of the evolution operator; it allows us to significantly expand a class of reconstructed systems. The method of parameterization of such models on the basis of artificial neural networks is developed, as well as technique of investigation of model parameter space is suggested. Possibilities of the approach with reference to the analysis of time series generated by high dimensional dynamic systems are demonstrated by model examples. In particular, the prediction of changes of characteristics of observed process is constructed. Possible other applications of the method are discussed.

Key Words: random dynamical systems, prognosis of qualitative behaviour

### **Synergetics control of aircraft lowering while chaotic wind disturbances**

Alexey S. Mushenko, Olga Zenkina

Technological Institute of Southern Federal University, Synergetics and Control Processes Department,  
Taganrog, Russia  
anatoly.kolesnikov@gmail.com

Unpredictable wind disturbances are very dangerous at aircraft lowering and landing. Most dangerous are local disturbances of nature state, i.e. wind micro impulses. Such disturbances at these type flight modes may be critical and brings to flying accident. So the problem of flight control system design providing prevention of such accidents is actual. We explore synergetics nonlinear control system of aircraft spatial motion under condition of unpredictable chaotic wind disturbances described by model of "vortex ring".

### **Symmetry Broken in Low Dimensional N-body Chaos**

David C. Ni<sup>1</sup> and Chou Hsin Chin<sup>2</sup>

<sup>1</sup> Direxion Technology, Taipei, Taiwan, <sup>2</sup> Department of Electro-Physics, National Chiao Tung University,  
Hsin Chu, Taiwan  
davidcni@yahoo.com, jchchin@cc.nctu.edu.tw

In this paper, we explore domains in conjunction with the defined parametric space of function  $f = h(z) \prod_i \{\exp(g_i(z))[(a_i - z)/(1 - \bar{a}_i z)]\}$ , which represents a N-body system in complex form. Interested observations on the computed results reveal limited levels of Herman Ring Fractals, Symmetry Broken, and transition to chaos based on phase parameter  $\exp(g_i(z))$  and  $a_i$ .

Keywords: N-body Chaos, Herman Ring Fractals, Meromorphic, Symmetry Broken.

### **CMOS Ultrawideband Microwave Chaotic Oscillator**

Artem Yu. Nikishov

Moscow Institute of Physics and Technology (State University), Dolgoprudny, Moscow region, Russia  
[nickishov@front.ru](mailto:nickishov@front.ru)

In the report ring oscillator, capable to generate ultrawideband microwave chaotic signal with uniform power spectral density, is considered. This oscillator realized as an integrated microcircuit on 180 nm CMOS process and consists of three microwave amplifiers and a frequency selective circuit connected in series in a closed loop. Simulation results of the oscillator circuit, its topology and its experimental realization are presented. Basic dynamics of the oscillation modes is described. The fact of the chaotic oscillations generation is shown. Bifurcation phenomena are analyzed. It is proved that chaotic oscillations are excited on the basis of mechanism of double-frequency oscillations mode destruction. The described CMOS oscillator can be used in different wireless communication applications as a compact device for ultrawideband microwave chaotic signal generation.

### **Periodicity of One Dimensional Chaotic Map**

Hassan N. Noura, Safwan El ASSAD

Ecole polytechnique de Nantes, Nantes, France  
[hassan.noura@univ-nantes.fr](mailto:hassan.noura@univ-nantes.fr)

Recently, chaotic systems have been widely used to design digital systems, such as: digital ciphers, pseudo-random number generators (PRNG) and digital communication systems. The chaotic map is realized in a finite precision; therefore, its orbits will eventually become periodic. However, the floating and fixed point representations are briefly studied and their impacts for cycle length are estimated by simulations. On the other hand, it is often required that the chaotic generators have very long cycle lengths to resist attacks. It had been found that the periods of chaotic trajectories can be rather short even the high-precision computation is applied. Furthermore, for each precision, the number of periodic orbits of computer realization is surprisingly small even if the precision is rather high. The obtained results show that the longest cycle length is smaller than the maximum possible one. It is believed that the problems of short period and small number of periodic orbits may seriously affect chaos' applications and result in either weak cryptography or secure communication. The goal of this work is to achieve long cycle lengths; therefore, two methods are proposed. The first one is a perturbation based on LFSR, and the second one consists of using a multiplexer with a few LFSR generator. Experimental and theoretical analyses show that the proposed methods have periods as large as practically unreachable

Keywords: Cycle length, fixed point, NIST Statistical properties, Balance of probability.

### **Multifrequency autoresonance and Whitham averaging of integrable systems**

V.Yu.Novokshenov

Institute of Mathematics, Russ.Acad.Sci., Ufa, Russia

[novik53@mail.ru](mailto:novik53@mail.ru)

Autoresonance is a powerful technique for controlling the amplitude of nonlinear modes. It is a robust method because, over a broad range of parameters, it does not depend on the details of the system, nor on the amplitude or exact range of the sweeping drive.

Autoresonance is usually associated with single frequency mode excitations due to the synchronization and phase lock of various nonlinear modes with the driving force. Despite this we propose a model of multifrequency autoresonance which occur in completely integrable systems. This phenomenon is due to a number stable invariant tori governed by integrals of motion of the integrable system.

The basic autoresonant effect of phase locking appears here as Whitham deformations of the invariant tori. This provides also a possibility to transfer a certain initial  $n$ -periodic motion to a given  $m$ -periodic motion as a final state.

Key Words: integrable systems, Lax pair, algebro-geometric solutions, theta functions, autoresonance, Whitham deformations, phase locking

### **Stochastic Models in Systems Analysis**

Gabriel V. Orman and Irinel Radomir

Department of Mathematical Analysis and Probability, "Transilvania" University of Brasov, Romania

[ogabriel@unitbv.ro](mailto:ogabriel@unitbv.ro)

From some time past our interest was focused to find new possibilities for characterizing the process of generation of the words by generative systems. In our previous papers Orman[8] and Orman[9] we have introduced some numerical functions able to characterize classes of derivations according to a given generative system up to an equivalence. They are referred to as derivational functions. In this paper, firstly we consider equivalence classes of derivations and we establish a property of symmetry. Secondly, we shall refer to some problems concerning the reliable systems. Many and very important results have been obtained especially by A.D. Solovyev and B.V. Gnedenko. In this sense we refer to some aspects regarding to the problem of the increase of the effectiveness of stand-by systems as a way in which the stochastic-approximation techniques can be applied in practice.

Keywords: random variables, Markov chains, transition matrices, stochastic differential equations, stochastic approximation procedures.

2000 MS Classification: 60J20; 60J10: 60K10, 60K20, 68M15, 68Q45

**Self-organized theory model of Solar flares: New frontiers from small -scale structures**

Alexei R. Osokin, Moisey A. Livshits  
Sternberg Astronomical Institute of Moscow University, Russia  
arno@sai.msu.ru

A further development of Solar flares model based on Self-organized critical (SOC) theory worked out by the authors is presented.

It is shown, that models based on SOC - theory approach to the study of rapid energy dissipation in magnetic plasma may be of equal importance with the localized, small - scale Magnetohydrodynamic (MHD) simulation. However refined SOC models are needed to establish a more physical connection between the model evolution rules and the observations.

The authors present a new model in the frame of which not only statistical results, but also basic for the model elements and processes, such as magnetic tubes are matched against the observational data. This approach allows further development of the model by introduction of specifications corresponding to a more refined physical image of the phenomenon.

We show that:

- i) continuous emersion and interactions (dissipation, reconnecting) of the tubes may occur as a self-organized criticality process, producing avalanches;
- ii) By taking into account flares inertia, we can construct and explain the flares statistic indices variation.
- iii) The model allows to determine certain physical parameters for small-scale magnetic tubes. This result is unusual for stochastic models.
- iv ) we used the system that builds its own spatial structure, similar different polarity zones on the Sun. The zone that divides them (the one, we might call "the neutral line") proves to be, like in the case of the physical Sun that of flares generation and of maximal energy output.

Key Words: Self-organized critical (SOC) theory, Solar flares, stochastic model

**Limiting curves, confinement and chaos in the dynamics of electrons in a Hall Thruster magnetic field configuration**

R. Pakter, S. Marini, and F.B. Rizzato  
Instituto de Fisica - Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil  
pakter@if.ufrgs.br

In this paper we investigate the nonlinear dynamics of electrons in a magnetic field configuration compatible to Hall Thruster applications. We determine the key role played by the Hamiltonian limiting curves in the confinement of the electrons. We also show that the electron dynamics is nonintegrable and chaos may appear depending on the relevant parameters of the system. In particular we discuss how the onset of chaos combined with the robust confinement imposed by the limiting curves may be used to enhance thruster operation.

Key Words: Hamiltonian systems, limiting curves, nonneutral plasmas

## On the dynamics of classical interacting spins

Leonidas Pantelidis

Department of Physics and Astronomy, Hanover College, Hanover, IN 47243, USA

Leon\_pantelidis@alum.mit.edu

We consider the general classical Heisenberg model (HM) with z-axis anisotropy and external magnetic field and show that its phase space is foliated into a family of invariant manifolds diffeomorphic to  $(S^2)^\wedge$ . The flow on each leaf  $S$  is Hamiltonian. Subsequently, we focus on the isotropic HM in the absence of external field. We discuss the rotational symmetry of the model and further analyze its phase space structure. We prove that the manifold  $\mathcal{F}$  of longitudinal fixed points (LFPs) intersects each leaf  $S$  orthogonally. For a real autonomous dynamical system with a continuous symmetry, we show that, under some general conditions, Lyapunov stability of fixed points (FPs) and orbits on an invariant subspace is extended to the whole phase space. We apply this theorem to the case of the isotropic HM to prove that the ferromagnetic (FR) state and the antiferromagnetic (AF) state with non-zero total spin are both stable FPs. The theorem breaks down at total spin zero, and as an example, the AF state on an equal-spins leaf is found to be unstable.

PACS numbers: 05.45.-a

## A TRANSMISSION LINE MODEL FOR THE SPHERICAL BELTRAMI PROBLEM

C. D. Papageorgiou<sup>1</sup>, T. E. Raptis<sup>2</sup>

<sup>1</sup>Dept. of Electrical & Electronic Engineering, National Technical University of Athens, <sup>2</sup>Division of Applied Technologies, National Centre for Science and Research "Demokritos", Athens, Greece

chrpapa@central.ntua.gr, rtheo@dat.demokritos.gr

We extend a previously introduced model for finding eigenvalues and eigenfunctions of PDEs with a certain natural symmetry set based on an analysis of an equivalent transmission line circuit. This was previously applied with success in the case of optical fibers [8], [9] as well as in the case of a linear Schroedinger equation [10], [11] and recently in the case of spherical symmetry (Ball Lightning) [12]. We explore the interpretation of eigenvalues as resonances of the corresponding transmission line model. We use the generic Beltrami problem of non-constant eigen-vorticity in spherical coordinates as a test bed and we locate the bound states and the eigen-vorticity functions.

## Two Aspects of Optimum CSK Communication: Spreading and Decoding

Theodore Papamarkou

University of Warwick, Department of Statistics, Coventry, UK

T.Papamarkou@warwick.ac.uk

This paper focuses on the optimization of performance of single-user chaos shift-keying (CSK). More efficient signal transmission is achieved in the coherent case by introducing the class of the so called deformed circular maps for the generation of spreading. Also, the paired Bernoulli circular spreading (PBCS) is introduced as an optimal choice, which attains the lower bound of bit error rate (BER). As interest shifts to the non-coherent version of the system, attention moves to the receiver end. Maximum likelihood (ML) decoding is utilized serving as an improvement over the correlation decoder. To make the methodology numerically realizable, a Monte Carlo likelihood approach is employed.

Keywords: Communication systems, Chaos shift-keying, Optimal spreading, Correlation decoding, Likelihood decoding, Monte Carlo likelihood.

Single-user coherent antipodal chaos shift keying (CSK) has been studied thoroughly and its theoretical foundations have been developed, see Lawrance et al. (2003). A relationship has been established between



BER, chaotic spreading and bit energy. One of the intrinsic features of such communication systems is the chaotic nature of the spreading, that is of the message carrier.

Proceeding in this CSK framework, the paper demonstrates how optimum performance can be attained on the basis of appropriately chosen chaotic spreading. It is explained how the minimization of bit energy variability improves the system's reliability. Concrete suggestions of spreading are provided along these lines using the newly introduced deformed circular map as an illustrative example.

The paper continues with the exact BER calculation of single-user non-coherent CSK. Maximum likelihood (ML) decoding is introduced. ML decoding is computationally intensive in this situation in comparison with its conventional engineering counterpart, namely the correlation decoder. However, it has two relative advantages. For one thing, ML decoding is established theoretically without needing to use the universal, yet not always justifiable, correlation decoding. The theoretical results are numerically realizable by employing statistical techniques, such as maximum likelihood estimation and Monte Carlo integration. Thus, the gap between theory and application is bridged, allowing for exact results from that perspective. The second benefit of ML over correlation decoding concerns the system's performance. BER simulations show that, independently of the spreading used, the ML decoder outperforms the correlation-based one.

#### Reference

Lawrance, A.J. and Ohama, G., "Exact calculation of bit error rates in communication systems with chaotic modulation". IEEE Transactions on Circuits and Systems, 50, 1391–1400, 2003.

### **Rendering Statistical Significance of Information Flow Measures**

Angeliki Papana, Dimitris Kugiumtzis  
Aristotle University of Thessaloniki  
agpapana@gen.auth.gr, dkugiu@gen.auth.gr

The estimation of the information flow among variables or sub-systems observed by bivariate or multivariate time series is essential in order to understand the dynamics of the underlying system. It is a subject of active research in many areas ranging from climate processes and electric circuits to finance and neurology. The nature of the inter-dependencies is usually nonlinear and asymmetric deeming linear symmetric measures ineffective and linear causality measures often inadequate. Constraining the problem to bivariate time series, it is essential to assess whether they originate from coupled or decoupled systems, detect the hidden causal dependencies between them and distinguish the driver and responder.

The standard approach for inferring the direction of interactions has been the Granger causality, testing whether one time series is useful in forecasting another. Different linear measures in the time and frequency domain have been developed, such as Directed Transfer Function, Directed Coherence and Partial Directed Coherence. In the recent years Granger causality was extended using approaches based on phase synchronization, nonlinear dynamics evolution and information flow. A number of measures of directed interaction have been proposed but the estimation from time series cautions for a number of complications as indicated in some very recent comparative studies. Aspects influencing the robust estimation of the causal measures are the finite time series length and the presence of noise. The estimation of the measures gets even more complicated when the possibly coupled systems are non-identical or when they have different complexity.

A thorough investigation for the validity and usefulness of the coupling measures should start with a test of significance, i.e. a measure should not identify coupling (or interaction) in any direction when it is not present. The second property of a coupling measure is its power, i.e. how sensitive the measure is in detecting interaction and identifying its direction. To quantify these two statistical properties we use the concept of surrogate data testing and modify the coupling measures in order to attain proper significance. Though this approach can be implemented on a variety of interaction measures we focus here on information-based measures for detecting asymmetric causal interdependencies between two time series. Specifically, we consider the transfer entropy (TE) (Schreiber, 2000) and the symbolic transfer entropy (STE) (Staniek, 2008). Computing TE on the set of the two original bivariate time series and on surrogate sets, where the assumed driving time series is randomly shuffled, one can derive the so-called effective transfer entropy (ETE) (Marschinski, 2002). Thus ETE attempts to remove bias in the estimation of transfer entropy that is not related to the interaction. However, this approach does not fully preserve the dynamics of each sub-system and our simulations have shown that it still lacks significance. We therefore propose a correction to the transfer entropy measure, termed corrected transfer entropy (CTE), using reshuffled points from the

driving time series. In the simulation study, we consider also the effective symbolic transfer entropy (ESTE) and the corrected symbolic transfer entropy (CSTE) defined similarly.

To assess the significance and power of the TE, ETE, STE, CTE, ESTE and CSTE measures we compute them on multiple realizations of uncoupled and coupled nonlinear systems (maps and flows), allowing also for a range of the coupling strength. The performance of the measures is examined for variations of the time series length, level of additive noise and embedding dimensions of the two reconstructed state spaces (for driver and responder). Preliminary results have shown that all measures are not crucially affected by the time series length or the addition of noise (we examined noise levels up to 20% of the standard deviation of the time series). However, the selection of the embedding dimensions is important both for the significance and the power of the measures. The proposed CTE and CSTE turn out to attain best significance results and are at the zero level in the case of no causal effect. This is an important statistical feature of CTE and CSTE with regard to applications as it leaves no doubt for actual causal relationship when it is estimated.

#### References

- Schreiber T., 2000. Measuring Information Transfer. *Physical Review Letters* **85** (2), 461-464.  
Marschinski R. and Kantz, H., 2002. Analysing the Information flow between financial time series. *European Physical Journal B* **30**, 275–281.  
Staniek M. and Lehnertz, K., 2008. Symbolic Transfer Entropy. *Physical Review Letters* **100** (15), 158101.

### **A numerical exploration of the dynamical behaviour of q-deformed nonlinear maps**

Vinod Patidar, G. Purohit and K K Sud

Department of Basic Sciences, School of Engineering, Sir Padampat Singhania University, Bhatewar,  
Udaipur , INDIA

[vinod\\_r\\_patidar@yahoo.co.in](mailto:vinod_r_patidar@yahoo.co.in)

In this paper we explore the dynamical behaviour of the qdeformed versions of widely studied 1D nonlinear map-the Gaussian map and another famous 2D nonlinear map-the Henon map. The Gaussian map is perhaps the only 1D nonlinear map which exhibits the co-existing attractors. In this study we particularly, compare the dynamical behaviour of the Gaussian map and q-deformed Gaussian map with a special attention on the regions of the parameter space, where these maps exhibit co-existing attractors. We also generalize the q-deformation scheme of 1D nonlinear map to the 2D case and apply it to the widely studied 2D quadratic map-the Henon map which is the simplest nonlinear model exhibiting strange attractor.

Keywords: q-deformation, Gaussian map, Henon map, Lyapunov exponent, Chaos, co-existing attractors

### **Non-equilibrium Collective Processes in Far from Equilibrium Distributed Systems.**

#### **Theory and Practice.**

George P. Pavlos<sup>(1)</sup>, A.C. Iliopoulos<sup>(1)</sup>, L.P. Karakatsanis<sup>(1)</sup>, V.G. Tsoutsouras<sup>(1)</sup>, M.A. Athanasiou<sup>(2)</sup>, E. G. Pavlos<sup>(3)</sup>

<sup>(1)</sup> Democritus University of Thrace, Department of Electrical and Computer Engineering, Xanthi, <sup>(2)</sup> Technical University of Serres, Department of Mechanical Engineering, Serres, <sup>(3)</sup> Aristotle University of Thessaloniki, Department of Physics, Greece.  
gpavlos@ee.duth.gr

The far from equilibrium dynamics of physical distributed systems reveals universal properties. Some of the highlights of the phenomenology of such systems are power law scaling, (multi)fractal space or time coherent structures, (spatio)temporal chaos, intermittent turbulence, critical dynamics, phase transitions, self organized criticality (SOC), nucleation processes, long range spatiotemporal correlations and clustering etc. These characteristics can be concluded from many studies of spatially distributed systems such as space plasma processes, solar activity, earthquakes and brain dynamics. The dynamics of the far from equilibrium distributed systems, as the above refereed physical systems, also belong to the type of driven nonlinear threshold dynamics. Both types of input-output and driven threshold dynamics include the possibility of critical point and phase transition phenomena, where avalanche and nucleation events can happen. Such characteristics can be the theoretical base for the physical explanation of the emergence of sporadic and localized coherent structures such as magnetospheric substorms, solar flares at the sun's surface, earthquakes and seismic clustering in the earth's lithosphere and epileptic seizures in the brain system. In this study, experimental evidence of chaotic and SOC dynamics is shown, obtained by the nonlinear analysis of time series concerning the space plasmas, solar activity, earthquakes and brain dynamics.

Keywords: Nonequilibrium processes, Distributed systems, Coherent Structures, Nonlinear Time Series Analysis, Chaos, SOC.

### **Predators in Turbulent Water: An Analytical Model and a Numerical Test**

H. L. Pécseli, J. K. Trulsen, Ø. Fiksen

Department of Physics, Institute of Theoretical Astrophysics, University of Oslo, Department of Biology, Bergen, Norway

In aquatic environments the encounter rates between small predators and their prey are increased by turbulence. We derive an expression for the flux of prey into the detective sphere of a small self-propelled predator. The model is then tested by a direct comparison of theoretical encounter rates and predictions from a numerical experiment where the Navier-Stokes equation is solved explicitly for a low Reynolds number turbulent flow. This allows us to estimate encounter rates under realistic small-scale flow environments, and to explore the accuracy of a simple theoretical formulation of this process. We find that the analytical model yield surprisingly accurate predictions independently of the assumptions made about the shape of the predator's reactive sphere and turbulence conditions. Different motion strategies are considered, cruising, spiralling or jump-pause motions.

Key Words: predator-prey encounter rates, turbulent waters, motion strategies

### **Introducing Chaos in Economic Gas-Like Models**

Carmen Pellicer-Lostao and Ricardo Lopez-Ruiz

Department of Computer Science and Institute for Biocomputation and Physics of Complex Systems (BIFI), University of Zaragoza, Spain  
carmen.pellicer@unizar.es and rilopez@unizar.es

This paper considers ideal gas-like models of trading markets, where each agent is identified as a gas molecule that interacts with others trading in elastic or money-conservative collisions. Traditionally, these models introduce different rules of random selection and exchange between pair agents. Unlike these traditional models, this work introduces a chaotic procedure able of breaking the pairing symmetry of agents  $(i; j)$ ,  $(j; i)$ . Its results show that, the asymptotic money distributions of a market under chaotic evolution can exhibit a transition from Gibbs to Pareto distributions, as the pairing symmetry is progressively broken.

Keywords: Complex Systems, Chaos, Econophysics, Gas-like Models, Money Dynamics, Chaotic Simulation.

### **Order and Chaos in the Hubble Diagram: I. Normal Spiral galaxies**

Angeles Perez-Villegas & Barbara Pichardo  
Intitute of Astronomy at UNAM (Mexico), Mexico City, Mexico  
mperez@astroscu.unam.mx

Using a reallistic steady model for spiral arms made of oblate spheroids as building blocks and a background analitical potencial, we study the effect of flocculency in the spiral arms motivated in infrared and optical observations on the stellar dynamics. We compare the classic cosine model for the spiral arms in orbital analysis with our material potential model.

Key Words: Chaos, galaxies

### **Reallistic Analytical Milky Way Potential for Orbital Analysis**

Barbara Pichardo, Octavio Valenzuela, Angeles Perez-Villegas,Edmundo Moreno  
Institute of Astronomy at UNAM (Mexico), Mexico City, Mexico  
barbara@astroscu.unam.mx

We present a new analytic potential for the Milky Way. The mathematical structure of the potential is flexible enough to follow multiple observational constraints. We discuss the consistency with several of the recent observational constraints such as the solar neighborhood kinematics and the bulge-bar structure, etc., and recent ideas about galaxy formation.

Key Words: Milky Way, galaxies

### **Selforganization and managment in development of innovation society during the transition from instable to stable development of society**

Polikarpov V.S.  
The Taganrog Technological Institute of Southern Federal University, Taganrog, Russia  
philosof@egf.tsure.ru

The paper deals with the problem of interrelations selforganization and managment in innovative society during the transition from instable to stable development of society

Key Words: selforganization, managment, development, innovation, society

### **Functional Implications of Tonic, Bursting and Chaotic Impulse Patterns on Neuronal Synchronization**

Svetlana Postnova and Hans A Braun  
Institute of Physiology, Philipps University of Marburg, Germany  
postnova@staff.uni-marburg.de

Diverse brain areas change their activity depending on the states of sleep and wake. For example, thalamocortical neurons undergo a transition from asynchronous tonic firing during wake to synchronized bursting discharges during sleep. These neurons are receiving synaptic connections from orexin-containing hypothalamic neurons, which generate high frequent single spikes in a wake state, thereby exciting the thalamocortical neurons, while they are silent during sleep.

In this study we use computational approach for a better understanding of the mechanisms which drive thalamocortical neurons along sleep-wake transitions and associated synchronization states. We use Hodgkin-Huxley type neurons and electrical gap junction coupling between thalamocortical neurons. The input from hypothalamus is modeled as a chemical synaptic connection from the wake active hypothalamic neuron or in a simplified form as an external current.

Using this model approach we could show that two identical electrically coupled neurons may undergo the transition from tonic firing to bursting simply due to the application of hyperpolarizing current. Such current is similar to the elimination of excitatory action of hypothalamic neurons during sleep. Furthermore the

simulations have shown that between the regimes of tonic firing and bursting there is a significant area of chaotic dynamics, which seems to be a necessary part of such transition.

Our simulation studies demonstrate that these transitions have significant impact also on the neurons' synchronization. In the seemingly simple regime of tonic firing one need to apply a relatively high coupling strength to achieve synchronization. Similar situation is observed in the chaotic regime. Surprisingly at the transition to bursting neurons synchronize in-phase even at infinitely small coupling.

Clearly there is a range of coupling strength between thalamocortical neurons where a simple hyperpolarizing input, or driving force from the hypothalamic neurons would lead to experimentally observed transition from asynchronous tonic firing to synchronized bursting. Moreover, when not the two coupled neurons, but the network of 100 neurons is considered the chaotic range between tonic firing and bursting becoming much shorter and may even disappear at some values of coupling.

The work was supported by the European Union through the Network of Excellence BioSim contract No LSHB-CT-2004-005137.

**Fractals and Fractal Operators for Non-Linear Radio Physics Problems:  
Fractal Radio Systems Designing**

Alexander A. Potapov

V.A. Kotelnikov Institute of Radio Engineering and Electronics RAS, Moscow, Russia

[potapov@mail.cplire.ru](mailto:potapov@mail.cplire.ru)

Main results of theoretical and experimental investigations since eighties of XX that led to formation and developing of new fundamental science discipline: "Fractal Radio Physics and Fractal Radio Electronics: Fractal Radio Systems Designing" are briefly classified in the paper.

Keywords: Fractal, Fractional operators, Scaling, Texture, Fractal systems.

**Modelling and computation of fractal antennas: circle monopole, the life-flower antenna**

Potapov A.A., Matveev E.N.

Institute of Radio Electronics by V.A. Kotelnikov, Moscow, Russia

[potapov@mail.cplire.ru](mailto:potapov@mail.cplire.ru)

This paper explores the modelling and computation of fractal antennas. In the beginning the fractal geometry of antennas explained Also two new kinds of fractal antennas described: circle monopole and Life-Flower geometry antenna. Both antennas are series of circles nested to each other in a special order. Computational modeling was performed over the range of 0.1Ghz. - 20 Ghz. Obtained results of electrodynamic characteristics of antennas present in the next section. The specific multi- and wide-band properties of the selected antennas are analyzed in the conclusion.

Keywords: Fractal antennas, Multiband, Wideband, Computational modeling.

## **The methods of the digital processing of small-contrast scenes for the real-time recognizing system**

A.A. Potapov, A.A. Pahomov  
Institute of Radio Electronics by V.A. Kotelinikov, Moscow, Russia,  
[potapov@mail.cplire.ru](mailto:potapov@mail.cplire.ru)

Work is dedicated to mathematical base to theories of the incorrect inverse problems in optometrist, as well as method of the processing and recovering the scenes on incomplete information on its Fourier-spectrum. This problem is part of the general problem of the eliminating the influence atmospheric and optical distortion when finding and registrations removed object on big range under bad atmospheric conditions

Keywords: Incorrect inverse problems, Image processing, Real-time processing, Fractal.

## **A klein-Gordon-Schrodinger system in an unbounded domain.**

Poulou Marilena, Stavrakakis Nikolaos  
NTUA, ATHENS, GREECE  
[mpoulou@math.ntua.gr](mailto:mpoulou@math.ntua.gr)

In this paper we prove the existence and uniqueness of solutions for a system of Klein-Gordon-Schrodinger type in an unbounded domain.

Key Words: klein-Gordon-Schrodinger system, global attractor, absorbing set

## **Quantum chaos with atoms in a laser field**

S.V. Prants  
Pacific Institute of Russ. Ac. Sci, Vladivostok, Russia  
[prants@poi.dvo.ru](mailto:prants@poi.dvo.ru)

Single cold atoms in an optical lattice, formed by counter propagating laser waves, are ideal objects for testing some foundation principles of quantum physics and quantum chaos. We review theory and experiments on quantum chaos with atoms in optical lattices. We find in numerical experiments a manifestation of Hamiltonian chaos of the fundamental atom-light interaction in the diffusive-like center-of-mass motion spontaneously emitting atoms which can be observed in real experiments.

Key Words: cold atoms, optical lattices, quantum chaos

1. V.Yu. Argonov and S.V. Prants. Nonlinear control of chaotic walking of atoms in an optical lattice. Europhysics Letters. Vol. 81 (2008) art. no. 24003.
2. V.Yu. Argonov, S.V. Prants. Manifestation of Hamiltonian chaos in dissipative atomic transport in a standing-wave laser field. JETP Letters. V. 88, is. 10 (2008).
3. V.Yu. Argonov and S.V. Prants. Theory of dissipative chaotic atomic transport in an optical lattice. Physical Review A. V.78 (2008) art. no 043413.

## **Quantum chaos with atoms in a laser field**

Sergey V. Prants  
Pacific Oceanological Institute of the Russian Academy of Sciences, Vladivostok, Russia

The mechanical action of light upon neutral atoms is at the heart of laser cooling, trapping and Bose-Einstein condensation. Atoms in an optical lattice, formed by a laser standing wave, is an ideal system for studying quantum nonlinear dynamics. Operating at low temperatures and controlling the lattice parameters, experimentalists now are able to tailor optical potentials and manipulate with internal and external degrees of freedom of atoms. Experimental study of quantum chaos has been carried out with ultracold atoms interacting

with a periodically modulated optical lattice. To suppress spontaneous emission and provide a coherent quantum dynamics, atoms in those experiments were detuned far from the optical resonance. We review recent experiments on quantum dynamical effects with cold atoms in a laser standing-wave field: dynamical localization and its suppression, chaos assisted tunneling, Levy flights and others.

A new arena of quantum nonlinear dynamics with atoms in optical lattices is opened if we work near the optical resonance and take the internal dynamics into account. In the Hamiltonian approximation, when one neglects spontaneous emission, the coupling of internal and external atomic degrees of freedom has been shown to produce a number of nonlinear effects in rigid (i.e. without any modulation) optical lattices: chaotic Rabi oscillations, chaotic atomic transport, dynamical fractals and Levy flights [1]. In reality the dynamics of atoms in near-resonant laser fields is not deterministic and continuous because of spontaneous emission, a kind of a shot noise which is not small. We simulate atomic ballistic transport in a standing-wave laser field in the framework of a Monte Carlo stochastic wavefunction approach in which the coherent Hamiltonian evolution is interrupted at random times by spontaneous emission events. It is shown in numerical experiments and confirmed analytically that the character of spatial and momentum diffusion of spontaneously emitting atoms changes abruptly in the atom-laser detuning regime where the deterministic Hamiltonian dynamics has been shown to be chaotic. Thus, we find a manifestation of underlying Hamiltonian chaos in the diffusive-like center-of-mass motion which can be observed in real experiments [2].

1. S.V. Prants, M.Yu. Uleysky. JETP Letters. V.82 (2005) P. 748;  
S.V. Prants, M.Yu. Uleysky, V.Yu. Argonov. Phys. Rev. A. V.73 (2006) art. 023807;  
S.V. Prants. Comm. Nonlin. Sci. Numer. Simul. V.12 (2007) P. 19.
2. V.Yu. Argonov, S.V. Prants. Phys. Rev. A. V.75 (2007) art.no. 063428;  
V.Yu. Argonov, S.V. Prants. Europhys. Lett. V. 81 (2008) art. no. 24003;  
V.Yu. Argonov, S.V. Prants. JETP Letters. V. 88 (2008) P. 752;  
V.Yu. Argonov, S.V. Prants. Phys. Rev. A. V.78 (2008) art. no 043413.

### **Possibilities of Presence of SCHLOGL Quasichemical Reactions in an Atmosphere of Own Silicon Defects**

E.P.Prokopiev

Federal State Unitary Enterprise B«State Science Centre of the Russian Federation- A.I.Alikhanov Institute for theoretical and experimental physicsB» Moscow, Russia,  
Moscow Institute of Electronic Technology (Technical University), TU MIET, Zelenograd, Moscow, Russia  
[eppropkoviev@mail.ru](mailto:eppropkoviev@mail.ru)

Within the limits of debatable discussion the important case of evolution of an atmosphere of own dot defects of silicon is considered. It is shown, that own interstitial atoms of silicon and to concentration of vacancies in an atmosphere of own defects of silicon presence by stable states is probably inherent in concentration, transition between which can be described Schlogl quasichemical reactions.

### **Experimental study of the nonlinear polarization dynamics induced by orthogonal optical injection in 1550 nm-Vertical-Cavity Surface-Emitting Lasers**

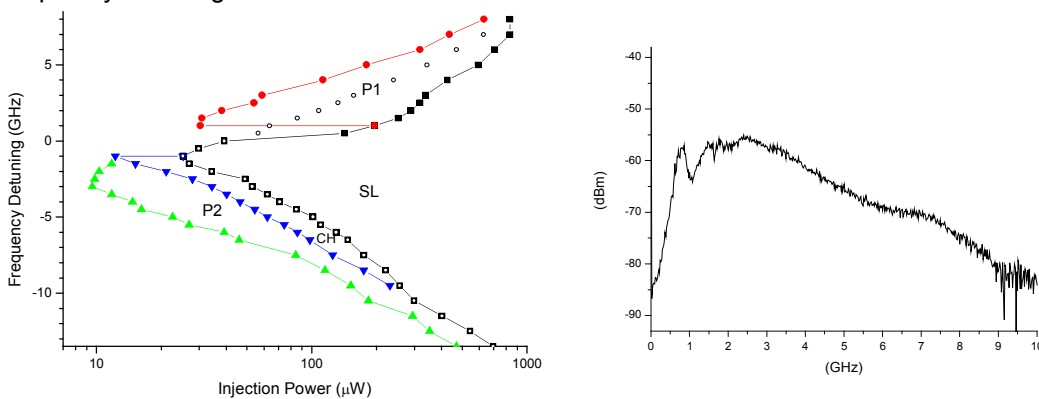
A. Quirce<sup>1,2</sup>, A. Hurtado<sup>3</sup>, A. Valle<sup>1</sup>, L. Pesquera<sup>1</sup>, M. J. Adams<sup>3</sup>

<sup>1</sup> Instituto de Física de Cantabria (CSIC-Univ.de Cantabria), Spain. <sup>2</sup> Departamento de Física Moderna, Fac.Ciencias, U. Cantabria, Santander, Spain. <sup>3</sup> Department of Computing and Electronic Systems, Univ. of Essex, UK.

Optical injection in vertical-cavity surface-emitting lasers (VCSELs) is an attractive method to improve the characteristics of the injected laser or to obtain nonlinear transfer functions that can be used in all-optical signal processing. Optical injection is also a method that can induce rich nonlinear dynamics in the light emitted by the VCSEL. An example of those dynamics has been recently obtained when measuring the polarization of a 850 nm wavelength VCSEL subject to orthogonal optical injection [1]. In that experiment

linearly polarized light from a tunable external laser source was injected orthogonally to the linear polarization of a free-running VCSEL that exhibited polarization switching (PS) between its two linear polarizations when increasing its applied current. In this work we perform an experimental study of the nonlinear dynamics of a 1550 nm wavelength single-mode linearly polarized VCSEL when subject to orthogonal optical injection. We have measured the mapping of the polarization resolved dynamics in the plane of detuning between the injection frequency and the free-running frequency of the VCSEL versus injected power. In contrast with previous results [1], our free-running VCSEL emits in a linearly-polarized fundamental transverse mode over the whole current range. This significantly affects the dynamics since our mapping shows qualitative differences with previously reported mappings [1].

Experimentally, the orthogonal optical injection from a tunable external-cavity laser diode in a commercial VCSEL (Raycan) is achieved by using an all-fiber setup. A bias current of 4 mA (approx.  $2.5 \times I_{th}$ ) was applied to the device. The power of the dominant (parallel) polarization of the solitary VCSEL was 0.2 mW. The orthogonal polarization was suppressed 35 dB. We show in Fig. 1 (left) the mapping of the dynamics of the total power when the injected power is swept for different frequency detunings around the frequency of the orthogonal polarization of the fundamental transverse mode of the device. Fig. 1 also shows the injected power required for PS to the orthogonal polarization of the VCSEL. Different regions corresponding to different dynamical regimes are shown in the figure. Region SL represents the stable locking range and regions P1, P2 show periodic dynamics. The P1 region is characterized by the appearance of a strong peak near the frequency detuning in the RF spectrum. In region P2 situations can be found where several peaks appear in the RF spectrum at multiples of one half the relaxation oscillation frequency of the free-running VCSEL indicating period doubling dynamics. The CH region is characterized by wide RF spectra (see Fig. 1 right) that are the signature of irregular and possibly chaotic dynamics. In contrast with Ref. [1] the irregular behavior is obtained for negative values of the frequency detuning. In conclusion, avoiding complicated nonlinear dynamics in applications where the injection power is changed requires operation at positive frequency detunings.



**Fig. 1** Left: Mapping of the dynamics of the VCSEL subject to orthogonal optical injection. SL: stable locking region, P1,P2: periodic regions, CH: irregular dynamics. PS is also shown with open circles. Right: RF spectrum in the CH region (Injected power: 50  $\mu$ W)

## References

- [1] J. Buesa, I. Gatare, K. Panajotov, H. Thienpont, and M. Sciamanna, "Mapping of the dynamics induced by orthogonal optical injection in vertical-cavity surface-emitting lasers", *IEEE J. Quantum Electron.* 42, 2,198-207, 2006.

## An Enhanced Tree-shaped Adachi-like Chaotic Neural Network Requiring Linear-time Computations

Ke Qin<sup>1</sup> and B. John Oommen<sup>2</sup>

<sup>1</sup> School of Computer Science and Engineering, University of Electronic Science & Technology of China, Chengdu, China, <sup>2</sup> School of Computer Science, Carleton University, Ottawa, Canada  
[oommen@scs.carleton.ca](mailto:oommen@scs.carleton.ca), [thinker qk@hotmail.com](mailto:thinker qk@hotmail.com)

The Adachi Neural Network (AdNN) [1{5}], is a fascinating Neural Network (NN) which has been shown to possess chaotic properties, and to also demonstrate Associative Memory (AM) and Pattern Recognition (PR) characteristics.

Variants of the AdNN [6,7] have also been used to obtain other PR phenomena, and even blurring. A significant problem associated with the AdNN and its variants, is that all of them require a quadratic number of computations. This is essentially because all their NNs are completely connected graphs. In this paper we consider how the computations can be significantly reduced by merely using a linear number of



computations. To do this, we extract from the original complete graph, *one* of its spanning trees. We then compute the weights for this spanning tree in such a manner that the modified tree-based NN has approximately the same input-output characteristics, and thus the new weights are themselves calculated using a gradient-based algorithm. By a detailed experimental analysis, we show that the new linear-time AdNN-like network possesses chaotic and PR properties for different settings. As far as we know, such a tree-based AdNN has not been reported, and the results given here are novel.

Keywords: Chaotic Neural Networks, Chaotic Pattern Recognition, Adachi Neural Network.

### **Distinguishing stochastic from chaotic nature of the data with applications in Mathematica**

Oana Rachieru  
Transilvania University of Brasov, Romania  
oana.rachieru@yahoo.com

We give methods of distinguishing stochastic from chaotic nature of the data with applications and numerical implementation in Mathematica.

Keywords: Stochastic process, Deterministic chaos, time series.

### **The Indian summer monsoon and its variability in high resolution Atmospheric Global General Circulation Models**

K. Rajendran  
rajend@cmmacs.ernet.in

Simulation of major characteristics of the summer monsoon climate over South Asia by an ultra-high resolution model of 20km spatial resolution was analyzed. For the first time, a long climate simulation at such high resolution with a global general circulation model at a spatial resolution of 20-km was achieved. In addition to accessing the simulation of mean summer monsoon climate, tropical convection and its organization on different spatio-temporal scales were also assessed. High resolution simulation is found to be better in resolving the finer climatological features over Asian monsoon region and South Pacific Convergence Zone (SPCZ), but, the amplitude and phase speed of convectively coupled equatorial waves show only marginal improvement suggesting that super high resolution alone will not resolve the vertical and spatial structure of the Madden Julian Oscillation (MJO), the dominant variability of tropical convection. This indicates the importance of further refinements in physical parameterizations especially that of convection for better MJO simulation.

Using the ultra-high resolution global climate model, we investigated the impact of future climate change on Indian summer monsoon. The fidelity of the 20-km resolution model is found remarkable in representing the regional distribution of the present day monsoon rainfall. Future scenarios of Indian summer monsoon show wide spread but spatially varying increase in rainfall over the interior regions and significant reduction in orographic rainfall over the west coast of Indian Peninsula and the eastern hilly regions around Assam. Future climate change also impacts to increase the number of extreme hot and wet days not only during the monsoon season, but in the pre-monsoon season as well.

# Chaos in an infinite-dimensional dynamical system

A.G. Ramm

Mathematics Department, Kansas State University,  
Manhattan, KS 66506-2602, USA  
ramm@math.ksu.edu

## Abstract

Let  $H$  be a Hilbert space,  $A = A^* \geq m > 0$  be a selfadjoint operator in  $H$ , possibly unbounded. Consider the following dynamical system:

$$\dot{u} = -Au + bu, \quad b := b(t) := b(u(t)) = \frac{(Au, u)}{(u, u)}, \quad u(0) = u_0; \quad \dot{u} = \frac{du}{dt}. \quad (1)$$

Here  $(u, v)$  is the inner product in  $H$ ,  $u_0 \in D(A)$ ,  $D(A)$  is the domain of  $A$ . Let us formulate our basic results:

1. Problem (1) has a unique solution defined for all  $t > 0$  and  $\|u(t)\| = \|u_0\| \forall t > 0$ .
2. The solution can be found analytically:

$$u(t) = \frac{e^{-tA}u_0}{(1 - 2 \int_0^t h(s)ds)^{1/2}}, \quad h(t) := (Ae^{-2tA}u_0, u_0). \quad (2)$$

Without loss of generality one may assume that  $\|u_0\| = 1$ , and then the solution can be rewritten as:

$$u(t) = \frac{\int_m^\infty e^{-ts} dE_s u_0}{(\int_m^\infty e^{-2ts} d\rho(s))^{1/2}}, \quad \rho(s) := (E_s u_0, u_0), \quad (3)$$

where  $E_s = E((-\infty, s])$  is the resolution of the identity of  $A$ .

3. If the interval  $[m, m + \delta]$  does not contain eigenvalues of  $A$  and is filled with an absolutely continuous spectrum of  $A$ , and if  $E([m, m + \delta])u_0 \neq 0$ , then the solution to (1) *does not have a strong limit in  $H$  and does not remain in any fixed finite-dimensional subspace of  $H$ .*

In this sense the solution exhibits chaotic behavior.

4. If  $m$  is an isolated eigenvalue of  $A$ ,  $P_m$  is the orthoprojector on the corresponding eigenspace  $H_m$  of  $A$ , and if  $P_m u_0 \neq 0$ , then the limit  $\lim_{t \rightarrow \infty} u(t) = \phi$  exists,  $\phi \in H_m$ , and  $\|\phi\| = \|u_0\|$ .

## Acoustic and electromagnetic wave scattering by many small particles and creating materials with desired properties

A.G. Ramm

Mathematics Department, Kansas State University, Manhattan, USA  
ramm@math.ksu.edu

Many-body scattering problem is solved asymptotically when the size of the particles tends to zero and the number of the particles tends to infinity.

A method is given for calculation of the number of small particles and their boundary impedances such that embedding of these particles in a bounded domain, filled with known material, results in creating a new material with a desired refraction coefficient.

The new material may be created so that it has negative refraction, that is, the group velocity in this material is directed opposite to the phase velocity.

Another possible application consists of creating the new material with some desired wave-focusing properties. For example, one can create a new material which scatters plane wave mostly in a fixed given

solid angle. In this application it is assumed that the incident plane wave has a fixed frequency and a fixed incident direction.

An inverse scattering problem with scattering data given at a fixed wave number and at a fixed incident direction is formulated and solved.

Many-body scattering problem is considered for electromagnetic (EM) wave scattering under various assumptions concerning small scatterers.

1Math subject classification: 35C15, 35J05, 35J10, 65M32, 74J10, 74J25, 78A25, 78A46, 78A48

2key words: wave scattering by small particles; wave-focusing; negative refraction; many-body scattering.

#### REFERENCES:

- 1) A.G.Ramm, Wave scattering by small bodies of arbitrary shapes, World Sci. Publishers, Singapore, 2005.
- 2) A.G.Ramm, Inverse problems, Springer, New York, 2005.
- 3) A.G.Ramm, Distribution of particles which produces a "smart" material, J. Stat. Phys., 127, N5, (2007), 915-934.
- 4) A.G.Ramm, Many-body wave scattering by small bodies and applications, J. Math. Phys., 48, N10, 103511, (2007).
- 5) A.G.Ramm, Scattering by many small bodies and applications to condensed matter physics, Europ. Phys. Lett., 80, (2007), 44001.
- 6) A.G.Ramm, Distribution of particles which produces a desired radiation pattern, Physica B, 394, N2, (2007), 253-255.
- 7) A.G.Ramm, Wave scattering by small impedance particles in a medium, Phys. Lett. A 368, N1-2,(2007), 164-172.
- 8) A.G.Ramm, Materials with the desired refraction coefficients can be made by embedding small particles, Phys. Lett. A, 370, 5-6, (2007), 522-527.
- 9) A.G.Ramm, A recipe for making materials with negative refraction in acoustics, Phys. Lett A, 372/13, (2008), 2319-2321.
- 10) A.G.Ramm, Wave scattering by many small particles embedded in a medium, Phys.Lett. A, 372/17, (2008), 3064-3070.
- 11) A.G.Ramm, Inverse scattering problem with data at fixed energy and fixed incident direction, Nonlinear Analysis: Theory, Methods and Applications, 69, N4, (2008), 1478-1484.
- 12) A.G.Ramm, Electromagnetic wave scattering by small bodies, Phys. Lett. A, 372/23, (2008), 4298-4306.
- 13) A.G.Ramm, Electromagnetic wave scattering by many conducting small particles, J. Phys A, 41, (2008), 212001.

#### **The Equivalence of the Agents in Time**

Ioana Ramniceanu, Daniela Marinescu, Dumitru Marin  
Academy of Economic Studies, Bucharest, Romania

[ioana.ramniceanu@hotmail.com](mailto:ioana.ramniceanu@hotmail.com), [danielamarinescu@hotmail.com](mailto:danielamarinescu@hotmail.com), [dumitrumarin@hotmail.com](mailto:dumitrumarin@hotmail.com),

In this paper we will analyze what happens when an agent has to choose between two or more jobs and he knows that after a period of time the wages will be the same. So, we could say that between the two agents there is no difference. But still there is a great one: if we will consider a small increase of time, then the utility of the new amount is different for the two agents.

The same analyze will be made for the exerted effort (having in mind that the function of the effort cost is increasing and convex). We know that the higher the reference standard from the previous period ( $w_{t-1}$ ) is, the higher the effort level is to obtain a greater utility.

Next we will define the equivalence of the agents in time using the non-neutrality measure.

We will find that to do the best choice the employer should know first the effort function for the two agents.

Keywords: Job satisfaction, Non-neutrality measure, Cost function.

## Experimental Unfolding and Theoretical Model of the Transition to Complex Dynamics in Sagged Cables

Giuseppe Rega

Department of Structural and Geotechnical Engineering, Sapienza University of Rome, Italy  
[giuseppe.rega@uniroma1.it](mailto:giuseppe.rega@uniroma1.it)

Large amplitude forced vibrations of suspended cables exhibit a rich variety of nonlinear phenomena, as highlighted by various theoretical models and analytical or numerical treatments [1]. Moreover, depending on problem parameters, experimental investigations show the occurrence of also involved bifurcation scenarios to complex response, un-modeled in theoretical analyses, and provide hints about possible occurrence of low-dimensional chaos [2].

In this lecture, an experimental polymeric cable with attached distributed masses, hanging between two supports at the same level and having geometrical and mechanical properties in the neighborhood of first crossover in the spectrum of in-plane natural frequencies, is considered. It realizes a reliable model of bare sagged cable. The system is in conditions of multiple internal resonance involving either all first four in-plane and out-of-plane, symmetric and anti-symmetric, modes (2:2:1:2) or only three of them (2:2:1, first in-plane and out-of-plane anti-symmetric, first out-of-plane symmetric), and it undergoes in-phase or anti-phase vertical motions of the supports at either primary or order  $\frac{1}{2}$ -subharmonic resonance of the higher frequency modes.

Upon giving an overview on the dynamical and mechanical features of some main experimentally observed transition scenarios to chaos, along with their robustness, attention is focused on the unfolding of the cable complex forced dynamics triggered by a divergence-Hopf codimension two bifurcation.

Classes of motion, bifurcation scenarios and complex phenomena are analyzed via proper reconstruction techniques of the dynamics from experimental measurements, paying proper attention to the characterization of system dimensionality in terms of both time and space complexity. The former is accomplished by calculating invariant measures of the dynamics in embedding pseudo-phase-spaces, and obtaining hints on the actual number of degrees-of-freedom taking meaningful part in the response. The latter is made by identifying the configurations most visited in the system temporal evolution via the proper orthogonal decomposition of spatially contemporaneous measures, which provides us with meaningful information on also the mechanical meaning (spatial shape) associated with the involved degrees-of-freedom.

The experimentally observed transition mechanisms are interpreted in the background of canonical bifurcation scenarios from dynamical systems theory. In particular, bifurcation features to complex dynamics are analyzed based on an overall feedback between experiments and theory which allows us

- (i) to qualitatively trace the experimental results back to a theoretical scenario,
- (ii) to exploit hints from the latter to improve and steer the experimental analyses,
- (iii) to pursue ahead the physical investigation by detailing the most robust features of system response and clarifying to which extent they can be referred to canonical scenarios from dynamical systems theory,
- (iv) to improve cable theoretical modeling,
- (v) to identify proper relevant reduced order models to be used for (partially) reproducing the experimental scenarios.

Based on the effects of the setup ambient temperature – by the way of material damping – on experimental results, a phenomenological reduced order model aimed at describing the interaction between temperature and forcing parameters is built [3]. Unfolding of canonical bifurcation scenarios is used to produce an highly degenerated periodically perturbed bifurcation set in an enlarged parameter space where the effects of material damping and forcing symmetry are evidenced. Considering the temperature as a controllable parameter besides excitation amplitude and frequency, and systematically investigating a thermally

conditioned setup, allows us to interpret the experimental scenario in the framework of the unfolding of the normal form of the divergence-Hopf codimension two bifurcation with square symmetry, which acts as the organizing centre of the overall dynamics [4].

Depending on control parameters, features of low-dimensional homoclinic chaos are evidenced for the system in the wider neighborhood of the divergence-Hopf bifurcation, within a strong richness and variety of observed response classes.

## References

- [1] Rega G., Nonlinear vibrations of suspended cables. Part I: Modeling and analysis, Part II: Deterministic phenomena. *Applied Mechanics Reviews*, **57**, 443-514, 2004.
- [2] Rega G., Alaggio R., Spatio-temporal dimensionality in the overall complex dynamics of an experimental cable/mass system. *Int. J. Solids Structures*, **38**, 2049-2068, 2001.
- [3] Alaggio R., Rega G., Low-dimensional model of the experimental bifurcation scenario of a polymeric cable, *Int. Conf. on Nonlinear Phenomena in Polymer Solids and Low-dimensional Systems*, 170-181, Russian Academy of Sciences, Moscow, 2008.
- [4] Rega G., Alaggio R., Experimental unfolding of the non-linear dynamics of a cable-mass suspended system around a divergence-Hopf bifurcation, *J. Sound and Vibration*, 2008 (submitted).

## Fractal functional regression for classification of gene expression data by wavelets

Margarita Maria Rincon<sup>1</sup> and Maria Dolores Ruiz-Medina<sup>2</sup>  
University of Granada, Spain

<sup>1</sup> [mmrh@correo.ugr.es](mailto:mmrh@correo.ugr.es), <sup>2</sup> [mruiz@ugr.es](mailto:mruiz@ugr.es)

Functional classification of fractal temporal gene expression data is performed in terms of logistic regression based on the wavelet-vaguelette decomposition of the temporal gene expression curves. The fractality features of the gene expression profiles comes from the stochastic evolutionary forces acting on genomes. The noise level introduced by such forces increases local singularity, that must be removed to make robust the classification procedure. Specifically, thresholding rules are applied to the wavelet-like decomposition of the gene expression profiles to eliminate the noise. Leave-one-out cross-validation is then performed to choose the threshold minimizing the classification error.

Keywords: Fractal gene expression profiles, functional classification procedures, functional data, wavelet-vaguelette decomposition.

## Implementation of Cryptographic Techniques Based on Dynamical Systems

Cristian-Iulian RÎNCU<sup>1</sup>, Vasile-Gabriel IANA<sup>2</sup>, Alexandru ȘERBĂNESCU<sup>1</sup>

<sup>1</sup> Military Technical Academy, Bucharest, <sup>2</sup> University of Pitești, Romania,  
[iulian.rincu@gmail.com](mailto:iulian.rincu@gmail.com), [giana2001@yahoo.com](mailto:giana2001@yahoo.com), [serbal@mta.ro](mailto:serbal@mta.ro)

The development of the new information security systems based on chaos theory represents a new research field in communication and information technology domain. At present secret communication plays an increasing role in many fields of common life, like banking, industry, and telecommunication. In the recent years, some cryptographic algorithms were designed based on dynamical chaotic systems. The essence of the theoretical and practical efforts which are done in this new field is represented by the idea that chaos-based cryptosystem is capable to have similar performances regarding the classic methods based on computational techniques. Technologic evolution, in the field of communication by using reprogrammable hardware structures, gives appropriate solutions for the implementation of the cryptographic modules in high speed applications. In this paper we present some aspects regarding the chaos-based cryptography stage concerning the implementation aspects.

Keywords: dynamical chaotic systems, cryptography

### **Lamellar modelling of mixing processes in chaotic flows**

Edward P. L. Roberts

University of Manchester, School of Chemical Engineering, Manchester, United Kingdom  
edward.roberts@manchester.ac.uk

The development of CFD techniques and the rapid increases in computational speeds is making increasingly complex flows accessible to simulation. However, for processes with fast kinetics and slow rates of diffusion (which are often mixing sensitive), simulation of the detailed concentration distributions associated with the mixing processes is often intractable or limited to situations where the mixing is poor. A Eulerian approach may be considered, where the convection diffusion equations are solved to find the concentration distribution. For systems with rapid mixing however the length scales of concentration fluctuations will rapidly fall to below the mesh size and the simulation will become highly inaccurate. Alternatively a Lagrangian approach may be used, where the boundary between two segregated fluids is followed in the absence of diffusion processes. In this case the length of the boundary will grow exponentially, leading to excessive memory requirements. Consequently 'micromixing' models are often used where the length scales are estimated from turbulence parameters.

In this study we present a new Lagrangian approach using stretch rates to determine the local lamellar structure, and from this the local micro-scale concentration distribution can be accurately calculated. To achieve this the deformation of an element of fluid moving in the flow is calculated and the orientation of maximum stretching rate of the fluid element is determined. This orientation corresponds to the local orientation of the lamellar structure at the fluid element location. A small fluid line perpendicular to this lamellar structure is then simulated backwards in time to the initial conditions. From the initial distribution of the segregated fluids and the stretch rates, the local lamellar structure at the fluid element location can be accurately calculated. Using a one dimensional simulation of the convection diffusion processes along the line across the lamellae, the concentration variation in this lamellar structure can also be calculated with a high degree of accuracy.

This approach has been developed by considering two-dimensional deterministic chaotic flows. For these flows the method has been shown to predict the local lamellar structure with a high degree of accuracy. Current work will evaluate the approach for CFD simulations of unsteady laminar flows. Further work will be needed to broaden the applicability to three-dimensional flows, direct numerical simulations of turbulent mixing, and to model diffusion and reaction processes.

Keywords: Chaotic advection, lamellar modelling, mixing, micromixing.

### **A new car-following model for highway traffic safety investigation**

Jozsef Rohacs

Department of Aircraft and Ships, Budapest University of Technology and Economy, Hungary  
[rohacs@rht.bme.hu](mailto:rohacs@rht.bme.hu)

A new car-following model recommended for analysis the traffic safety is combined from the deterministic model (like GHR) and stochastic model. The vehicle controlled stochastic motion is decomposed into the interdependent sub processes and are approximated by generalized Markov process discredited in field of vehicle conditions and traffic and environmental situations and activated by drivers' subjective decisions.

Keywords: car-following models, simulation, chaos

### **Synchronization in Chaotic Systems: from Plasma to Chua to Neurons**

Epaminondas Rosa  
Dept. of Physics, Illinois State University, Normal, USA  
[erosa@ilstu.edu](mailto:erosa@ilstu.edu)

Synchronization in chaotic systems is a well studied subject matter, with many examples of various types of chaos synchrony. One kind of synchronization of special interest involves systems with their phases in step with each other while maintaining no correlation about their amplitudes. This means that two chaotic oscillations in phase synchrony would maintain their peaks in step with each other but there would be no connection between their amplitudes.

In the particular case of three mutually coupled systems, say A, B, and C, where each oscillator is coupled to the other two, or where systems A and C are coupled to system B but are not directly coupled to each other, there are a few interesting types of behaviour that have been observed. For example, depending on the kind and strength of the couplings, system B alternates phase synchronous states with system A and system C. That is, system B synchronizes with system A (but not with system C) for some time, then breaks its synchronism with system A and synchronizes with system C for some time, then breaks synchronism with system C and synchronizes back to system A, and so on.

In this presentation we discuss similarities and differences in synchronous processes involving chaotic oscillators such as Roessler, experimental Chua circuits, experimental plasma discharge tubes, and neurons.

### **Stochastic Modeling of Fluctuations in Solar Wind-Magnetosphere Interaction**

K.Rypdal, B. Kozelov, M. Rypdal, T. Zivkovic  
University of Tromsø, Norway  
[kris@phys.uit.no](mailto:kris@phys.uit.no)

It has recently been shown that fluctuations of global quantities (let us name it  $X$ ) in certain avalanching and turbulent systems can be described by stochastic differential equations (SDEs) driven by a colored noise term with a diffusion coefficient depending on  $X$ . The equation also contains a deterministic drift term, which keeps  $X$  within certain limits. This SDE has been determined for the Bak-Tang-Wiesenfeld sandpile model in [1], and for the Zhang-sandpile and a simulated two-dimensional (2D) Navier-Stokes turbulence in [2], and may provide criteria for distinguishing between sandpile avalanching and 2D turbulence from observational time-series data. In this contribution we employ this modeling technique to observational time-series data which are believed to reflect large-scale properties of the solar wind or the magnetosphere-ionosphere system. However, time-series analysis of quantities like the interplanetary magnetic field, disturbed storm-time index, and auroral electrojet index, reveal a multifractal structure. Thus, stochastic modeling of these signals requires that we replace the colored noise with a multifractal source term in the SDE. We demonstrate how this kind of analysis and modeling can be employed to characterize the dynamics of different elements in the Sun-Earth interaction.

We contrast this analysis with simultaneous quantification of the determinism in the signal characterizing the solar wind and magnetospheric dynamics, respectively. The method employed is the so called recurrence plot quantification analysis. The variation in the determinism of the two signals under different conditions and the variations in their multifractal spectra constitute complementary information that can provide further insight into the physical nature of the solar wind-magnetosphere interaction and the subtle relationship between the rare magnetic storms and the much more frequent substorms.

Keywords: Stochastic differential equation, Multifractal, Determinism, Recurrence plot, Self-organized criticality, Solar wind, Magnetosphere, Magnetic storm, Substorm.

### **References**

- [1] M. Rypdal, and K. Rypdal. A stochastic theory for temporal fluctuations in self-organized critical systems, *New Journal of Physics* 10:123010, 2008.
- [2] M. Rypdal, and K. Rypdal. Modeling temporal fluctuations in avalanching systems, *Phys. Rev. E* 78:051127, 2008.

### **Three Dimensional Numerical Modeling Study of the Coastal Upwelling in the Persian Gulf**

Masoud Sadrinasab

Khorramshahr University of Marine Science and Technology, Iran

[masoud.sadri@gmail.com](mailto:masoud.sadri@gmail.com)

A numerical study is made of the dynamics of the circulation that arises from forcing by a steady, uniform alongshore wind in the Persian Gulf which is a shallow semi-enclosed sea, with an average depth of 34 and a maximum depth of 120 meters. It is connected to the Gulf of Oman and the Indian Ocean through the Straits of Hormuz. A three-dimensional hydrodynamic model (COHERENS) has been employed to investigate wind-driven coastal upwelling in the northern part of the Persian Gulf. Atmospheric forces as well as tidal force have been employed in this model. Findings of the model suggested that dominant water circulation pattern in the Gulf is counter-clockwise and driven by density gradients. A seasonal thermocline is evident in the model outputs with a surface to bottom temperature difference of around 12 oC in summer. Simulated results illustrate that when the wind direction is parallel to the coast with of greater than 8 m/s upwelling occurs in the northern part of the Gulf. There is a very good agreement between the model results and the observations.

Key Words: Persian Gulf, Numerical modelling, ekman transport, upwelling

### **The account of influence of time delays of processing of signals in digital control systems**

Leonty K. Samoylov

Technological Institute of Southern Federal University, Taganrog, Russia

[samoilov@fep.tsure.ru](mailto:samoilov@fep.tsure.ru)

Output signals of digital control systems have an essential delay concerning input signals. This delay is the reason of an additional error of control. Influence of a delay of the information is offered to be considered in the form of a component of dynamic error of process of digitization - restoration. At such approach the delay increase leads to increase in demanded frequency of digitization or to increase in an error of control.

Keywords: digital control systems, delay, dynamic error, control error



### **Dynamic generalization of cartographical maps**

Leonty K. Samoylov, Dmitry S. Samoilo  
Technological Institute of Southern Federal University, Taganrog, Russia  
samoilov@fep.tsure.ru

Property of geointelligence systems continuously to store the existential information leads to uncontrolled growth of complexity of the cartographical maps formed by inquiries of users. Selfdescriptiveness of maps falls despite growth of number of cartographical objects. Dynamic generalisation – one of approaches to problem solution. By introduction of additional informational structures it is possible to pass in area of a global maximum of selfdescriptiveness.

Keywords: cartographical maps, complexity, dynamic generalization

### **Reduced order evolution equations for stochastic fluid flows**

Themistoklis Sapsis<sup>1</sup> and Pierre Lermusiaux<sup>2</sup>  
Massachusetts Institute of Technology, Department of Mechanical Engineering, Cambridge, USA  
<sup>1</sup> [sapsis@mit.edu](mailto:sapsis@mit.edu), <sup>2</sup> [pierrel@mit.edu](mailto:pierrel@mit.edu)

Uncertainties in the ocean, from turbulent to climate scales, are of very large dimensions due to the size of the multidisciplinary state space and due to the very limited observations. In such predictions, uncertainties arise from a number of sources and consist of several components. These include the: approximations inherent in the deterministic models; boundary condition uncertainties; parametric uncertainties; measurement models; and, uncertainty of the initial fields. In general, stochastic error models are used to represent uncertainties and data assimilation used to correct model estimates based on measurements. Ocean estimations and predictions should include uncertainty estimates. A challenge is to reduce the uncertainty dimensions such that the prognostic equations in the reduced uncertainty space are optimal approximations of the full problem while being computationally tractable (Lermusiaux and Robinson [3]; Vishik and Fursikov [5]; Yaglom and Monin [4]; Lermusiaux [2]).

In this work we derive exact, reduced-order evolution equations for general stochastic flow fields. By hypothesizing a decomposition of the random field into a stochastic and deterministic part we derive an exact, closed-system of equations consisting of a Partial Differential Equation (PDE) for the deterministic part of the field, a family of PDEs for the orthonormal base where the stochasticity 'lives' as well as a system of Stochastic Differential Equations (or equivalently a Fokker-Planck-Kolmogorov equation) that describes how the stochasticity itself evolves in the time varying stochastic subspace. By assuming further conditions on the form of the representation we recover both Proper-Orthogonal-Decomposition equations (Holmes et al, [1]) and generalized Polynomial-Chaos equations (Xiu and Karniadakis, [6]). We apply the derived equations to the case of 2D viscous fluid flows described by Navier-Stokes equations and we compare our results with Monte-Carlo simulations.

Keywords: Evolution of uncertainty, Proper orthogonal Decomposition, Polynomial-chaos Method.

### **Clustering of inertial particles in 3D steady flows**

Themistoklis Sapsis<sup>1</sup> and George Haller<sup>2</sup>  
Massachusetts Institute of Technology, Department of Mechanical Engineering, Cambridge, USA  
<sup>1</sup> [sapsis@mit.edu](mailto:sapsis@mit.edu), <sup>2</sup> [ghaller@mit.edu](mailto:ghaller@mit.edu)

We study the motion of inertial particles in three-dimensional steady fluid flows that contain a family of two-dimensional invariant manifolds. Using results from Ergodic Theory we derive a condition that predicts if the considered invariant manifold for the flow will persist as an invariant manifold for inertial particles. We illustrate our results for the three-dimensional ABC flow with parameters corresponding to a non-integrable case.

Keywords: Inertial Particles, Ergodic Theory, Melnikov Theory.

## **Neural Networks and Outliers identification in ATHEX stocks and indices series**

Anastasios Saraidaris and Athanasios Margaritis  
University of Macedonia, Thessaloniki, Greece  
[anasara@otenet.gr](mailto:anasara@otenet.gr) and [amarg@uom.gr](mailto:amarg@uom.gr)

In this paper Neural Networks and Fractals are employed in an attempt to identify outliers as extreme values in ATHEX stocks and indices return series with the use of non linear models. The use of these models is attempted due to their advantage to determine the non linear structure of the series regardless any distribution properties.

The examined series found to reveal a weak though clear evidence of chaotic behaviour prior and after the ATHEX classification in the developed stock markets in 1.6.2001.

Outliers found in clusters or randomly distributed are classified accordingly to their characteristics and contrasted to those found by the application of alternative outliers identification statistical tests.

The data series employed in the test are daily returns of stock prices of ten Greek banks as well as the indices: General Index, FTSE/ASE 20 and FTSE/ASE mid 40. The study aims to provide evidences on the diffusion pattern of news on macroeconomic events, company announcements and regulatory changes in stock returns.

Keywords: Outliers, extreme events, Neural Networks.

## **Extreme values in financial markets**

Thomas Schwiertz  
[thomasschwiertz@email.de](mailto:thomasschwiertz@email.de)

In Financial Markets usually price fluctuations are modelled via Gaussian random walks. Especially in Financial Risk Management financial institutions are bound to Gaussian models due to regulatory rules and laws. The current Financial Crisis is just another well known empirical demonstration to use more sophisticated models: Extreme Value Statistics, truncated Lévy Flights, stochastic volatilities etc. Nevertheless more sophisticated does not mean more accurate. In this special session we show results of the industry's practices of nonlinear processes that money and interest rates go and that have a chaotic character along with the stochastic part by mean of stochastic fluctuations.

## **Universal Characteristics of Fractal Fluctuations in Prime Number Distribution**

A.M.Selvam  
[amselvam@gmail.com](mailto:amselvam@gmail.com)

The frequency of occurrence of prime numbers at unit number spacing intervals exhibits selfsimilar fractal fluctuations concomitant with inverse power law form for power spectrum generic to dynamical systems in nature such as fluid flows, stock market fluctuations, population dynamics, etc. The physics of long-range correlations exhibited by fractals is not yet identified. A recently developed general systems theory visualises the eddy continuum underlying fractals to result from the growth of large eddies as the integrated mean of enclosed small scale eddies, thereby generating a hierarchy of eddy circulations, or an inter-connected network with associated long-range correlations. The model predictions are as follows: (i) The probability distribution and power spectrum of fractals follow the same inverse power law which is a function of the golden mean. The predicted inverse power law distribution is very close to the statistical normal distribution for fluctuations within two standard deviations from the mean of the distribution. (ii) Fractals signify quantumlike chaos since variance spectrum represents probability density distribution, a characteristic of quantum systems such as electron or photon. (ii) Fractal fluctuations of frequency distribution of prime numbers signify spontaneous organisation of underlying continuum number field into the ordered pattern of the quasiperiodic Penrose tiling pattern. The model predictions are in agreement with the probability distributions and power spectra for different sets of frequency of occurrence of prime numbers at unit number interval for successive 1000 numbers. Prime numbers in the first 10 million numbers were used for the study.

### **Dynamic enhancement and chaos elements in theory of a nucleus and electron internal conversion in nuclides**

Inga N. Serga  
Odessa University, Odessa (Odessos), Ukraine  
[nucserga@mail.ru](mailto:nucserga@mail.ru)

We consider spectra of the barium isotopes and turn attention on definition of the corresponding internal conversion electron coefficients. It is continued discussion, which began in [1,2]. The neutron-deficient nuclides of  $^{125,127}\text{Ba}$  are theoretically studied and the level structures for high-spin states is interpreted within the framework of the RMF model. The electron internal conversion coefficients in the  $^{125,127}\text{Ba}$  nuclides are calculated on the basis of the relativistic Dirac-Fock method. It is performed a comparison of the obtained theoretical data and data by Rossel et al [3], which are  $1.1 \cdot 10^3$  and  $8.5 \cdot 10^4$  for M2 and E3, respectively, the 24.0-keV transition can be considered mainly an M2 transition. The other  $a_K$  values of the 79.4-, 114.3-, 128.7-, 134.3-, 220.4-, 243.0-, 253.3-, 269.6-, 285.6-, and 318.7-keV  $\gamma$  transitions associated with the decay of  $^{127}\text{La}$  are deduced from the electron internal conversion measurements [4]. It is confirmed that the E1 transitions between parity doublets are characterized by a two to four orders of magnitude enhancement compared to those of more normal cases. A possibility of manifestation of stochastic elements (dynamic enhancement) and quantum chaos is discussed.

#### References

1. Raman, S., Nestor Jr., C.W., Ichihara, A. and Trzhaskovskaya, M.B., How good are the internal conversion coefficients now// Phys. Rev.-2002.-Vol.C66.-P.044312.
2. Kibedi T., Burrows T., Trzhaskovskaya M.B., Davidson P., Nestor C., Evaluation of theoretical conversion coefficients using BrIcc // Nucl. Instr. and Meth.-2008.-Vol.A589.-P.202-229
3. Rossel F., Fries H.M., Alder K., Pauli H.C., Rossel F., Fries H.M., Alder K., Pauli H.C., [Internal conversion coefficients for all atomic shells](#) //Atomic Data Nucl. Data Tables.-1978.-Vol.21.-P.91-289.
4. Serga I.N. , Electron internal conversion in the  $^{125,127}\text{Ba}$  isotopes// Photoelectr.-2009.Vol.18.-P.91-96.

### **Lorenz Attractor of an Average Enterprise**

Viktor I. Shapovalov  
The Volgograd Branch of Moscow Humanitarian-Economics Institute, Volgograd, Russia.  
[shavi@rol.ru](mailto:shavi@rol.ru)

It was shown, that the system “an average firm, in terms of the number of the employees and value of the working capital” could have chaotic Lorenz attractor. It was also revealed, that by change of the control parameters’ values, the system “firm” is possible to remove from the chaotic attractor.

Keywords: Lorenz attractor, Chaotic attractor, Chaos in dynamic economic models, Self-organization, Synergetics.

### **Entropy Oscillations in Linear and Nonlinear Processes**

Viktor I. Shapovalov  
The Volgograd Branch of Moscow Humanitarian-Economics Institute, Volgograd, Russia.  
[shavi@rol.ru](mailto:shavi@rol.ru)

The opportunity of occurrence of entropy oscillations around of a stationary state in linear and nonlinear processes is theoretically shown. For the proofs of this phenomenon two conditions have been used: the system is under influence of entrostate; the system is near to a stationary state.

Keywords: Entropy, Entrostat, Entropy oscillations, Self-organization, Open systems,

# Gradient vector fields with impulse action on manifold

Sharko Yulia<sup>1</sup>

T. Shevchenko Kiev National University (e-mail: sharko@imath.kiev.ua)

**Definition 1** We say that the four-tuple  $(X, \Gamma^{n-1}, \Sigma^{n-1}, \varphi)$  is called a vector field with impulse action on  $M^n$ , if

- a)  $X$  is a smooth vector field on  $M^n$ ;
- b)  $\Gamma^{n-1} \subset M^n$  and  $\Sigma^{n-1} \subset M^n$  are closed smooth submanifold of codimension 1 (in general unconnected), such that  $\Gamma^{n-1} \cap \Sigma^{n-1} = \emptyset$ ;
- c) the vector field  $X$  is transverse to submanifold  $\Gamma^{n-1} \cap \Sigma^{n-1}$ ;
- d)  $\varphi : \Gamma^{n-1} \rightarrow \Sigma^{n-1}$  is a diffeomorphism.

Let  $(X, \Gamma^{n-1}, \Sigma^{n-1}, \varphi)$  be a vector field with smooth impulse action,  $p \in M^n \setminus \Gamma^{n-1}$ , and  $(a, b)$  be an interval containing 0. Then by integral curve we will call a smooth map  $\alpha : (a, b) \rightarrow M^n$  such that  $\alpha(0) = p$ ,  $\alpha(t) \cap \Gamma^{n-1} = \emptyset$ , and  $\alpha'(t) = X(\alpha(t))$ . In some case when the integral curve  $\alpha : (a, b) \rightarrow M^n$  extends to the value  $b$  so that  $\alpha(b) \in \Gamma^{n-1}$ , then it is called disconnected. This means that the point  $\alpha(b)$  is mapped to the point  $\varphi(\alpha(b)) \in \Sigma^{n-1}$  and then moves along the integral curve, that passes through the point  $\varphi(\alpha(b))$ .

Let  $f : M^n \rightarrow [0, 1]$  be a smooth function with finite number of critical points. Suppose, that  $0 = c_1 < c_2 < \dots < c_{k-1} < c_k = 1$  are all critical values of  $f$ . Choose regular values  $p_i, q_i$  of  $f$  such that

$$0 < p_1 < q_1 < c_2 < p_2 < q_2 < c_3 < \dots < c_{k-1} < p_{k-1} < q_{k-1} < c_k = 1,$$

and consider submanifolds  $M_{p_i} = f^{-1}(p_i)$  and  $M_{q_i} = f^{-1}(q_i)$ .

Let  $\varphi_i(\text{grad}_\rho f) : M_{p_i} \rightarrow M_{q_i}$  and  $\varphi_i(\text{grad}_\sigma f) : M_{p_i} \rightarrow M_{q_i}$  be diffeomorphisms constructed using gradient vector fields for Riemannian metrics  $\rho$  and  $\sigma$  on  $M^n$ . Then we can define the following diffeomorphism:

$$\Phi_i(\text{grad}_\sigma f, \text{grad}_\rho f) = \varphi_i(\text{grad}_\sigma f)^{-1} \cdot \varphi_i(\text{grad}_\rho f)$$

which in general is not the identity on  $M_{p_i}$ . Denote

$$\Gamma^{n-1} = \cup_i M_{q_i}, \Sigma^{n-1} = \cup_i M_{p_i}, \varphi = \cup_i \varphi_i, X = \text{grad}_\rho f.$$

**Definition 2** By a disconnected orbit of  $i$ -th floor of a gradient vector field with smooth impulse action  $(X, \Gamma^{n-1}, \Sigma^{n-1}, \varphi)$  we will call the orbit which starts on submanifold  $\dot{D}_i^n = f^{-1}(q_i, q_{i+1})$  and attain submanifold  $M_{q_{i+1}}$ .

Among disconnected trajectories of  $i$ -floor there may exist one such that after the first "meeting" with submanifold  $M_{q_{i+1}} \subset \Gamma^{n-1}$  and after application of diffeomorphism  $\varphi_{i+1}$  this moment or after some time move over points of submanifold  $\mathcal{E}_{i+1} = f^{-1}(p_{i+1}, q_{i+1})$ , that they already "passed". We called such trajectories quasi-closed.

**Theorem 1.** *Let  $M^n$  be a smooth closed manifold  $M^n$ ,  $f : M^n \rightarrow [0, 1]$  be a smooth function with finite number of critical values, and  $(X, \Gamma^{n-1}, \Sigma^{n-1}, \varphi)$  be the gradient vector field of  $f$  with smooth impulse action constructed using Riemann's metrics  $\rho$   $\sigma$ . If Euler characteristic of a regular hypersurface*

$$\chi(M_{p_{i+1}}) \neq 0,$$

*then among disconnected trajectories of  $i$ -floor always exist quasi-closed trajectory. Intersection of sets of quasi-closed trajectories of  $i$ -floor with submanifold  $M_{p_i}$  is a compact subset in  $M_{p_i}$ .*

**Definition 3** *Let  $(X, \Gamma^{n-1}, \Sigma^{n-1}, \varphi)$  be a gradient vector field with smooth impulse action on smooth closed manifold  $M^n$ . Suppose, that  $\gamma$  is a quasi-closed trajectory of  $i$ -floor. We say that it is orbitally stable if for every  $\epsilon$ -neighbourhood  $U_\epsilon$  there exists a  $\delta$ -neighbourhood  $V_\delta \subset U_\epsilon$  that satisfies the following condition: any disconnected trajectory of  $i$ -floor  $\gamma_1$  that starts in  $V_\delta$  leaves in  $U_\epsilon$  and then after every "beating" by submanifold  $M_{p_{i+1}}$ .*

**Definition 4** *Let  $X$  be a compact space,  $F : X \rightarrow X$  be a homeomorphism, and  $y \in X$  be a fixed point of  $F$ . We say that point  $y$  is quasi-attracting, if for every neighbourhood  $U$  of  $y$  there exists a smaller neighbourhood  $V \subset U$  of this point, such that for every natural number  $n$  we have  $F^n(V) \subset U$  ( $F^n = \underbrace{F \circ F \circ \dots \circ F}_n$ ).*

**Theorem 2.** *Let  $M^n$  be a smooth closed manifold,  $f : M^n \rightarrow [0, 1]$  be a smooth function with finite number of critical values, and  $(X, \Gamma^{n-1}, \Sigma^{n-1}, \varphi)$  be a gradient vector field of  $f$  with smooth impulse action constructed using Riemann's metrics  $\rho$  and  $\sigma$ . Suppose that  $\gamma$  is a quasi-closed trajectory of  $i$ -floor of  $(X, \Gamma^{n-1}, \Sigma^{n-1}, \varphi)$ , that intersect the submanifold  $M_{p_{i+1}}$  at some point  $x$ . Suppose also that  $x$  is a fixed quasi-attracting point for the diffeomorphism*

$$\Phi_{i+1}(\text{grad}_\sigma f, \text{grad}_\rho f) : M_{p_{i+1}} \rightarrow M_{p_{i+1}}.$$

*Then the quasi-closed trajectory  $\gamma$  will be orbitally stable.*

### Nonlinear Shallow Water Equation in Polar Coordinates

Alexander Shermenev

General Physics Institute, Russian Academy of Sciences, Moscow, Russia  
sher@orc.ru

An interaction of two water waves in a circular basin is studied within quadratic approximation. When the polar coordinates are used, the usual perturbation techniques in separation of variables method inevitably lead to a series of overdetermined systems of linear algebraic equations for unknown coefficients (in contrast with the Cartesian coordinates). However, if we formally introduce a new function satisfying the first system of this series, all these overdetermined systems become compatible (remaining overdetermined) for the special case of the nonlinear shallow water equation. Using the new function and quadratic polynomials of the Bessel functions of radius, we explicitly express the coefficients of the resulting harmonics. It gives solutions describing the two-waves interaction which are found with the same accuracy as the nonlinear shallow water equation is derived. As a consequence, a general boundary problem Boundary problem can be explicitly solved in these terms.

[1] Shermenev, A. & Shermeneva, M. 2000 Long periodic waves on an even beach. *Physical Review E*, No. 5, 6000--6002.

[2] Shermenev, A. 2005A Separation of variables for the nonlinear wave equation in cylindrical coordinates, *Physica D: Nonlinear Phenomena*, 212:3-4, pp 205-215.

Key Words: Wave equation, Bessel function, nonlinear wave

### **Chaotic dynamics of some nonideal electroelastic system**

Aleksandr Yu. Shvets and Volodymyr Pechernyi

National Technical University of Ukraine "Kiev polytechnic institute", Kiev, Ukraine

[alex.shvets@bigmir.net](mailto:alex.shvets@bigmir.net)

Nonideal electro-elastic system "piezoceramic transducer – generator" is considered. Nonlinear interaction between generator and piezoceramic transducer is taken into account. The main attention is given to occurrence, development and disappearance of deterministic chaos in such systems. Maps of dynamical regimes of the system and bifurcation trees are constructed and analysed. Phase portraits, Poincaré's sections, distributions of spectral density of regular and chaotic attractors of systems "generator – piezoceramic transducer" are investigated in details. Existence variety of types of attractors, both regular, and chaotic, including hyperchaotic are specified. It is shown, that almost all scenarios of transition to deterministic chaos, known in non-linear dynamics, are realised in the system.

Keywords: Transition to chaos, limited power-supply, map of dynamical regimes.

### **Computational modeling of bi-directional communication between neurons and astrocytes**

Alexander N. Silchenko and Peter A. Tass

Institute of Neuroscience and Biophysics 3, Research Center Juelich, Juelich, Germany

[a.silchenko@fz-juelich.de](mailto:a.silchenko@fz-juelich.de)

According to the classical view of the nervous system, the numerically superior glial cells have inferior roles in that they provide an ideal environment for the function of neuronal cells.

Their main function is supposed to be the clearance of extracellular space (ECS) from glutamate, potassium and others neurotransmitters released during synaptic activity.

However, recent experimental findings revealed that glial cells are intimately involved in the active control of neuronal activity and synaptic neurotransmission.

In particular, it was shown that astrocytes respond to external stimuli with a transient increase of the intracellular calcium concentration or can exhibit self-sustained spontaneous activity.

Both evoked and spontaneous astrocytic calcium oscillations are accompanied by exocytosis of ATP and glutamate caged in astrocytes leading to the spread of intra-cellular calcium waves and paroxysmal depolarization shifts (PDS) in neighboring neurons.

We present a mathematical model of the interaction between astrocytes and neurons that is able to numerically reproduce the experimental results concerning the initiation of the calcium waves and PDS.

The timing of glutamate release from the astrocyte is studied by means of a combined modeling of a vesicle cycle and the dynamics of SNARE-proteins.

The neuronal slow inward currents (SICs), induced by the astrocytic glutamate and leading to PDS, are modeled via the activation of presynaptic glutamate receptors.

The dependence of the bidirectional communication between neurons and astrocytes on the concentration of glutamate transporters and diffusion of ATP in ECS is analyzed, as well.

Our numerical results are in line with experimental findings showing that astrocyte can induce synchronous PDSs in neighboring neurons, resulting in a transient synchronous spiking activity.

Key Words: astrocytes, neurons, synchronization, PDS, release of ATP

### **Non-Linear Dynamics in Switched-Mode Power Electronics Converters**

A.K.Singh & K.S. Sherpa  
AICTE, Gangtok, India  
[c\\_amit143@rediffmail.com](mailto:c_amit143@rediffmail.com)

It is now known that the behavior of a power electronic (PE) converter is sensitively dependent on the parameter choice. Hence, a complete knowledge about the domains of subharmonic behavior and chaos in the parameter space is very important for the practicing engineer who must choose the parameter values depending on the desirable output behavior. The present paper aims at bridging this gap.

In this paper, a study of the non-linear dynamics DC-DC converter (Buck) is carried out. Through simulations, the existence of period doubling bifurcations and chaos is demonstrated. Our goal is to gain sufficient understanding that converters could be designed with reliability and predictability in their performance, when operating under instability or even chaotically. Key Words: Buck converter; nonlinear dynamics; period-doubling

### **Strange Nonchaotic Limit Sets**

Th. Umeshkanta Singh, H. H. Jafri, and R. Ramaswamy  
School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India.  
[umeshkanta@gmail.com](mailto:umeshkanta@gmail.com)

We investigate the behaviour of chaotically forced nonlinear mapping and show that under specific conditions it is possible to obtain stable aperiodic dynamics. Subsequent to a blowout bifurcation, the response dynamics is nonchaotic and is confined to a limit set which is nonsmooth or strange. There is dependence of the dynamics on the initial conditions of the chaotic drive. The attracting limit set can be characterized through parameter sensitivity exponents, which in turn are related to the distributions of finite-time Lyapunov exponents. Generation of nonchaotic aperiodic dynamics is of potential importance in applications such as secure communications, and in understanding the dynamics of biological systems.

Keys Works: Blowout bifurcation, Generalized synchronization, Parameter sensitivity exponents, Finite-time Lyapunov exponents.

### **Chaotic Modeling and Simulation: General Overview and Illustrations**

Charilaos Skiadas<sup>1</sup> and Christos H. Skiadas<sup>2</sup>

<sup>1</sup>Hanover College, IN, USA

<sup>2</sup>Technical University of Crete, Chania, Greece

Chaotic modeling and simulation is developing in a new way that influences the world around us, and consequently also influences our ways of approaching, analysing and solving problems[1]. A systematic presentation and analysis of the chaotic tools is given in a way that it would be useful to model builders and scientists from various fields. The chaotic simulation is not only an illustrative tool but also it could be of particular importance for the selection of the best model for a specific situation.

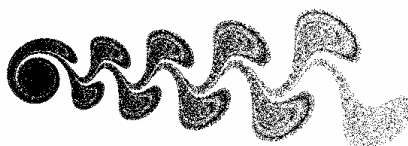
[1] C.H. Skiadas and C. Skiadas, Chaotic Modeling and Simulation. Analysis of Chaotic Models, Attractors and Forms, Taylor & Francis / CRC Press, Boca Raton, FL, USA, 2008.

## **A Simulation of Von Karman Vortex Streets by using the Reflection-Translation Theory**

Christos H. Skiadas  
Technical University of Crete

The famous Von Karman chaotic phenomena are presented in several formations, especially in the sea and are illustrated by photographs taken from space (satellite views).

The Von Karman phenomenon appears when in a fluid flow past an obstacle in the form of a cylinder or an island in the ocean. In the later case the fluid flow lines or trajectories pass from both sides of the island. To simplify the modeling we observe that a mirror image of the flow appears in both sides of the island or a reflection like process appears. A translation parameter is added to keep the direction of the flow. In modeling the process the direction of flow is parallel to the x axis. The phenomenon is modeled by using a reflection-translation set of equations[1].



A simulation of the vortex streets with space expansion ( $b=1.1$ )

[1] C. H. Skiadas, Topics on Chaotic Systems - Selected Papers from Chaos 2008 International Conference, World Scientific, 2009.

[2] C.H. Skiadas and C. Skiadas, Chaotic Modeling and Simulation. Analysis of Chaotic Models, Attractors and Forms, Taylor & Francis / CRC Press, Boca Raton, FL, USA, 2008.

## **Electron Quantum Transport Through a Mesoscopic Device: Dephasing and Absorption Induced by Interaction with a Complicated Background**

Valentin V. Sokolov  
Budker Institute of Nuclear Physics, Novosibirsk, Russia  
V.V.Sokolov@inp.nsk.su

Effect of a complicated many-body environment is analyzed on the chaotic motion of a quantum particle in a mesoscopic ballistic structure. The absorption and dephasing phenomena are treated on the same footing in the framework of a schematic microscopic model. The single-particle doorway resonance states excited in the structure via an external channel are damped not only because of the escape onto such channels but also due to ulterior population of the long-lived background states. The transmission through the structure is presented as an incoherent sum of the flow formed by the interfering damped doorway resonances and the retarded flow of the particles re-emitted by the environment.

Keywords: Quantum Transport, Chaos, Dephasing, Absorption.



### **The Irreversibly Mechanics of the Structured Particles Systems**

Vyacheslav. M. Somsikov  
Institute of ionosphere, Alma-Ata, Kazakhstan  
[vmsoms@rambler.ru](mailto:vmsoms@rambler.ru)

The mechanics of the structured particles develops. The substantiation of applicability of such mechanics for the description of processes of evolution in open nonequilibrium systems is offered. The mechanism of irreversibility is explained. The consequences following from the equations of dynamics of structured particles are analyzed.

Keywords: Dynamics, nonequilibrium, irreversibility, Hamilton formalism, classical mechanics, entropy.

### **Order in the Weather Chaos**

Dmitry M. Sonechkin  
P.P. Shirshov Oceanology Institute of Russian Academy of Sciences, Moscow, Russia  
[dsonech@mecom.ru](mailto:dsonech@mecom.ru)

The predictability limit position is a function of the forecasting model being used but not the chaoticity of the real atmospheric motions only. Two possible ways exist to overcome the present-day predictability limit: to complicate forecasting models more and more (the “brute force” approach); and to make using different mutual orderings in the heterogeneous atmospheric motion variations in order to filter out unpredictable components from forecasting model solutions (the “new knowledge” approach). Two new kinds of such ordering are considered in this paper that can be used in the frame of the “new knowledge” approach. One of them consists of a synchronous propagation of the planetary waves in the extratropical westerlies. The so-called quasi-synchronous model of the low-frequency atmospheric dynamics is depicted taking this ordering in explicit consideration. Even if this model is a toy-model in fact it is capable to overcome the weekly predictability limit inherent to all of the contemporary comprehensive forecasting models. The second kind of the ordering consists of the existence of essential super harmonics in the annual course of the planetary wave dynamics. The super harmonics of the synoptic waves are phase-looked, and amplitudes of some super harmonics are prominent by time-localised “rhythms”.

Keywords: The Lorenz’s chaoticity paradigm, the predictability limit, co-existence of chaos and order in weather variations, filtered weather forecasting models.

### **On the bifurcations inducing the 40-to-100 kyr transition of the Pliocene/Pleistocene glacial cycles**

D.M. Sonechkin, N.N. Ivashchenko, N.V. Vakulenko  
P.P. Shirshov Oceanology Institute Russian Academy of Sciences, Moscow, Russia  
[dsonech@mecom.ru](mailto:dsonech@mecom.ru)

Using a specially designed wavelet-transform technique I demonstrate a nonlinear and bifurcational nature of the famous 40-to-100 kyr transition of the Pleistocene glacial cycles. It can be depicted as a result of combined actions of two factors. The first factor is a general climate system cooling during the whole Pliocene/Pleistocene time period essentially accelerated after the Panama seaway closure about 4000 kyr BP. The second factor is the quasiperiodic oscillations of insolation at the Milankovitch orbital frequencies. The response of the climate system to the 41-kyr-periodic insolation forcing was stable during the warm Pliocene times, and so the climate variations consisted of a ~40-kyr limit cycle. As a result of the climate system cooling this limit cycle lost its stability, and a new climatic limit cycle of the doubled period and larger amplitude has been excited about 1250-1500 kyr BP because of a resonance of this new-born cycle with insolation forcing at the combinational tone of the eccentricity variations  $1/82=1/95-1/1307+1/413$ . Some more climate cooling implied the loss of stability this doubled cycle too, and instead, the next climatic limit cycle of the trebled period has been excited because of the another resonance with insolation forcing at the combinational tone of the eccentricity variations  $1/123=1/95-1/413$ .

Key Words: Paleoclimate, Milankovitch theory, insolation forcing, glacial cycles, bifurcations resonances

## Computing Fujita's Unite Subduced Cycle Index Table for the Non-rigid Group p-Xylene

M. R. Sorouhesh<sup>1</sup>, A. Moghani<sup>2</sup> and A. Zaeembashi<sup>3</sup>

<sup>1</sup> Department of Mathematics, Islamic Azad university, South branch Tehran, <sup>2</sup> Department of Color Physics, Institute for Colorants Paint and Coating (ICPC), <sup>3</sup> Department of Mathematics, Shahid Rajaei Teacher Training University, Tehran, Iran.  
sorouhesh@azad.ac.ir

Using non-rigid group theory, it was shown that the full non-rigid (f-NRG) group of p-Xylene is isomorphic to the group  $C_2 \times (C_3 \text{ wr } C_2)$  of order 36, where  $C_n$  is the cyclic group of order  $n$ , the symbols  $\times$  and  $\text{wr}$  stand for direct and wreath products, respectively (see MATCH Commun. Math. Comput. Chem. 56, 271, 2006). In this paper the Unite Subduced Cycle Index (USCI) table of the unmatured full non-rigid group p-Xylene is successfully computed for the first time.

Keywords: Full non-rigid group, Symmetry, USCI, p-Xylene.

## Composing Chaotic Music from a Varying Second Order Recurrence Equation

Anastasios D. Sotiropoulos and Vaggelis D. Sotiropoulos

School of Music, Composition-Theory Division

University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, USA

E-mail: asotiro2@illinois.edu, sotirop1@illinois.edu

Music is composed algorithmically from a varying second order recurrence equation which defines sound frequency,  $x$ , at each step  $n$  knowing sound frequency and amplitude,  $y$ , of the previous step,  $n-1$ , as:  $x_n = 1 - ax_{n-1}^2 + y_{n-1}$  with  $a$  being an arbitrary parameter to be chosen by the composer. The second order effect comes from the dependence of the sound amplitude at each step on the sound frequency of the previous step according to:  $y_n = b(x_{n-1})^\lambda$  with  $b$  being an arbitrary parameter and  $\lambda$  any real number greater than or equal to zero. If we choose the amplitude to be the same for every sound,  $\lambda = 0$ , and the recurrence equation reduces after a change of variables to the classical logistic map of well known bifurcation and chaotic characteristics. Furthermore, if the amplitude depends linearly on the frequency of the previous step,  $\lambda = 1$ , and the recurrence equation becomes the Hénon map also of known bifurcation and chaotic behavior. For each of these cases music has been composed by previous investigations in the literature. In the present study, however, the recurrence equation is not in general the same at each step but *varies* according to the value of  $\lambda$  which can change, through use of discrete form boxcar functions, either in consecutive steps or after a finite number of steps. So that even if  $\lambda$  is chosen either as zero or one, which in fact is done in a series of examples here, the resulting bifurcation diagrams depend on the number of steps after which  $\lambda$  changes. Other values of  $\lambda$  are chosen as well to examine their effect on the bifurcation diagrams and, for the purpose of the study, on the resulting music composition and its melody. Special attention is paid to each of the cases of square root and of square amplitude dependence on the previous frequency. The effect of the two frequencies chosen as the composition's starting two notes is also examined. Last, the frequencies obtained from the algorithm based on the recurrence equation are converted to MIDI (Musical Instrument Digital Interface) note numbers ranging from 0 to 127 identifying the actual notes of the complete composition. The resulting scores are played for the audience.

## Music Composition from the Cosine Law of a Frequency-Amplitude Triangle

Vaggelis D. Sotiropoulos and Anastasios D. Sotiropoulos

School of Music, Composition-Theory Division

University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, USA

E-mail: sotirop1@illinois.edu, asotiro2@illinois.edu

We propose a frequency-amplitude triangle whose cosine law is used as a recurrence equation to algorithmically compose music. The triangle is defined by two sides and the angle between them; one of the sides is the sound frequency,  $x$ , at a step, the other side is the sound amplitude,  $y$ , at the same step, while the angle between them is a free parameter to be chosen by the composer. The resulting third side of the triangle is defined as the square root of the sound frequency,  $x$ , of the next step. This frequency, using the cosine law, is given in terms of the frequency and amplitude of the preceding step as:  $x_{n+1} = x_n^2 + y_n^2 - 2x_n y_n \cos\theta$ . The sound amplitude,  $y$ , at each step depends, in general, on the amplitude and frequency of the same or previous step(s) in any way the composer chooses, that is, in any functional manner. We remark that if the amplitude is equal to the frequency of the preceding step and it coincides on the triangle with the frequency direction, the resulting composition consists of frequencies defined by the Fibonacci numbers. As a starting point and to test

our proposition for bifurcation and chaos against known solutions, we consider the case where the amplitude depends only on the frequency of the same or some previous step as  $y_n = b(x_{n-m})^\lambda$ , with  $b$  being a free parameter,  $m$  either zero or a positive integer, and  $\lambda$  a real number greater than or equal to zero. If  $\lambda$  is taken as zero, the resulting equation after a change of variables becomes the one parameter logistic recurrence equation with known solutions and bifurcation diagram. From the known range of the parameter where many bifurcation points exist, we obtain the range of the sound amplitude for which real angles,  $\theta$ , yield chaotic music; the sound amplitude for which the proposed frequency-amplitude triangle in fact gives chaos. Other values of  $(\lambda, m)$  are also chosen, among which are the values  $(1, 1)$  and  $(1, 2)$ , to make bifurcation diagrams and complete compositions based on the proposed cosine law of the frequency-amplitude triangle. The resulting musical scores are played for the audience of the *Chaos 2009* international conference.

### **Chaos in a Fractional-Order Jerk Model using Tanh Nonlinearity**

Banlue Srisuchinwong

Sirindhorn International Institute of Technology, Thammasat University, Pathum-Thani, Thailand

[banlue@siit.tu.ac.th](mailto:banlue@siit.tu.ac.th)

Chaos in a fractional-order jerk model using hyperbolic tangent nonlinearity is presented. A fractional integrator in the model is approximated by linear transfer function approximation in the frequency domain. Resulting chaotic attractors are demonstrated with the system orders as low as 2.1.

Keywords: Chaos, Fractional order, Jerk model, Hyperbolic tangent nonlinearity.

### **Deterministic Chaos Parameters of Human Brain Bioelectrical Activity (norma and Pathology)**

Irene Starchenko, Vitaliy Omelchenko, Denis Dushenin

TIT SFU, Taganrog, Russia

[star@tsure.ru](mailto:star@tsure.ru)

Last years application of nonlinear dynamics methods for processing and recognition of medical signals on the output of difficult systems is considered as a perspective way of creation of new diagnostic aids and forecasting of a condition of biological objects.

Application of methods of deterministic chaos theory for EEG analysis is caused by that a brain as dynamical system is sensitive to the initial conditions, therefore separate trajectories of this system cannot serve for identification of a condition of system and restoration of its parameters (EEG analysis). Therefore it is necessary to be able to allocate dynamic invariants of the system. The most representative invariant is correlation dimension of EEG trajectory.

The major information characteristics are considered the following: attractor's forms, correlation dimension (and sizes functionally connected with it); the form of EEG power spectrum envelope; the form of spatial distribution of accumulated information for the left and right brain hemispheres; phases of EEG own fluctuations etc.

Key Words: EEG, correlation dimension, surrogate data, attractor

## Using tools from nonlinear dynamics to model and analyze the heart rate kinetics in response to exercise

James Robert Stirling (a), Maria Zakyntinaki (b,a), Ignacio Refoyo (a), Javier Sampedro (a)  
(a) Facultad de Ciencias de la Actividad Física y del Deporte, INEF, Universidad Politécnica de Madrid, (b)  
Instituto de Ciencias Matemáticas, CSIC-UAM-UC3M-UCM, Madrid, Spain

We present a model [2], in the form of a set of coupled nonlinear ordinary differential equations, for the basic response pattern [5] of the heart rate kinetics in response to exercise. Our heart rate model is an adaptation of the model of oxygen uptake kinetics of Stirling et al. [4,7]. Using the ALOPEX algorithm [1,6] we fit the model to a set of raw un averaged data for multiple constant intensity exercises for an individual at a particular level of fitness. We then analyze the geometry of the phase space of our model and perform a linear stability analysis of the fixed point solutions to obtain the bifurcations. We present how the point of maximum curvature can be used as a marker [3]. We finish by explaining how chaos is an important phenomenon when one wants to understand the classical problems regarding the predictive power of the physiological tests commonly used in medicine and sport to understand the response to exercise.

[1] M.S. Zakyntinaki and J.R. Stirling, "Stochastic optimization for the calculation of the time dependency of the physiological demand during exercise and recovery". *Computer Physics Communications*, 179(12), 888-894, 2008.

[2] J. R. Stirling, M. Zakyntinaki, I. Refoyo and J. Sampedro, "A model of heart rate kinetics in response to exercise". *Journal of Nonlinear Mathematical Physics*, 15, Supplement 3, 426-436, 2008.

[3] J.R. Stirling and M.S. Zakyntinaki, "The point of maximum curvature as a marker for physiological time series". *Journal of Nonlinear Mathematical Physics*, 15, Supplement 3, 396-406, 2008.

[4] J.R. Stirling, M.S. Zakyntinaki and V.L. Billat, "Modeling and Analysis of the Effect of Training on  $\dot{V}O_2$  Kinetics and Anaerobic Capacity". *Bulletin of Mathematical Biology*, 70(5), 1348-70, 2008.

[5] M.S. Zakyntinaki, J.R. Stirling, M. Sillero, J. Sampedro and I. Refoyo, "Obtaining the basic response pattern of physiological time series data: a comparison of methods". *Materials Mathematics* 2007.

[6] M.S. Zakyntinaki and J.R. Stirling, "Stochastic optimization for modelling physiological time series: application to the heart rate response to exercise". *Computer Physics Communications*, 176(2), 98-108, 2007.

[7] J.R. Stirling, M.S. Zakyntinaki and B. Saltin, "A model of oxygen uptake kinetics in response to exercise: Including a means of calculating oxygen demand/deficit/debt". *Bulletin of Mathematical Biology*, 67(5), 989-1015, 2005.

## The Fokker-Planck equation for an isolated N- particle system

Nadia-Mirela Stoian  
Transilvania University of Brasov, Romania  
[Nadia\\_Stoian@yahoo.com](mailto:Nadia_Stoian@yahoo.com)

It is known that the Fokker-Planck equation with constant coefficients of diffusion and linear friction describes the ensemble of the stochastic evolutions in velocity space of a Brownian test particle immersed in a heat bath of fixed temperature.

The same partial differential equation, but now with constant coefficients which are functionals of the solution describes the kinetic evolution of an isolated N-particle system with certain stochastic interactions.

Key Words: Fokker-Planck equation, diffusion equation on a high-dimensional sphere, kinetic theory, Kac program, propagation chaos.

### **Characterization of multifractal patterns in rock discontinuities.**

Ioannis L. Stratakos, Michael G. Sakellariou

National Technical University of Athens, School of Rural & Surveying Engineering, Division of Infrastructures & Rural Development. Athens, Greece

In this paper we describe an integrated methodology for the study and characterization of multifractal patterns in rock discontinuities. Rock mass discontinuities are generated through chaotic related processes and present geometric properties inherent of the underlying processes, such as repeatability and structural complexity. In the case of rough rock surfaces, complexity is studied in terms of fractal magnitudes, namely Fractal Dimension and Proportionality Constant. The variance of chaotic processes that affect a single surface may produce a multifractal pattern that need to be studied in order to gain knowledge about the mechanical and hydraulic behavior of the surface. In the recent years an extensive study has been carried out mainly using samples of small size and laboratory devices. Due to lack of suitable digitization devices, the research has not been extended in discontinuities of larger sizes. This paper describes the complete methodology developed for the recording, modeling, studying and the representation of multifractal patterns obtained from large size rock joint samples (in the order of 80m<sup>2</sup>).

The applied methodology is consisted of the digitization of large scale surfaces using a high performance geodetic laser scanner and the implementation of some known fractal techniques. The usage of the specific scanner gives the opportunity to scan a large area densely and accurately and thus model the geometric patterns that emerge or change over scale. Firstly, the acquired data were pre-processed so that the datum was corrected and several non-fractal components, such as adjacent vegetation and discrete rock parts, were removed from the digitization. The modeling of the discontinuities was performed using special developed software, throughout which the estimation of the Fractal Dimension and the Proportionality Constant is performed. The Fractal method used for this was the Semivariogram, adapted for usage with 3-dimension data.

The main analysis of multifractal properties was performed in two ways. In the first approach, using a regression algorithm, the correlation length at which the fractal magnitudes present a remarkable change is estimated. According to the second approach the fractal magnitudes are estimated over a shifting window of the sample surface. Fractal Dimension and Proportionality Constant changes are modeled with respect to location.

The valuation of the presented numerical results provides important conclusions regarding the multifractal character of rock joints. The existence of distinct multifractal characteristics was confirmed in all three surfaces. The developed methodology yielded the scale at which fractal pattern changes and thus multifractal components emerge. The estimation of the cross-over scale value consorted with visual observation of the surfaces.

The ability of describing patterns with disparate fractal characteristics inside the same surface is of great importance as it provides knowledge, not only of multifractal phenomena themselves, but of the chaotic processes responsible for their emerge too.

### **Hybrid projective synchronization of two-cell Quantum-CNN oscillators by adaptive method**

Sebastian Sudheer

Research scholar, Department of Physics, Cochin University, Cochin, India

[sudheersebastian@yahoo.com](mailto:sudheersebastian@yahoo.com)

Recently micro or nano chaotic oscillators have received great attention. A Quantum -CNN oscillator is a micro/nano oscillator which becomes chaotic for certain parameter values. In this work we investigate hybrid projective synchronization of two chaotic Quantum-CNN oscillators using adaptive control method. All the parameters of the system are assumed to be unknown. We design adaptive controllers and parameter update laws such that two pairs of states are synchronized upto a constant factor and other two pairs of states are anti-synchronized. Simulation results verify the effectiveness of the method. Key Words: Synchronization, Adaptive control, Hybrid, Projective

## The sea and ocean 3D acoustic waveguide: stochastic modeling and chaos phenomena

Andrey A. Svinarenko<sup>1,3</sup>, Alexander V. Glushkov<sup>1,2</sup>, Nikoly Serbov<sup>1</sup> and Tat'yana Lukash<sup>1</sup>  
<sup>1</sup>Odessa University, Odessa (Odessos), Ukraine, <sup>2</sup>Russian Academy of Sciences, Troitsk, Russia  
[quantsvi@mail.ru](mailto:quantsvi@mail.ru)

We have considered a physics of the sea and ocean 3D acoustic waveguide [1-3]. On the basis of Hamiltonian equations of rays it is studied a dynamics of rays. It has been shown that for acoustic waveguide in a shallow sea with non-level bottom under the rays propagation in a waveguide dependence of the of temporal frequency upon the output angle represents a fractal measure in accordance with Abdullaev-Zaslavsky result. For the ocean 3D acoustic waveguide on the basis of solving the eiconal equations in the Hamiltonian form it has been studied the fractal dynamics, including the chaotic one. There are presented the data of numerical solution of equations for the typical acoustic channel in the North-Atlantic region. The conditions for the Arnold diffusion effect realization are discussed.

### References:

- [1]. S. Abdullaev S., Zaslavsky G.M., *Acoust.Journ.* 34:578-586, 1981.
- [2]. D.C. Palmer et al, *Geophys.Res.Lett.* 15:569-574, 1988.
- [3]. A.Glushkov, V.Khokhlov, N.Loboda, etal, *Stoch Environ.Res Risk Assess.* (Springer) 22:777-788,2008; V.D. Rusov, A.V. Glushkov, A.A. Svinarenko et al, *Advances in Space Research.* 42:1614-1617 (2008).

## Symmetric and Asymmetric Chaos in Vector-Field Lasers

Larissa Svirina

Belarussian National Technical University, Minsk, Belarus

[lsvirina57@yandex.ru](mailto:lsvirina57@yandex.ru)

On the basis of the experimentally confirmed models the routes to symmetric and asymmetric chaos have been elucidated in four-frequency anisotropic cavity ring gas class-A lasers. The invariance properties of the model of a four-frequency ring class-A laser with the linear coupling due to backscattering [1] have been revealed. The diagrams of attractors have been calculated on the plane of the amplitude of the backscattering coefficient and detuning of the cavity frequency from the line center.

The regimes, typical of both standing-wave and running-wave lasers, have been found. It has been shown that the transition from the running-wave operation to the standing-wave operation is accompanied by the pitchfork bifurcation and spontaneous phase symmetry-breaking (restoration). The pitchfork bifurcation of periodic solution, as a result of which the symmetric limit cycle is decomposed into two asymmetric limit cycles, can be accompanied by a deterministic and a noise-induced chaos [2].

With increasing tuning at constant value of the backscattering, chaotic oscillations appear as a result of the period doubling bifurcation cascade of the asymmetric limit cycle. Then after a series of inverse period doubling bifurcations two asymmetric cycles collide and disappear and the symmetric cycle originates as a result of the pitchfork bifurcation for periodic solution (symmetry is restored). When the control parameter changes in the opposite direction, the symmetric cycle is breaking into two asymmetric cycles.

In the region of the deterministic chaos, multistability of attractors with different topology has been revealed, among which are: symmetric limit cycle, two asymmetric Feigenbaum attractors and two asymmetric attractors arising when their trajectories in the phase space come through basins of both Feigenbaum attractors.

At small values of the backscattering coefficient noise-sensitive operation has been found. First, an asymmetric limit cycle of the second kind appears. The specificity of this regime, making it sensitive to noise of any physical origin, is that the intensity of one of the four waves oscillates near the lasing threshold.

With increasing tuning, as a result of nonlinear interaction, the amplitude of noise-sensitive variable grows, which results in increasing the amplitude of noisy component in power spectrum. At that this variable is fully influenced by noise and such a regime can be regarded as stochastic.

With further increase in tuning, the amplitude of noise-sensitive variable grows even more, so that preserving the complicated form of oscillations, it losses the sensitivity to noise action. Nevertheless, the amplitude of oscillations of "noisy" variable becomes high enough to affect the behavior of the other variables and to complicate their oscillations. Because the system is not sensitive to noise any more, and has a fractal dimensionality, we can regard this regime as an asymmetric chaos. With further increase in tuning this regime, transforms into an asymmetric limit cycle. Then, the pitchfork bifurcation occurs, as a result of which two asymmetric limit cycles of the second kind collide and disappear and a symmetric limit cycle with

complicated form arises, which loses its stability and a symmetric chaos, arising through intermittency, is indicated.

Key Words: vector-field laser with linear coupling, multimode operation, involutive symmetry, routes to symmetric and asymmetric chaos, stochastic behavior, symmetry-breaking bifurcations

- 1.L.P. Svirina. Journal of Quantum & Semiclassical Optics, JEOS, part B, 10 (1998) 425.
2. L.P. Svirina. Sov. J. Quantum Electron, invited paper, 38 (2008) 1.

### **Application of HeB's parameter-expansion method to synchronization dynamics of coupled Van der PolB–Duffing oscillators**

N. H. Sweilam

Cairo University, Faculty of Science, Mathematics Department, Giza, Egypt

[n\\_sweilam@yahoo.com](mailto:n_sweilam@yahoo.com)

In this Paper we apply HeB's parameter-expansion method (PEM) to synchronization dynamics of coupled Van der PolB–Duffing oscillators. The method, taking full advantage of the perturbation method, does not depend upon small parameter assumption. One iteration step provides an approximate solution which is valid for the whole solution domain.

### **Assimilation of Observations in a Chaotic System**

Olivier Talagrand

Laboratoire de Météorologie Dynamique, École Normale Supérieure, Paris, France

[talagrand@lmd.ens.fr](mailto:talagrand@lmd.ens.fr)

Assimilation of meteorological observations, which originated from the need of defining initial conditions for numerical weather prediction, is the process by which observations are combined together with a numerical model of the flow in order to obtain as accurate as possible a description of the state of the atmosphere.

Assimilation can be considered as a problem in Bayesian estimation. Evaluate the probability distribution for the state of the atmosphere, conditioned to all available relevant information. That information essentially consists of the observations and of the numerical model of the flow.

Standard methods for assimilation are pragmatic extensions to weakly nonlinear situations of methods that are basically linear and Gaussian. These standard methods consist of two broad classes. In variational assimilation, the assimilating model is globally adjusted to the observations available over a period of time. In sequential assimilation, the most advanced form of which is at present Ensemble Kalman Filter (EnKF), the state predicted by the model is constantly updated with new observations.

Taking into account the full nonlinear and chaotic character of the atmospheric flow raises substantial difficulties. Ensemble methods, in which the required conditional probability distribution is described by a sample of points in state space (and of which EnKF is one form), seem the most promising. Particle filters, which were originally developed for totally different applications, are capable of achieving Bayesian estimation for a nonlinear chaotic system. Their cost seems however to be prohibitive for large dimension applications such as meteorology. The perspectives for further development of assimilation of meteorological observations are discussed.

Keywords: Assimilation of observations, chaos

**Direct Adaptive Control in Unknown Nonlinear Systems that exhibit Brunovski Canonical Form, using Neuro-Fuzzy High Order Neural Networks, with Robustness Analysis**

Dimitris C. Theodoridis\*\*, Yiannis A. Boutalis\*\*, Manolis A. Christodoulou\*

\*\*Department of Electrical and Computer Engineering, Democritus University of Thrace Xanthi, \*Department of Electronic and Computer Engineering, Technical University of Crete, Chania, Crete, GREECE  
dtheodo@ee.duth.gr, ybout@ee.duth.gr, manolis@ece.tuc.gr

The direct adaptive regulation of nonlinear dynamical systems in Brunovsky form with modeling error effects, is considered in this paper. The method is based on a new Neuro-Fuzzy Dynamical System definition, which uses the concept of Fuzzy Adaptive Systems (FAS) operating in conjunction with High Order Neural Network Functions (HONNFs). Since the plant is considered unknown, we first propose its approximation by a special form of a Brunovsky type fuzzy dynamical system (FDS) assuming also the existence of disturbance expressed as modeling error terms depending on both input and system states. The fuzzy rules are then approximated by appropriate HONNFs. This practically transforms the original unknown system into a neuro-fuzzy model which is of known structure, but contains a number of unknown constant value parameters. The development is combined with a sensitivity analysis of the closed loop in the presence of modeling imperfections and provides a comprehensive and rigorous analysis of the stability properties of the closed loop system. The proposed scheme does not require a-priori information from the expert on the number and type of input variable membership functions making it less vulnerable to initial design assumptions. The existence and boundness of the control signal is always assured by introducing a novel method of parameter hopping and incorporating it in weight updating law. Simulations illustrate the potency of the method and its applicability is tested on the well known benchmarks "Inverted Pendulum" and "Van der pol", where it is shown that our approach is superior to the case of simple Recurrent High Order Neural Networks (RHONNs).

**To a question on self-organizing literary genres: chaos, structure, system, model in the literature, author's innovative genres**

Palina P. Tkachova

Belarusian State University, Belarus  
polynom@newman.bas-net.by

Self-organizing was that bridge which has allowed to connect together various under the laws and development of system of the alive and inanimate nature. However, having made a step from the inanimate nature to a human, scientists have considered only biological systems, not having finished process of generalization and connection together all processes. For the staff there was one of the basic processes of human creativity – art, created by the person, culture – that layer where, in our opinion, self-organizing is present, also as well as in complex systems (physical, chemical, biological etc.).

Keywords: self-organizing literary genres, system, chaos, innovative genres.

**Dynamical Reaction Theory and Time Series Analysis**

Mikito Toda

Physics Department, Nara Women's University, Nara, Japan  
toda@ki-rin.phys.nara-wu.ac.jp

We provide an overview of the recent progress of the dynamical theory of reactions. After summarizing the conventional statistical reaction theory, we explain the basic concepts underlying the dynamical theory, i.e., normally hyperbolic invariant manifolds (NHIMs) and the Arnold web. Then, we go on to discuss the dynamical theory using these concepts. Here, we discuss the following three processes: (i) redistribution of energy among vibrational modes in the well, (ii) going over the potential saddle, and (iii) dynamical connection among multiple saddles.

In particular, we focus our attention to those processes where limitations of the conventional statistical theory become manifest. We will also discuss time series analysis to extract dynamical information from molecular dynamics simulations involving multi-dimensional Hamiltonian systems.

Keywords: Phase Space Structures, Reaction Theory, Time Series Analysis.



### **Modelling Complex Multicellular Tumour–Immune Systems**

Francisco Torrens and Gloria Castellano

Universitat de València and Universidad Católica de Valencia San Vicente Mártir, València, Spain

[francisco.torrens@uv.es](mailto:francisco.torrens@uv.es); [Francisco.Torrens@uv.es](mailto:Francisco.Torrens@uv.es)

The report develops a variety of mathematical tools to model the dynamics of large systems of interacting cells. Interactions are ruled not only by laws of classical mechanics but also by some biological functions. The mathematical approach is the one of kinetic theory and non-equilibrium statistical mechanics.

Keywords: Cancer modelling, Multiscale modelling, Complexity in biology, Living system, Kinetic theory, Multicellular system, Asymptotic limit.

### **EPAD Chaotic Oscillator**

Odysseus Tsakiridis<sup>1</sup>, Evangelos Zervas<sup>2</sup>, Vasilis Stefanidis<sup>3</sup>  
<sup>1,2,3</sup> Technological Educational Institute of Athens, Athens, Greece  
[odysseas@ee.teiath.gr](mailto:odysseas@ee.teiath.gr)

This paper outlines the basic theory and the design and implementation of a low voltage Colpitts chaotic oscillator based on an Electrically Programmable Analog Device matched Pair Mosfet Array (EPAD). The Oscillator is capable of producing chaotic carriers in very low supply voltages, which is a feature very useful in mobile and low power consumption utilities.

Keywords: Chaos, Colpitts Oscillator, Low Voltage, EPAD.

### **Routh-Hurwitz Conditions and Lyapunov Second Method for a Nonlinear System**

Omur Umut

Abant Izzet Baysal University, Turkey

[umuto@ibu.edu.tr](mailto:umuto@ibu.edu.tr)

In this paper, a Lyapunov function is generated to determine the domain of asymptotic stability of a system of three first order nonlinear ordinary differential equations describing the behaviour of a nuclear spin generator (NSG).

The generated Lyapunov function, is a simple quadratic form, whose coefficients are chosen so that the Routh-Hurwitz criteria are satisfied for the corresponding linear differential equations.

Keywords: Routh-Hurwitz conditions, Lyapunov method, Lyapunov function, nuclear spin generator, domain of stability, Cartwright's method.

## **Dynamical Processes Chaos Relativity to Environment Implement Scope - DYVELOP**

JIRI F. URBANEK, JAROSLAV PRUCHA  
University of Defence, CZECH REPUBLIC  
jiri.urbaneck@unob.cz

The requirements of chaos relativity comprehensibility are bringing new approaches for end-users as dominant clients of communication - cyber-informatics's service providers. Chaos comprehensibility is related to definition/ discrimination/ resolution/ reception/ sensation/ setting/ background/ empathy levels (aspects) – i.e. to the environments & theirs zoom in practice. Suitable 'language' for analysis, modelling, simulation and evaluation apparatus and methodology must bring fundamental solutions of this problem; namely if the end-user is crisis situations manager operating in threats life cycles. Here up-graded apparatus UML, (UP)/DYVELOP is proposed and tested. The specialists from diverse branches and in various environments can easy manage these apparatus and methodology without sophisticated preliminary disposition. They are available to model dynamical temporal extraordinary events on mass serving computers even. Here are introduced three kinds of initially chaotic → consequently comprehensive use cases – 1/ the Mastering of <<DYVELOP®>>, 2/ emergency applicable - Baseline CAMouflage Architecture for ADAPTIV project and 3/ the Family in a Crisis. Static system's / dynamic process relationships and logistic flows will be displayed by means of original 'blazons' - maps of roles. They show big potential of this apparatus for among-branches using in various environments. Dynamic blazons are the best to show in live on-line PowerPoint presentation, which will be dramatized at conference finally.

Key-Words: Chaotic Events Modelling; Requirements/Concurrent Engineering; Blazon; UML; DYVELOP; Application Development Life Cycle

## **Nonlinear Targeted Energy Transfer in Dynamical Systems**

Alexander F. Vakakis Lawrence A. Bergman D. Michael McFarland  
University of Illinois, Mechanical Science and Engineering, Urbana, USA  
avakakis@illinois.edu

We study nonlinear targeted energy transfer (TET) from linear discrete or continuous oscillators to lightweight essentially nonlinear attachments acting, in essence, as nonlinear energy sinks. We discuss the dynamics of TET, i.e., fundamental or subharmonic transient resonance captures, and study conditions for optimal TET by performing slow/fast partition of the strongly nonlinear dynamics. Applications to instability suppression, and to shock and vibration isolation are discussed.

Key Words: Essential nonlinearity, targeted energy transfer

## **Chaos and criticality in city traffic under resonant conditions**

J.A. Valdivia, J. Rogan, V. Munoz, B. Toledo, A. Varas, M.D. Cornejo, J. Villalobos, R. Zarama  
Departamento de Fisica, Facultad de Ciencias, Universidad de Chile, Las Palmeras, Santiago, Chile  
alejo@macul.ciencias.uchile.cl

We explore in detail the traffic model proposed in Toledo et. al. (Phys. Rev. E 70 016107, 2004) in which a single car travels through a sequence of traffic lights. The chaotic behavior shown for a given bound in the acceleration/braking ratio is examined more carefully, and the region in parameter space for which we observe chaotic behavior is found. The complex behavior that occurs when traffic lights are synchronized is studied. Two strategies are considered: all lights in phase, and a "green wave" with a propagating green signal. It is found that traffic variables such as traveling time, velocity, and fuel consumption, near resonance, follow critical scaling laws. For the green wave, it is shown that time and velocity scaling laws hold even for random separation between traffic lights.

The system is also modeled with cellular automata, where an analogous resonant behavior is found for the two strategies mentioned above. The resilient of the critical behavior is analyzed as we introduce perturbations. These results suggest the concept of transient resonances, which can be induced by adaptively changing the phase of traffic lights. This may be important to consider when designing strategies for traffic control in cities, where short trajectories, and thus transient solutions, are likely to be relevant.

Key Words: city traffic

**Prediction of irradiation doses for population under implementation of Russian Federal Program:  
“Development of Russian atomic energy industrial complex (ARFP) on 2007-2020 years”.**

<sup>1</sup>Valyaev A.N., <sup>1</sup>Krylov A. L., <sup>1</sup>Semenov V.N., <sup>2</sup>Dolgenkov I.V., <sup>2</sup>Dolgikh A.P.

<sup>1</sup>Nuclear Safety Institute, Russian Academy of Sciences, Moscow, Russia, <sup>2</sup>Concern “Rosenergoatom”

Today in the whole world the intense growth of electric energy at nuclear power plants (NPP) is observed. According to IAEA prediction to 2030 year its generation will be about 700 Gig watt. NPP production results to generation of radionuclide's gas-aerosol atmospheric discharges (RGAD) and liquid radioactive discharges (LRD) into NPP surface heat sinks with the additional pollution of environment. It is necessary to provide the exclusive safety measures, in particularly provide the levels of irradiation doses for population (PID) will be not exceeded the 10 Micro Sievert. 17 new atomic power units on the base of will be put in exploration at 7 homeland now operated NPP. Motivation this work is the PID and risk assessments. We have collected and analyzed RGAD and LRD for all 10 Russian NPP during 1995 -2007. The observed stable annual tendency of RGAD and LRD decreasing has created the well ground scientific base for prediction of their levels of each NPP according to our own special developed methodology. Then these levels will be used for PID calculations on the special certified model “Kassandra” and “Nostradamus” information-simulation systems, developed in our Nuclear Safety Institute for assessment of irradiation dose of human organism through all possible ways and chains: water, breath, food (meat, milk, fish, vegetables, fruits) and others under the response of the following varied natural climate temporal space random factors: wind, its velocity and directions, snow, rains, temperature and humanity, really registered at each NPP region. For most critical population group “fishers” we used such assumptions and predictions that PID obtained assessments were the maximum (conservative) ones. The stochastic compartmental “Kassandra” [1] is successfully used for radionuclide's transport and assessment of their concentrations in water, bottom sediments and flood plains of rivers and heat sinks, connected with real NPP. System of the special diffusion equations describing the transfer have been resolved for concrete conditions. Simulation of radionuclide's migration was used with taking into account of mass their exchange between main stream and underflow for river contamination model under the persistent radioactive discharges during long time. The integral computer NOSTRADAMUS system was developed for the effective forecasts of radioactive situation with atmospheric radionuclide's emission and it is based on 3-D Lagrangian trajectory stochastic (Monte-Carlo) model [2]. The impurity plume (or cloud) is presented as large amount of test particles. Every particle moves according to wind velocity and undergoes to random displacement that simulates turbulent scattering. A certain activity is assigned to every particle so that total activity of all particles is equal to activity released from the source. Impurity volume concentration is associated with particles concentration (number of particles in certain control volume divided by this volume). Results of PID assessment is presented in Table 1.

**Table 1. Predicted of irradiation doses for population in zone of Russian reconstructed NPP observation**

Nuclear power plant (NPP)	Effective dose of irradiation for water consumption, Micro Sievert	Effective dose of irradiation for water consumption, Micro Sievert	Effective dose for all possible ways of irradiation, Micro Sievert
Kursk NPP	6,69	0.19	6.86
Kola NPP	7,8	0.014	7.814
Kalinin NPP	3,4	0.012	3.412
Volgodonsk NPP	3,99	0.0026	3.9926
Leningrad NPP	0,62	0.24	0.86
Novovoronezh NPP	0,828	0.023	0.851
Smolensk NPP	5,14	0.1	5.24

These PID values provide the permitted risk level less than  $10^{-6}$  in year. Our proposed method and methodology have the universal character and may be used for decision of some thematic problem of atomic energy.

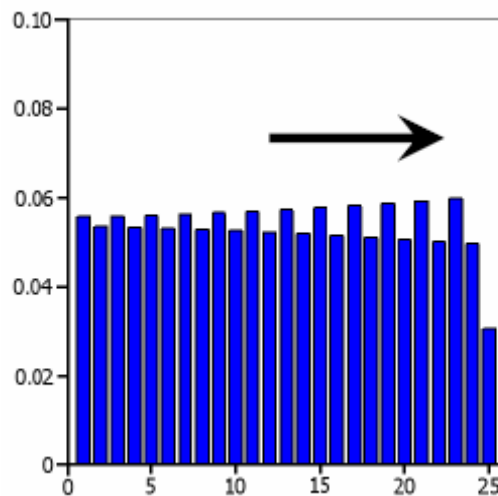
1.A. Krylov et. al. “Importance of the process of mass-exchange between main stream of a river and underflow for modelling of concentration of radioactive substances in river water and bed sediments.” in Proc. Fourth Intern. Conf. –River Basin Management, 21-23 May 2007, Kos Island, Greece, v. IV, pp. 493-504. WIT press.

2. R.V.Arutunjan, V.N.Semenov et.al. "Computer System "NOSTRADAMUS" for Decision-Making Support at Emergency Discharges at Radiation Hazardous Objects." Applied Energy: Russian Journal of Fuel, Power and Heat Systems, 1995, V.33, N4, pp.14-21.

### Critical Flow and Chaotic Pattern Formation in Granular Transport

Ko van der Weele, Giorgos Kanellopoulos, and Christos Tsiavos  
 Center for Research and Applications of Nonlinear Systems,  
 Department of Mathematics, University of Patras, Patras, Greece  
 weele@math.upatras.gr

One of the major problems with the transport of grainy materials in industrial machinery is the spontaneous formation of dense particle clusters (due to the inelasticity of the particle collisions [1]); whenever this happens, the flow is obstructed and the whole production line must be halted. We study the flow of granular material on a transport device consisting of a 1D or 2D grid of vertically vibrated compartments. A steady inflow  $Q$  is applied to the top of the grid and we describe the conditions that ensure a continuous flow all the way down to the last compartments, i.e., an outflow that equals the inflow  $Q$ .



Wavy density profile on a conveyor belt consisting of 25 compartments, at an inflow rate  $Q$  just below the critical value  $Q_{cr}$  at which clustering sets in. The arrow indicates the direction of the flow.

Given the vibration strength and the dimensions of the grid, we determine the maximum flow rate  $Q_{cr}$  beyond which cluster formation becomes inevitable. It is shown that the clusters are announced in advance (below the critical value  $Q_{cr}$ ) by the appearance of an oscillatory pattern in the density profile along the conveyor belt: The array of compartments - uniformly filled at smaller values of  $Q$  - is turned into an alteration of dense and dilute ones. This provides a new and potentially very valuable warning signal for practical applications. The critical flow and the associated wavy density profile are explained quantitatively in terms of a dynamical flux model [2, 3]. The appearance of the wavy pattern turns out to be connected to a reverse period doubling bifurcation of the previously uniform density profile.

In 1D, the formation of one cluster automatically implies the vanishing of the outflow. In 2D, however, the material can stream around the clusters and many of them are required to completely stop the outflow. The positioning of these clusters over the grid is a prime example of spontaneous pattern formation [4] and sensitively dependent on small random density fluctuations of the type encountered in experiments.

[1] I. Goldhirsch and G. Zanetti, *Clustering instability in dissipative systems*, Phys. Rev. Lett. **70**, 1619 (1993).

[2] J. Eggers, *Sand as Maxwell's demon*, Phys. Rev. Lett. **83**, 5322 (1999).

[3] K. van derWeele, D. van der Meer, M. Versluis, and D. Lohse, *Hysteretic clustering in granular gas*, Europhys. Lett. **53**, 328 (2001).

[4] M.C. Cross and P.C. Hohenberg, *Pattern formation outside of equilibrium*, Rev. Mod. Phys. **65**, 851 (1993).

**Ordered Dislocations in Solid after Radiation**

Vanina E.A., Astapova E.S., Veselova E.M.  
Amur State University, Blagoveshchensk, Russia  
[evanina@yandex.ru](mailto:evanina@yandex.ru)

After neutron irradiation in ceramic materials there are processes of self-organization of point defects and formation of interstitial and vacancy dislocation loops. The dislocation-deformation instabilities developed with formation of dislocation periodic structures or periodic lattices of aggregate point defects. The simulation of ordered dislocations was considered and developed in this work. The period of dislocation density lattice was estimated.

**Economic, Social and Political Scenarios of Mexico in the Next Two Decades**

José G. Vargas-Hernández  
Sistema Nacional de Investigadores, Departamento de Mercadotecnia y Negocios Internacionales, Centro Universitario de Ciencias Económico Administrativas U de G.  
México  
[josevargas@cucea.udg.mx](mailto:josevargas@cucea.udg.mx), [jgvh0811@yahoo.com](mailto:jgvh0811@yahoo.com), [jvargas2006@gmail.com](mailto:jvargas2006@gmail.com)

This research proposal is aimed to analyze the economic, social and political foreseeable scenarios for México by the year 2030. Starting from the analyzes recent economic, social and political developments, it continuous searching the trends in specific economic issues such as international commerce, energy, employment, environmental constraints, etc.; social trends such as demographic transition, fertility, population growth, aging, migration, education, health, housing, human development, etc. and political trends such as democratization processes, social upheaval, human rights, etc. Finally, the research will conclude describing and discussing the scenarios at three levels: pessimistic, more realistic and optimistic. The key findings will be analyzed in more detail.

The methodology to be used are time series analysis for historical data, correlation analysis for data series of the different variables, the Delphi technique, panel of experts, interviews to some clue economic, social and political actors. Also for the analysis, will be used prospective techniques.

The final paper will identify the factors that will be most important in shaping the economic, social and political landscape of México in 2030 and beyond. It will examine how the Mexican society will cope with the broad range of challenges and will assess what conditions may be key to transforming economic, social and political trends into security and social welfare issues.

Key words: Economic scenarios, México, social scenarios, political scenarios  
JEL: 011, 016, 021.

## **Synergetics control of multilinked robotics systems (plenary report)**

Gennady E. Veselov

Technological Institute of Southern Federal University, Synergetics and Control Processes Department,  
Taganrog, Russia  
deanfibs@tsure.ru

We propose new approach to hierarchical systems synthesis for manipulating robots based on methods of synergetics control theory and synergetics approach to hierarchy control. The key concept is that we build the controls for high level control without solving inverse kinematic problem. And all levels control laws synthesis we obtain from full nonlinear models of manipulating robots subsystems motion. The synthesized set of controls provides asymptotic stability of closed loop system at all admissible field of phase coordinate variation.

### **Nonlinear Predictive Load Control of Boiler-Turbine-Generating Unit Based on Chaos Optimization**

Wang Shuang-xin Li Han Zhang Xiu-xia Wang Zhi-qin

School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University, Beijing China  
[shuangxinwang@263.net](mailto:shuangxinwang@263.net)

Large-scale boiler-turbine-generating is a nonlinear and complex system which usually uses coordinated control system. Thermal power unit is composed of boiler, steam turbine, generator, electric network and Load equipment. Boiler-turbine unit load control system is the core of the control system, whose main task is to achieve rapid response to the change of load demand while maintaining the main steam pressure in the permitted range. However, due to the strong coupling and nonlinear characteristics of the unit load control system, those conventional linear control systems cannot obtain satisfactory control performance<sup>[1]</sup>.

Predictive control is a new type of computer control approach which contains dynamic optimization, predictive model and feedback correction. It can solve the problems of uncertainties and restrictions effectively. The basic idea of this algorithm is to control plant after forecasting the future plant behavior. However, with regard to nonlinear system, it is difficult for the basic predictive control to achieve good results. So it is necessary to do some research on prediction and optimization based on nonlinear model<sup>[2]</sup>.

The main difficulties of predictive control are modeling and optimization for nonlinear system. To avoid these difficulties, one novel nonlinear predictive control approach is proposed based on chaos and neural network. A RBF neural network, which is obtained by off-line identification, is used for the prediction of future plant behavior. The receding horizon optimization problem is solved on-line by chaotic hybrid optimization algorithm which is based on Skew Tent map, thus to obtain the corresponding optimal control actions at each sampling instant.

As nonlinearity and uncertainty of the plant, it is difficult to establish precise mathematical model. RBF neural network has the capability of approximating to nonlinear function to predict system output. So it is an effective way to solve the problem of nonlinear system modeling with RBF network.

Keywords: Load Control; Nonlinear Predictive Control; NN Identification; Chaos Optimization.

### **On Fuzzy Modeling of Superheated Steam Temperature Using Chaos Genetic Algorithm**

Wang Zhi-qin Wang Shuang-xin Zhang Xiu-xia Li Han

School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University, Beijing China  
[shuangxinwang@263.net](mailto:shuangxinwang@263.net)

The boiler system is crucial parts of most power plants . It has been concerned with analyzing power system dynamics in various works. Superheated steam temperature is one of the main processes in the boiler because situated just before the turbine . In normal operating condition the superheated steam temperature of the boiler should be maintained within limits . If the temperature is too high , it will cause the damage of the superheater , the steam tube and the turbine ; if the temperature is too low , it will cause the efficiency decreasing and aggravate the erosion of turbine blade .

The drum-boiler is a highly nonlinear dynamic system. Many factors can affect superheater outlet temperature, such as steam flux, combustion condition, feed water temperature of boiler, steam enthalpy value of superheat inlet; flue gas temperature, flux, velocity of flow of traverse superheater etc[1] Traditional linear modeling technique is not suitable to the highly nonlinear plant of thermal engineering process.

Fuzzy modeling has been proven to be an effective way of building nonlinear-process, uncertain, and complex model. Takagi and Sugeno proposed T-S model in 1985[2] It approaches the dynamic system by dividing a non-linear model into a number of fuzzy linear models essentially. It describes a system by establishing relations between the relevant system variables [e.g., inputs and outputs] in the form of if-then rules, which can approach nonlinear function at a required precision. It is able to integrate experts knowledge and inputs-outputs, and the model developed has been given a linguistic interpretation, comparing to black box model.

Keywords: Fuzzy T-S Identification; Chaos Optimization; Genetic algorithm

[1] W. F. Lin, Y. Hu. Automatic control technology on unit. China Electric Power Press, 2008.

[2] T. Takagi, M. Sugeno. Fuzzy identification of systems and its applications to modeling and control, IEEE Trans. Systems Man Cybernetics, 1985, 15(1): 116-132.

### **Bioaccumulation of Metals in Fish Associated With Petroleum Pollution**

Oti Wilberforce J.O

Dept. of Industrial Chemistry Ebonyistate University, Ebonyi, Nigeria

[oti\\_wbf@yahoo.com](mailto:oti_wbf@yahoo.com)

Petroleum pollution was simulated by adding different concentrations of crude oil into four artificial ponds. The least concentration used was 1.25ml/L while the highest was 5.0ml/L. The fourth one serves as a control. Different metals were determined in five different fish species (mean weight= 180B± 0.5g) by atomic absorption technique. The results revealed that the metals Fe, Zn, Cd, Ni and V were found to range from 45.65-764.51, 0.50-19.57, 1.05-22.12, 1.42-38.42 and 0.50-5.43 respectively with Fe, Zn and Cd having the highest concentrations. Bioaccumulation factor was higher in the gills than the tissue. The implication of these metals in an aquatic environment were examined in addition to their associated health hazards. The variation in the parameter determined were found to be statistically significant ( $p < 0.01$ ) as determined by one-way analysis of variance.

Keywords: Fish species, gills, tissue, metals, petroleum

### **Chaotic behavior of plasma surface interaction. A table of plasma treatment parameters useful to the restoration of metallic archaeological objects**

C. L. Xaplanteris<sup>(1,2)</sup> and E. Filippaki<sup>(2)</sup>

(1) Hellenic Military Academy, Vari Attika, (2) Plasma Physics Lab, IMS, NCSR "Demokritos", Athens, Greece

[lfilip@ims.demokritos.gr](mailto:lfilip@ims.demokritos.gr)

In Plasma Physics laboratory of NCSR "Demokritos" the plasma chemistry method has been used for the restoration and conservation of metallic archaeological objects during the last decades. The obtained experience had led us to conclude that plasma parameters and different status of treated objects are so specific, so as to become unique. In the present paper the theoretical and experimental results of our laboratory are summarized. A treatment table of plasma parameters is given, which claims to be useful for the conservators. It is obvious that this treatment table needs to be completed and extended, so that it meets the uniqueness of each artifact. A theoretical study and the treatment of a variety of iron objects are presented.

Keywords: plasma sheath potential, plasma restoration, corrosion, external potential, plasma parameters

## Chaos-based communication utilizing attractor statistic detection

Y. Xu, P. Charge & D. Fournier-Prunaret  
LATTIS Laboratory, University of Toulouse

During recent decades the communication domain has experienced many developments, from wireline to wireless, from narrow-band to wide-band, from voice communication to data transmission. Meanwhile, several challenges have come along with these developments, such as the lack of sufficient frequency resource, the requirement of high-rate transmissions, the demand of low-cost equipment, and so on. A research interest hence arises which seeks the possibility of achieving a system employing a simple and low-cost transceiver to transmit data through a wide frequency band with low power density. Furthermore, because of the wireless propagation environment, the transmitted data can be only detected in a non-coherent way.

Several researchers have already worked on this task, such as Kolumban *et al.* (2007) and Chong *et al.* (2008). They have proved that chaotic systems is one of the possible solution, because of the wide-band property of chaotic signals and the simplicity of signal generation. As far as non-coherent detection is concerned, differential chaos shift keying (DCSK) of Kolumban *et al.* (2002) is the most researched; it involves transmitting a reference information part together with a modulated information part, and demodulation is realized by a correlation decoder applied to these two parts. Obviously, transmitted reference (TR) systems, such as DCSK, have a disadvantage in regard to transmission efficiency. An innovative realization of non-coherent detection in chaotic systems which avoids the need for a reference segment is to utilize special chaotic attractors, Xu *et al.* (2008).

This paper aims at introducing the chaotic cyclic attractor shift keying (CCASK) system, which uses chaotic cyclic attractors (CCA) to modulate information and avoid reference transmission. The detection is realized by observing the special statistics of these attractors. It is proved by analysis and simulation that, under long symbol duration, CCASK using statistical detection, possesses better performance than DCSK through additive white Gaussian noise (AWGN) channels, as well as through multi-path channels.

### References

- Chong, C.C., and Yong, S.K., "UWB direct chaotic communication technology for low-rate wpan applications", *IEEE Transactions on Vehicular Technology*, 57, 3, 1527-1536, 2008.
- Kolumban, K., Kennedy, M.P., Jako, Z. and Kis, G., "Chaotic communications with correlator receivers: theory and performance limits", *Proceedings of the IEEE*, 90, 5, 711-732, 2002.
- Kolumban, G. and Krebesz, T., "UWB radio: Digital communication with chaotic and impulse wavelets," *IEICE Transaction Fundamentals*, E90-A, 10, 2248-2249, 2007.
- Xu, Y., Charge, P. and Fournier-Prunaret, D., "Chaotic cyclic attractors shift keying", *International Conference on Neural Networks and Signal Processing*, June 7-11, 2008, Zhenjiang, China, 62-66, 2008.

## Fuzzy Awakening in Meander Loops Modeling

Levent Yilmaz

Hydraulic Division, Civil Engineering Department, Technical University of Istanbul, Turkey

[lyilmaz@itu.edu.tr](mailto:lyilmaz@itu.edu.tr)

Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. It can be thought of as the application side of fuzzy set theory dealing with well thought out real world expert values for a complex problem (Klir, 1997). Fuzzy logic basic application might characterize subranges of a continuous variable. The common and simple approach in the assessment of meander loop distribution – discharge relationship is the use of regression analysis. The simplicity of this method lies in its basic data requirements, specifically discharge and meander loop measurement records. On the other hand, it is well known that the use of regression equations is not useful for the very complicated discharge and meander loop distribution processes that exist. In this way, the variable is considered not as a global and numerical quantity but in partial groups which provide better room for the justification of sub-relationship between two or more variables on the basis of fuzzy words. For instance, in this paper discharge and planform meander distribution variables are considered as five partial



subgroups, namely “small”, “medium small”, “medium”, “medium big”, and “big”. In practical studies, in the preliminary stage the number of subgroups is selected as four or five (Sen, 2001). Five subgroups in each variable imply that there are  $5 \times 5 = 25$  different partial relationship pairs that may be considered between the discharge and planform meander distribution variables. Figure 1 shows the relative positions of the fuzzy words employed in this paper. Each one of the middle fuzzy words is shown as a triangle with the maximum membership degree at its apex. The most left and right fuzzy words, namely “low”, and “high”, are represented by trapeziums. It is significant to consider that neighboring fuzzy subsets interfere with each other providing the fuzziness in the modeling. In the case of systems that lie outside the preconceived triangle, these triangles change shape depending on the climatic regions, soil types, valley slope, e.g. laboratory boundary bottom fine sediment with diameter smaller than 0.05 mm can take 0.20 l/s of discharge and 0.5 (LR/LV ratio of meandering loop) where LR is the length along river bend and LV is the straight length along the river valley, and 3.1 (ML / MB ratio of meandering loop) where ML is the meander length and MB is the length of the meander belt. To investigate the actual relationship and its validity, river data or laboratory data for meandering flumes were needed for all the parameters involved. The study of the effect of parameters  $W/D$  where  $W$  is the surface width of channel and a convenient way to define meander size is by expressing the diameter of meander center line of bend ( $W/D$ ), and the tortuosity ratio which uniquely determines the shape of meanders. For any one value of tortuosity ratio, there are associated single values of the ratios of  $R/W$  or  $MB / W$ , which are another convenient way to define meander size by expressing the ( $R$ ) radius of center line of bend or meander belt to surface width of channel ( $MB/W$ ). If the tortuosity ratio

increases, in

where S, MS, M, MB and B are abbreviations for fuzzy subgroups of “small”, “medium small”, “medium”, “medium big” and “big”, respectively. The general appearance of such a model is given in Figure 2 where, rather than a regression model of the classical calculations, a fuzzy region of discharge- planform meander length relationship is considered with uncertainty domain. In order to show two applications of fuzzy inference, in Figure 4 two rules of the discharge- planform meander length relationship are shown with membership degree,  $\mu$ . Given the discharge,  $Q = 0.20$  l/s both MB and M fuzzy subgroups of discharge variable are triggered. The consequent part of each planform meander length variable appears as a truncated trapezium for each rule on the right hand side in Figure 3. The overlapping of these two truncated trapeziums indicates the combined inference from these two rules as in the lower part of the same figure which is represented in Figure 4 with relevant numbers. In this figure A1, A2, A3, A4, A5 and A6 indicate triangular and rectangular subareas in the fuzzy inference. For hydrologic design purposes, it is necessary to deduce from these combined fuzzy subgroups a single value which is referred to as “defuzzification” in the fuzzy systems terminology. The purpose of defuzzification is to convert the final fuzzy set representing the overall conclusion into a real number that, in some sense, best represents this fuzzy set. Although there are various defuzzification methods the most common method is centroid defuzzification (Ross, 1995; Sen, 2001). In general, given a fuzzy set with membership degree  $\mu(x)$  defined on the interval  $[a, c]$  of variable  $x$ , the centroid defuzzification prediction,  $\hat{x}$ , is defined as

$$\hat{x} = \frac{\int_b^c x\mu(x)dx}{\int_b^c \mu(x)dx} \quad (1)$$

By applying this formula to the fuzzy inference set in Figure 4, it is possible to obtain a defuzzification value by numerical calculation

### **System dynamical rebuilding interacting with environment during its evolution (plenary report)**

Vilor L. Zakovorotny

Donskoy State Engineering University 1, Russia  
anatoly.kolesnikov@gmail.com

We propose math. model of system complicated evolution. System parameters are varying by extraction of power in system-environment coupling. Parameters are introduced by second kind Volterra integral operator in respect of job-power trajectory. We present methodologies of synthesis for stationary evolution trajectories, as well problems of system dynamical rebuilding and bifurcation.

Key Words: Bifurcation, modelling, system synthesis

## **Bifurcation and transport in the phase space of a nonlinear model of experimental human balance data**

M.S. Zakyntinaki (a,b) J.R. Stirling (b), A. López Díaz de Durana (b), C.A. Cordente Martínez (b), M. Sillero Quintana (b), J. Sampedro Molinuevo (b) and G. Rodriguez Romo (b)

(a) Instituto de Ciencias Matemáticas, CSIC–UAM–UC3M–UCM, (b) Facultad de Ciencias de la Actividad Física y del Deporte, INEF, Universidad Politécnica de Madrid, Madrid, Spain

[mzakyn@mat.csic.es](mailto:mzakyn@mat.csic.es)

We investigate stability and the maintenance of balance with the use of tools used to understand nonlinear and chaotic dynamical systems. In particular we investigate the application of such tools to the study of the ground reaction forces resulting from an individual being perturbed from quiet stance. We develop a nonlinear model [3] consisting of a set of coupled nonlinear ordinary differential equations for the derivative with respect to time of the angles between the resultant ground reaction forces and the vertical in the anteroposterior and mediolateral directions. We then analyze the geometry of the phase space and its effect on the resulting transport. The phase space contains a basin of attraction bound by a closed curve which we call the critical curve. It is only inside this curve that perturbations can be corrected, with the orbit spiraling back onto an attractor corresponding to quiet stance. The ALOPEX stochastic optimization algorithm [1] is used to calculate the optimal critical curve. We show how this work is currently being used to analyze balance in elite sport, in particular judo [2].

“This work is supported by the projects i-math C3-0106 and Simumat ”

[1] M. Zakyntinaki, J. R. Stirling, A. Lopez Diaz de Durana, C. A. Cordente Martinez, M. Sillero Quintana, J. Sampedro Molinuevo, "Stochastic optimization for the calculation of the optimal critical curve from experimental data in a model of the process of regaining balance after perturbation from quiet stance". Computer Physics Communications, 179, (8), 562-568, 2008.

[2] J. R. Stirling, C. A. Cordente Martinez, A. Lopez Diaz de Durana, M. Sillero Quintana, "Analysis of the imbalances in elite athletes with application to the improvement of technique and the prevention of injuries". Technical Report, Consejo Superior de Deportes 07/UPB10/07 (2007).

[3] J.R. Stirling and M.S. Zakyntinaki "Stability and the maintenance of balance following a perturbation from quiet stance". Chaos: An Interdisciplinary Journal of Nonlinear Science, in March 2004, Volume 14, Issue 1, pp. 96-105.

## **Exploring stability, bifurcations and chaos in exploited resource-based trophic chains**

Nikolay N. Zavalishin

A.M. Obukhov Institute of atmospheric physics RAS, Moscow, Russia

[nickolos@ifaran.ru](mailto:nickolos@ifaran.ru)

Research of an exploited partially closed trophic chain with explicit nutrient description is carried out considering stability of steady states and their bifurcations under harvesting efforts and varying of input nutrient or energy flux. Exploitation can be allowed for modification of mortality coefficients at necessary trophic levels. Complex dynamic behavior with limit cycles and chaotic attractors is demonstrated as a result of bifurcations of steady states under perturbations of two parameters  $B$ – external resource input flux and harvesting mortality coefficient for the last species in the chain of length  $n$ . Increasing of harvesting mortality coefficient can result in a monotone decrease of a last species as well as in forming of a chaotic region in the parameter space which separate stability domains for the chain with length  $n$  and the shorten one with length  $n-1$ . This chaotic region can be used to recognize an approach of the chain to the critical boundary where the last species disappears. A 2dimensional parametric portrait is constructed using bifurcation theory for analytical calculation of local bifurcation expressions and numerical continuation software to clarify global bifurcation curves. Different effects are also possible in case of harvesting an intermediate species in the chain: monotone decreasing of the rest species following the harvested can give place to periodic or chaotic oscillations of their biomasses depending on the value of input resource flux.

Key Words: biological food chains, energy/matter flux, steady state, bifurcation, chaos

**Triangulation Pattern Based Approach to Free Form Surface Modelling**

Huaying Zhong

Southeast University, China

(Guest researcher in Technical University of Delft, Netherlands)

wetmonkey2006@hotmail.com

Free form modelling is one of the core techniques in non-standard architecture. Single layer surfaces are widely used to describe a non-standard form. But a single layer surface without the support of an additional structure can only be constructed in small scale with today's technology. Multilayered surfaces are more effective as regards their application for creating a full scale building. This paper introduces two different approaches for developing buildable surface using RhinoScript[1]: the first one is an approach to derive a free form surface from a point cloud, the second one focuses on deriving a multilayered surface from a reference surface. The triangulation based subdivision of surfaces as a strategy in both cases is also specifically deployed owing to its economic feasibility. This paper further explores a method to modify the geometry of the triangular pattern according to its relation with the reference surface in order to expand the adaptability of this system.

Keywords: Non-standard, Point cloud, Multilayered Surface, Triangular pattern.

**Risks: Institutional and Self-regulating Management Mechanisms**

Yulia Zubok, Vladimir Chuprov

Russian Academy of Sciences Inst for Socio-Political Research, Moscow, Russia

uzubok@mail.ru

Risk and uncertainty are well recognized features of modern dynamically changing societies. They penetrate social development mechanisms and become an integral part of the social reality. The search for ways of risk management becomes a topic of fundamental theoretical research. In this connection, mechanism of uncertainty and risk emergence in the social development the paper discovers changes in the level of environment and activity risks, and considers ways of their regulation. The analysis deals with grounding of sociological mechanisms of risk management rather than with concrete risk tendencies. A particular attention is given to an institutional means of risk diminishing and to non-institutional ways of individual regulation.

Key Words: risk, uncertainty, institutional regulation, individual self-regulation



## Chaos Applications in Telecommunications and Sensors

### *CATS International Workshop*

2-3 June 2009  
Chania, Crete, GREECE

*CATS is a public dissemination event for the EU-STREP project IST-34551-PICASSO*

CATS International Workshop includes original contributions on the applications of chaotic dynamics in the field of telecommunications and sensors. The majority of the contributions involve optical or electro-optical systems that employ semiconductor devices. Specifically, several works analyze the complexity of dynamics emitted by semiconductor devices or sophisticated and fully controllable integrated circuits. A number of contributions refer to the synchronization efficiency between optical chaotic oscillators. The study of security and reliability of chaos encryption methods in optical communication systems is the topic of several works. Finally, applications of such systems are presented such as fast pseudorandom bit generation, chaos steganography and time-domain reflectometry.



*Organized within the CHAOS 2009 - 2nd Chaotic Modelling  
and Simulation International Conference*



# Experimental study of nonlinear dynamics and chaos in a 1550nm-VCSEL subject to polarized optical injection

A. Hurtado<sup>1</sup>, A. Quirce<sup>2</sup>, L. Pesquera<sup>2</sup>, A. Valle<sup>2</sup> and M.J. Adams<sup>1</sup>

1. School of Computer Science and Electronic Engineering, University of Essex, Wivenhoe Park, CO4 3SQ Colchester, United Kingdom. E-mail: [ahurt@essex.ac.uk](mailto:ahurt@essex.ac.uk)

2. Instituto de Física de Cantabria (CSIC-Univ.de Cantabria), Avda. Los Castros s/n, E39005, Santander, Spain

**Abstract:** We report the experimental observation of nonlinear dynamics including chaos in a 1550nm-VCSEL subject to parallel- and orthogonally-polarized optical injection.

## 1. Introduction

Injection-locked 1550nm-vertical cavity surface emitting lasers (VCSELs) are very promising devices for use as optical sources in optical telecommunication systems [1]. However, stable locking is only attained in a small range of values in the plane of frequency detuning between the Master Laser (ML) and the Slave Laser (SL) versus the optical injected power. Outside this locking range a rich variety of nonlinear dynamics including chaos can be observed [2].

## 2. Experimental results

We have experimentally studied the nonlinear dynamics in a 1550nm-VCSEL subject to parallel and to orthogonal polarized injection into the two orthogonal polarizations of the fundamental transverse mode. For both polarization modes, different regions of nonlinear dynamics, including limit cycle, period doubling, bistability, polarization switching and also regions of chaotic dynamics have been observed.

Figs. 1(a) and 2(a) show, respectively, the optical and the electrical spectrum of the solitary 1550nm-VCSEL used in the experiments. The optical spectrum of the device exhibits two modes corresponding to the two orthogonal polarizations of the fundamental transverse mode. The emitting mode has parallel polarization and it is located at 1544.7 nm while the subsidiary mode has orthogonal polarization and is shifted approximately 0.5 nm to the long-wavelength side of the lasing mode. Figs. 1(b) and fig. 1(c) show respectively the optical spectra subject to parallel and orthogonal optical injection into the parallel and orthogonal polarization mode. The injected power and the initial frequency detuning, respectively, were equal to  $P_{inj} = 1140 \mu\text{W}$ ;  $f - f_{1VCSEL} = 1 \text{ GHz}$  and equal to  $P_{inj\perp} = 20 \mu\text{W}$ ;  $f - f_{1VCSEL} = -2.5 \text{ GHz}$  for the cases of parallel and orthogonally-polarized injection. Figs. 2(b) and 2(c) show the electrical spectra of the VCSEL for the same conditions as in figs. 1(b) and 1(c). For both cases of polarized injection, chaotic dynamics characterized by a multiple peak and wide optical spectrum, and by a wide electrical spectrum with an increase of the noise level, have been observed for both polarization modes. Fig. 1(c) also shows that polarization switching appears associated with the occurrence of chaotic dynamics for the case of orthogonal optical injection.

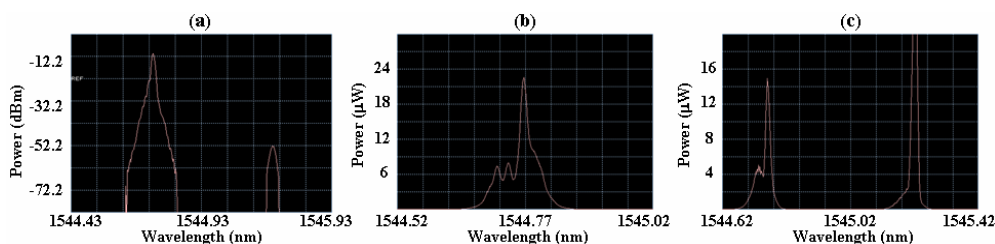


Fig. 1. Optical spectrum of the 1550nm-VCSEL (a) without optical injection and subject to (b) parallel and to (c) orthogonal polarized injection.

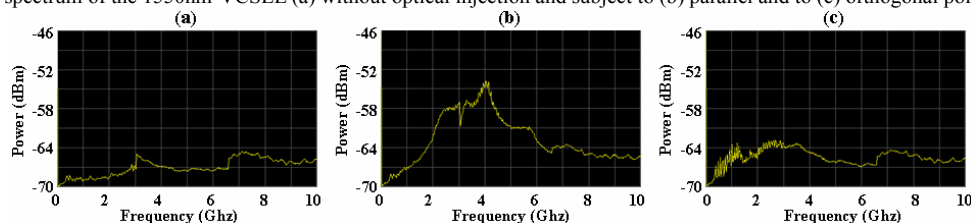


Fig. 2. Electrical spectrum of the 1550nm-VCSEL (a) without optical injection and subject to (b) parallel and to (c) orthogonal polarized injection.

## 3. Conclusions

We report the experimental observation of nonlinear dynamics including chaos in a 1550nm-VCSEL subject to parallel and orthogonally polarized injection into the two orthogonal polarizations of the fundamental mode.

## 4. References

- [1] C.-H. Hang et al, "Injection locking of VCSELs", J. Select. Topics Quantum Electron., **9**, 1386-1393 (2003).
- [2] J. Buesa et al, "Mapping of the dynamics induced by orthogonal optical injection in vertical-cavity surface-emitting lasers", J. Quantum Electron. **42**, 198-207 (2006).

# Computer-aided analysis of the Poincaré map for the characterisation of optically-injected semiconductor lasers

C. A. Stolz, D. Labukhin, N. Zakhleniuk, R. Loudon, M. J. Adams

School of Computer Science and Electronic Engineering, University of Essex, Wivenhoe Park, Colchester, CO4 3SQ, UK  
 cstolz@essex.ac.uk, dlabuk@essex.ac.uk, naz@essex.ac.uk, loudr@essex.ac.uk, adammm@essex.ac.uk

**Abstract:** A new automated analysis of the Poincaré map is suggested to perform a complete stability investigation of optically-injected lasers simulated with the travelling wave approach.

## 1. Introduction

The dynamics of optically-injected semiconductor lasers have been investigated for several years [1-6] and they can be simulated either using the rate equations (REs) [1] or the travelling wave (TW) [2] approach. In recent years the TW model has been used to find the dynamics of the system [4, 5]. The TW model can easily be used to find the locking bandwidth of the system but so far no distinction between regions of different instabilities has been made. In this paper a new method will be presented that uses the trajectory of the system to perform a complete stability analysis in which regions of different dynamics can be identified.

## 2. Method

The system is simulated using a commercial software program [7] and for each time moment the average carrier density and the absolute value and phase of the electric field are saved to create the trajectory of the system. It has been shown [3] that the trajectory depends on the state of the system. For the analysis a Poincaré section is taken through the carrier density – electric field space with a constant phase, and the intersection points of the trajectory with the plane are investigated to construct the so-called Poincaré map. To simplify the analysis the Poincaré map is divided into small sections and the intersection points per slice are counted. These numbers give a distribution which can be used for the analysis. For example, the wider the intersection points are spread the more chaotic the system is.

## 3. Results

Figure 1 shows an automatically-obtained stability map (shaded fields). White fields show the region where the system is stably locked. The darker the fields are shaded the more chaotic the system is. The dashed lines are the locking region boundaries obtained by manual analysis of the simulated laser spectra, as defined by a side-mode suppression ratio of 30 dB. As is seen from the figure, the agreement in the locking bandwidth, as well as the qualitative agreement with experimental results [6], is very good.

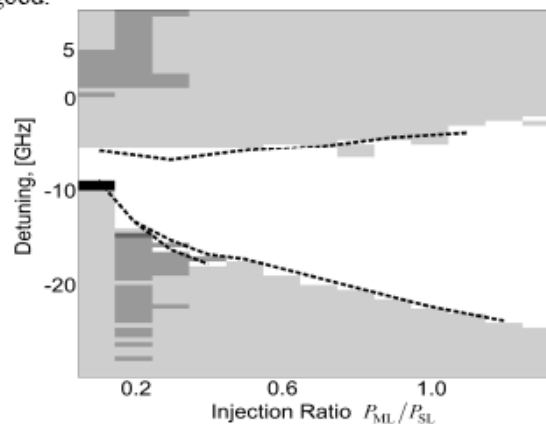


Fig.1. Stability map obtained automatically (shaded fields) and manually (dashed lines)

## 4. Conclusion

It was shown that the trajectory of the system strongly depends on the state of the system. This dependence in turn can be used for a complete stability analyses. The results obtained by the new method agree well with experimental data [6].

## 4. References

- [1] R. Lang, "Injection locking properties of a semiconductor-laser," *IEEE J. Quantum Electron.* **18**, 976-983 (1982).
- [2] G. R. Hadley, "Injection locking of diode-lasers," *IEEE J. Quantum Electron.* **22**, 419-426 (1986).
- [3] S. Wieczorek, B. Krauskopf, T. B. Simpson, and D. Lenstra, "The dynamical complexity of optically injected semiconductor lasers," *Physics Reports-Review Section Of Physics Letters* **416**, 1-128 (2005).
- [4] R. Gordon, "Fabry-Perot semiconductor laser injection locking," *IEEE J. Quantum Electron.* **42**, 353-356 (2006).
- [5] D. Labukhin, C. A. Stolz, N. Zakhleniuk, R. Loudon, and M. J. Adams, "Modified Fabry-Perot and rate-equation methods for the nonlinear dynamics of an optically injected semiconductor laser," *IEEE J. Quantum Electron.*, to be published.
- [6] N. M. Al-Hosiny, I. D. Henning, and M. J. Adams, "Tailoring enhanced chaos in optically injected semiconductor lasers," *Optics Communications* **269**, 166-173 (2007).
- [7] VPIsystems (2009, March 18<sup>th</sup>) [Online]. Available: <http://www.vpiphotonics.com>.

# Investigations of Coherence Collapse scenarios of Quantum Cascade Lasers

Jan-Eric Nimsch, Jens von Staden, Dominik Blömer, Wolfgang Elsäßer

AG Halbleitertechnik, Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstr. 7, D-64289 Darmstadt, Germany  
Jan-Eric.Nimsch@physik.tu-darmstadt.de

**Abstract:** Different regimes of a Quantum Cascade Laser (QCL) operating at a wavelength of  $8.6\mu\text{m}$  and subject to a delayed optical feedback are measured and mapped according to critical parameters.

## 1. Introduction

The characteristic effects observed in semiconductor lasers (SLs) under optical feedback have attracted a lot of attention, as their chaotic behaviour provides an ideal physical model for investigations of nonlinear dynamic systems. From a technological point of view, feedback-induced instabilities in SLs are important to study for noise reduction, and are also a promising way of implementing cryptographic communication<sup>[1]</sup>.

Quantum Cascade Lasers, (QCLs) on the other hand, made their appearance in 1994<sup>[2]</sup>. Unlike classical SLs, light in QCLs is emitted by electrons making transitions between confined states created by quantum confinement in a multilayer semiconductor quantum-well structure. This makes it possible to build lasers emitting in the mid- and far-infrared ranges—ranges that cannot be reached with classical SLs. In fact, QCLs with emitting wavelength of  $3\mu\text{m}$  to  $300\mu\text{m}$  have been achieved. For communication purposes, QCLs are of particular interest, as their emitted wavelengths make it possible to build free space-communication with virtually no quality losses by using the transmission window of the atmosphere in the mid-infrared region.

In this work, we will depict different phenomena occurring in QCLs under optical feedback with differing parameters, leading to the well-known coherence collapse.

## 2. Experimental Setup

Figure 1 shows the experimental setup we used for measuring the resulting emission of a Quantum Cascade Laser ( $8.6\mu\text{m}$ ) submitted to an optical feedback signal. A characteristic criterion for verifying the strength of the feedback is by measuring the reduction of the threshold current of the laser as depicted in figure 2.

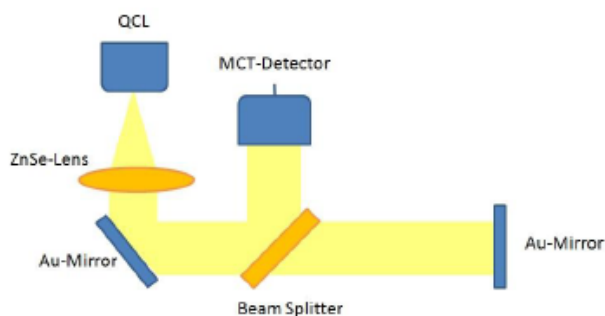


Figure 1 : Experimental Setup

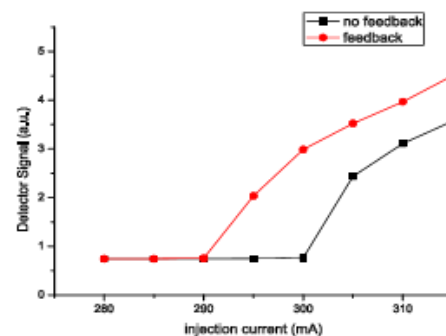


Figure 2 : Reduction of threshold current

Critical parameters of the feedback setup are, in addition to the injection current, the strength of the feedback and the length of the external cavity. By varying these parameters, we mapped the different regimes of dynamical behaviour encountered by the QCL; very similar to prior works conducted by our group on classical semiconductor lasers in the NIR<sup>[3]</sup>.

## 3. Conclusions

Optical feedback in a Quantum Cascade Laser has been demonstrated. We also depicted the dynamic behaviour of a QCL subject to delayed optical feedback by varying critical parameters.

The results presented show a first approach to the use of Quantum Cascade Lasers as sources for encrypted communication channel in a free space context. Future experiments by our group should now enquire how chaos synchronization of two similar QCLs can be achieved.

## 4. References

[1] A. Argyris et al., "Chaos-based communications at high bit rates using commercial fibre-optic links," *Nature* 438, 343-346 (2005).

[2] J. Faist et al., "Quantum Cascade Laser," *Science* 264, 553-556 (1994).

[3] I. Fischer et al., "Emission Dynamics of Semiconductor Lasers Subject to Delayed Optical Feedback," *AIP Conference Proceedings* 548, 218 (2000).



# Quantum-Dot InAs/InGaAsP/InP (100) Twin-Stripe Lasers for Secure Encrypted Communication

J. Pozo<sup>1</sup>, A. Corradi<sup>1</sup>, E. Smalbrugge<sup>1</sup>, T. de Vries<sup>1</sup>, M.K. Smit<sup>1</sup>, D. Lenstra<sup>3</sup>, R. Nötzel<sup>2</sup>

(1) OED group and (2) PSN group, COBRA, Technische Universiteit Eindhoven, The Netherlands.

(3) Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, The Netherlands.  
j.m.pozo.torres@tue.nl

**Abstract:** Quantum-dot twin-stripe lasers have been fabricated and characterized. Dynamic features have been observed indicating regimes of chaotic operation that make these lasers suitable for chaotic-encryption application.

## 1. Introduction

Non-linear dynamics in Quantum Dot (QD) lasers have attracted the attention of the research community for over a decade. These interesting non-linear dynamic features can not be only studied in detail but also exploited. Encryption schemes for hiding messages in chaotic signals have also attracted attention to a great extent in order to transmit information securely. But to date these encryption systems have had two major issues: (1) although chaos on a laser chip already has been proven experimentally [1], the fabrication of reproducible chaotic lasers is still a major issue; (2) also, traditionally, optical chaos has been created by externally influencing a laser in complicated set-ups making difficult the use of the system for commercial applications. Our approach is to simplify the system and increase its reproducibility by producing the chaos 'on chip', without adding extra components to the set-up. For that purpose, we use twin-stripe lasers.

## 2. Device details

By using InAs/InGaAsP/InP (100) QD material [2] operating at 1.5  $\mu\text{m}$  to fabricate devices consisting of two laterally coupled non-linear oscillators, or twin-stripe lasers, we have the advantage, due the zero dimensional confinement of the QDs, of achieving evanescent coupling between the stripes with no lateral carrier diffusion through the active region. In this material, lateral carrier diffusion, through thermal carrier excitation to the wetting layer or the barriers, takes place over up to 100 nm.

A SEM image of the resulting device can be observed in figure 1. The resulting devices are 4 mm long with two ridge waveguides with a width of 2  $\mu\text{m}$  each, separated by 2.5  $\mu\text{m}$ . The fabricated lasers have then been characterized showing good performance with a threshold current of 200 mA in each stripe at 285 K and an output power of up to 8 dBm per stripe and per facet.

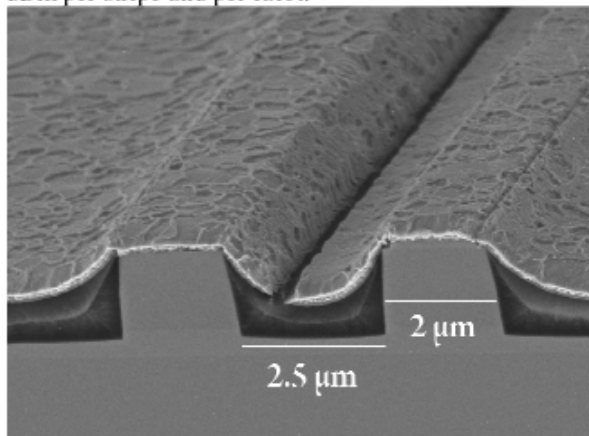


Figure 1. SEM image of one of the facets of the twin-stripe laser.

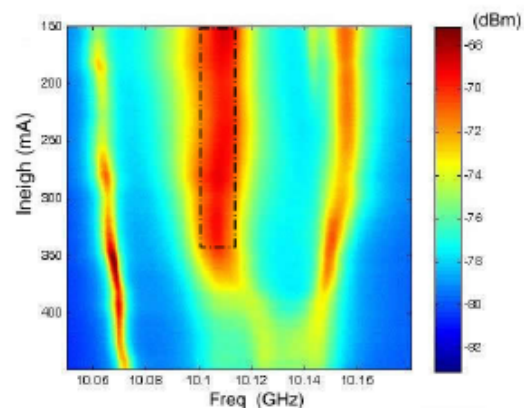


Figure 2. rf-spectra of the output of one of the stripes biased at 400mA as a function of the bias current on its neighbor stripe ( $I_{\text{neigh}}$ ).

## 3. Dynamic characterization

The dynamics of the lasers are influenced by the evanescent coupling between the stripes, and altering parameters such as the separation between the stripes –in the fabrication process– or the bias current in either one of the stripes, transitions to chaos similar to those found in single-stripe lasers subject to external influences have been observed [1,3]. For example, in figure 2 the rf-spectra of the output of one of the stripes have been plotted as a function of the bias current on its neighbor stripe ( $I_{\text{neigh}}$ ). In that figure, marked with a dashed line, there is a region with unpredictable dynamical behavior. We used the points of operation contained in that region for the synchronization of a master and slave laser which can work as emitter and receiver of an encrypted communication link.

## 4. References

- [1] M. Yousefi et al., "New Role for Nonlinear Dynamics and Chaos in Integrated Semiconductor Laser Technology", PRL 98, 044101, (2007).
- [2] S. Anantathanasarn, et al., "Lasing of wavelength-tunable (1.55  $\mu\text{m}$  region) InAs/InGaAsP/InP (100) quantum dots grown by metal organic vapor-phase epitaxy," Appl. Phys. Lett. 89, 073115 (2006).
- [3] I. Fischer et al., "Synchronization of chaotic semiconductor laser dynamics on subnanosecond time scales and its potential for chaos communication", PRA 62, 011801 (2000).

# Chaos generation and communications using integrated sources with an air gap

V. Z. Tronciu<sup>1</sup>, C. Mirasso<sup>2</sup>, P. Colet<sup>2</sup>, M. Hamacher<sup>3</sup>, M. Benedetti<sup>4</sup>, and V. Annovazzi-Lodi<sup>4</sup>

<sup>1</sup>Weierstrass Institute for Applied Analysis and Stochastics Mohrenstr. 39, 10117 Berlin, Germany

<sup>2</sup>Instituto de Física Interdisciplinar y Sistemas Complejos, Universitat de les Illes Balears, E- 07122 Palma de Mallorca, Spain

<sup>3</sup>Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institute, Einsteinufer 37, D-10587 Berlin, Germany

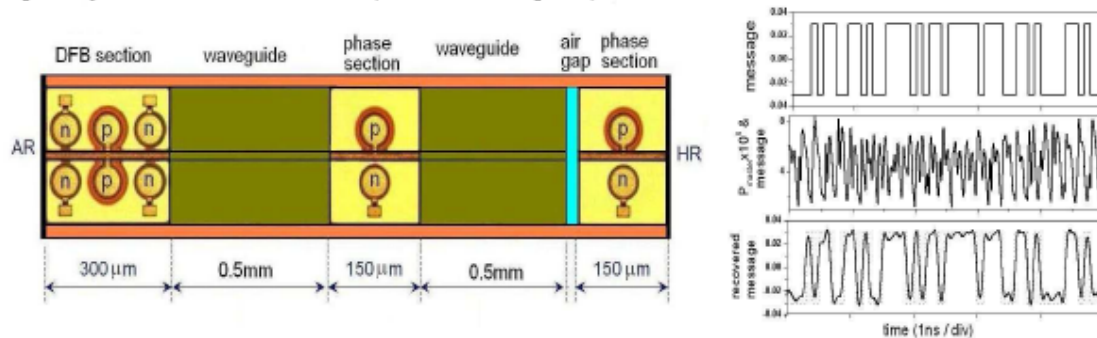
<sup>4</sup>Università di Pavia, Dipartimento di Elettronica, Via Ferrata 1 I-27100, Pavia, Italy

Author e-mail address: tronciu@wias-berlin.de

**Abstract:** We report results of numerical and experimental investigations of the dynamical behaviour of semiconductor lasers under the influence of multiple feedbacks. The optimal conditions for chaos generation and synchronization are identified and examples of message encoding and decoding are presented.

Recent technological progress brings into reach stable compact multisections semiconductor lasers. Such devices may be very suitable for chaotic secure communication [1,2]. We report results of numerical and experimental investigations of the dynamical behaviour of continuous-wave semiconductor lasers under the influence of multiple feedbacks (see Figure 1 left panel). The system consists of DFB laser composed of 6 QWs and coupled to two external phase sections and an airgap section. The DFB structures were grown by metalorganic chemical vapor deposition. The external phase sections can be driven independently. We show that multiple feedbacks lead to a more complex behaviour, which, in fact, is already indicated when looking at the number and location of the fixed points [3]. The theoretical analysis is based on structure of actually fabricated laser samples. In the present study, the laser dynamics is analyzed in the framework of the extended Lang-Kobayashi equations for the complex field amplitude and excess carrier density [4]. The optimal conditions for chaos generation are identified and a comparison of the dynamics of this configuration with that of conventional optical feedback is presented. A good agreement is obtained between measurements and theoretical simulations.

We have found both in theory and experiment that two of these devices can be synchronized when operating in the chaotic regime in a master-slave configuration. We report also on the influence of parameters mismatch on the synchronization quality and show how the features of the external cavities have an influence on the laser behaviour. We also found that for small enough mismatches, good quality synchronization is achieved. For the parameter values where good synchronization is achieved, it is possible to encode a message in the carrier using the chaos modulation technique. Right panel of Fig. 1 depicts the numerically obtained process of a 10 Gbit/s message encryption that can be appropriately recovered at the receiver (see the bottom panel).



**Fig. 1** Left: a sketch of the proposed semiconductor laser for chaos synchronization and message encoding. Right: numerical results of encoding and decoding of a 10 Gbit/s digital message for a closed loop scheme. Top: encoded message. Centre: output of the master laser with a message. Bottom: recovered message after filtering (solid line) and input message (dotted line).

While the chaos modulation technique is efficient and simple to implement, other codification methods could be used as well. In this sense, we found in the theoretical treatment that the on/off phase shift keying encryption method can be successfully applied to such system at a rate of hundreds of Mbit/s. We believe that our work provides a good basis for future study and, in particular, provides some pointers for more detailed investigations of multi-section integrated devices and their applications for chaos-based communication systems

## References

- [1] A. Argyris et al "Chaos-based communications at high bit rates using commercial fibre-optic links," Nature 438 343 (2005).
- [2] C.R. Mirasso, P.Colet and P.Garcia-Fernandez, "Synchronization of Chaotic Semiconductor Lasers: Application to Encoded Communications," IEEE Photon. Technol. Lett. 8 299 (1996)
- [3] V Z Tronciu, Claudio R Mirasso and Pere Colet, "Chaos-based communications using semiconductor lasers subject to feedback, from an integrated double cavity," J. Phys. B: At. Mol. Opt. Phys. 41, 155401 (2008)
- [4] R. Lang and K. Kobayashi IEEE J. Quantum Electron. 16 347 (1980)

# Investigating the chaotic behaviour of multi-section semiconductor lasers using the transmission line laser model

Dmitry Labukhin, Christopher A. Stolz, Nickolay Zakhleniuk, Rodney Loudon, Michael J. Adams

School of Computer Science and Electronic Engineering, University of Essex, Wivenhoe Park, Colchester, CO4 3SQ, UK  
 dlabukh@essex.ac.uk, cstolz@essex.ac.uk, naz@essex.ac.uk, loudr@essex.ac.uk, adamm@essex.ac.uk

**Abstract:** A modified transmission line model was developed to investigate the chaotic dynamics of multi-section lasers: fast-tracking of the steady state and the Jacobian matrix analysis were used to improve its time efficiency.

## 1. Introduction

The chaotic behaviour of optically injected multi-section lasers, which consists of active and passive Fabry-Perot (FP) and DBR sections, has been of practical use for many applications [1]. Several numerical techniques for theoretical investigation of such dynamics are based on the rate-equation or FP method [2,3] and employ fast-tracking of the steady-state solution and subsequent Jacobian matrix analysis. However, they were developed only for simple one-section lasers and did not fully incorporate the spatial variation of the internal parameters [3]. On the other hand, the methods that take into account longitudinal non-uniformity of the laser cavity [4] are usually based on time-evolution techniques and require long computing time to accumulate data for laser dynamics analysis. In this study, we present the method that combines the advantages of the two approaches: it employs fast-tracking of the steady state point and the Jacobian matrix analysis and can handle a complex longitudinal structure with an arbitrary configuration.

## 2. Method, structure, and results

The governing equations describe the discrete-time evolution of a laser system. They are based on the transmission-line laser model, in which the cavity of a laser is divided into small subsections with piece-wise uniform longitudinal structures. The equations for the forward and backward propagating EM field are in the form of a scattering matrix that accounts for distributed feedback in DBR sections. The time-evolution formula for the carrier density is derived from the correspondent rate equation.

The setup consists of a master laser (ML) injecting light into a tuneable slave laser (SL) (Fig. 1). The dynamics of the SL is studied for different values of injection power and detuning between the ML frequency  $f_{ML}$  and the proper frequency of the solitary SL  $f_{SL}$ . In the first step, the steady-state of the SL under injection is fast-tracked using the transfer matrix approach and an iterative algorithm. The governing equations are then linearised with respect to a small perturbation to the steady state and the eigenvalues of the Jacobian matrix are calculated. The criterion for stability of a discrete time-evolution system is the magnitudes of all its eigenvalues must be less than one. The simulation results presented in Fig. 2 and 3 are (a) the spectrum, (b) the dynamics trajectories, and (c) the time series of the SL output signal for two values of the detuning (in the units of the relaxation oscillation frequency  $f_{RO}$ ).

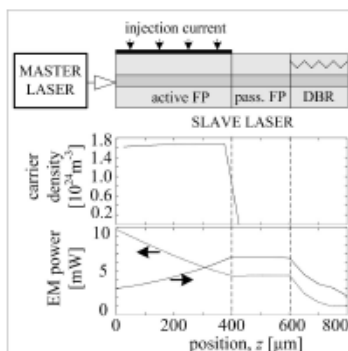


Fig. 1. General setup and structure.

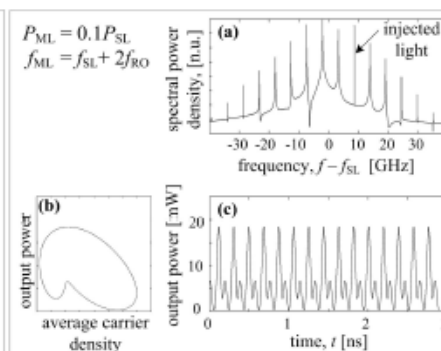


Fig. 2. Period-2 oscillation

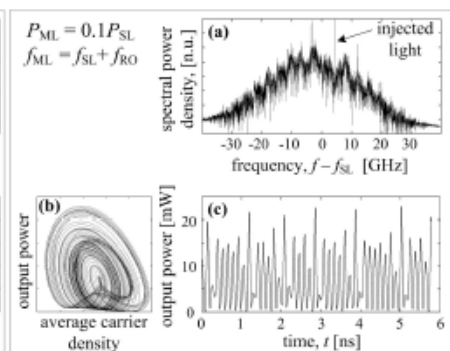


Fig. 3. Chaotic oscillation

## 3. Conclusion

A new approach has been proposed to investigate the chaotic behaviour of an arbitrary laser cavity. It combines two existing methods, the Jacobian-matrix analysis of the FP method and the spatio-temporal modelling of laser dynamics, in order to achieve the high computational efficiency of the former and retain the accuracy and versatility of the latter.

## 4. References

- [1] J. Ohtsubo, *Semiconductor Lasers: Stability, Instability and Chaos*, (Springer-Verlag, Berlin, 2006).
- [2] F. Mogensen, H. Olesen and G. Jacobsen, "Locking conditions and stability properties for a semiconductor laser with external light injection", *IEEE J. Quantum Electron.*, **21**, 784 (1985).
- [3] D. Labukhin, C. A. Stolz, N. Zakhleniuk, R. Loudon and M. J. Adams, "Modified Fabry-Perot and rate-equation methods for the nonlinear dynamics of an optically injected semiconductor laser", *J. Quantum Electron.*, to be published in July 2009.
- [4] M. Radziunas and H.-J. Wuensche, "Multisectional Laser: Longitudinal Modes and their Dynamics," in *Optoelectronic Devices*, J. Piprek, Ed., New York: Springer (2005), pp. 121-150.

# Opto-electronic devices with double feedback loop.

Romain Modeste Nguindo, Pere Colet, Claudio R. Mirasso  
 IFISC (CSIC-UIB), Campus Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain  
 modeste@ifisc.uib-csic.es, pere@ifisc.uib-csic.es, claudio@ifisc.uib-csic.es

**Abstract:** We study the dynamics of optoelectronic oscillators subject to delay feedback affecting both the interferometer and the pump laser current.

Opto-electronic oscillators (OEOs) provide a rich variety of dynamical behaviours. In particular they have been used a chaos generator for encoded optical communications. A typical OEO consist of a Mach-Zehnder (MZ) interferomete pump by a semiconductor laser (SL), a fibre delay line, a photo-detector and a gain amplifier. Chaos is induced by the delayed feedback on the refractive index of one of the arms of the MZ, while the SL itself operates in CW. However delayed optoelectronic feedback on the injection current of SL can induce chaos by itself. Here we combine both, so that feedback affects the MZ as well as the SL injection. We consider two set-ups shown in Fig. 1.

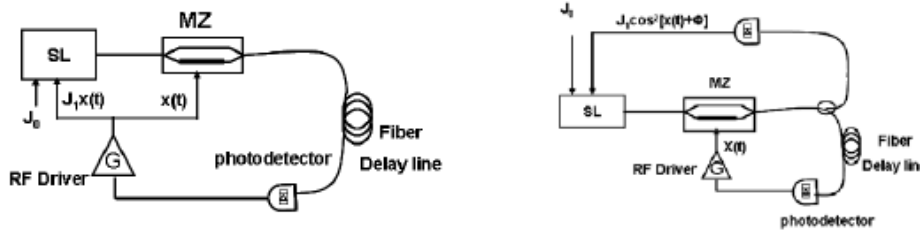


Fig. 1  
 Set ups considered in this work.

The dimensionless voltage applied to the MZ  $x$ , the number of photons  $I$  and carriers  $N$  are given by

$$\begin{aligned} \dot{I} &= (G - \gamma)I \\ \dot{N} &= J_0 - \gamma_e N - GI + J_1 f(x) \\ x + \dot{x} + \theta^{-1} \int x &= \beta_1 I \cos^2(x(t-T) + \phi) \end{aligned}$$

Where  $T=2.5\text{ns}$  is the delay time,  $\theta = 5 \mu\text{s}$  and  $\tau=25 \text{ps}$  are the amplifier cut-off frequencies,  $\beta_1=2.89 \cdot 10^{-5}$  is the proportionality coefficient for the MZ,  $\phi$  is the delay phase,  $\gamma=3.3 \cdot 10^{11} \text{ s}^{-1}$  is the inverse photon lifetime,  $\gamma_e = 5 \cdot 10^8 \text{ s}^{-1}$  is the inverse carrier lifetime,  $J_0$  is the injection current,  $J_1$  is the feedback laser coefficient and  $G=g(N-N_0)/(I+sI)$  where  $g=1.5 \cdot 10^8 \text{ ps}^{-1}$  is the gain,  $N_0=1.2 \cdot 10^8$  the carriers at transparency and  $s=2 \cdot 10^{-7}$  the nonlinear saturation). For the set up on the left of Fig.1,  $f(x(t))=x(t)$  while for the one on the right  $f(x(t))=J_1 \cos^2(x(t) + \phi)$ .

Fig. 2 shows that  $J_1$  can increase the chaos or induce chaos for parameters where it was not present.

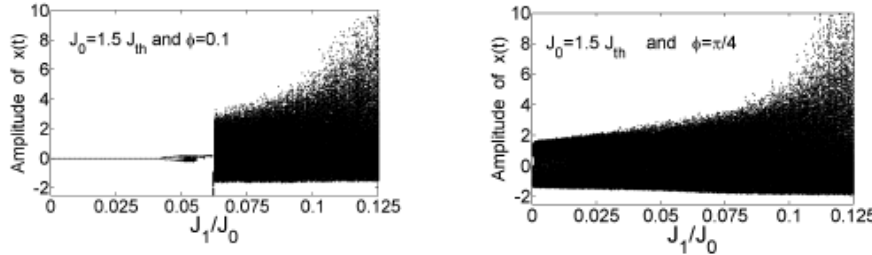


Fig. 2 Bifurcation diagram as increasing  $J_1$  for two values of the feedback phase. We have considered the set-up shown in Fig. 1 left.

Fig. 3 shows how increasing  $J_1$  the correlation time decreases. This effect is more noticeable in the sep-up corresponding to Fig 1 right.

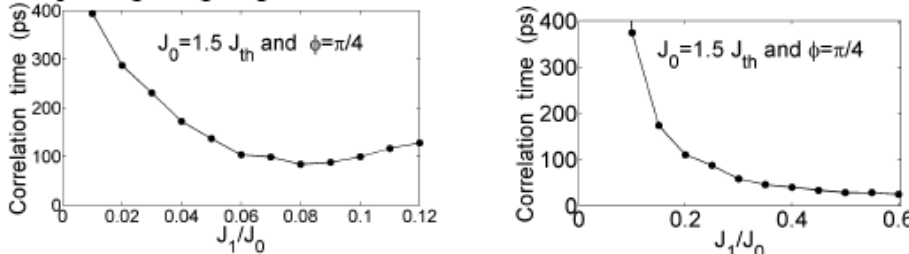


Fig. 3 Correlation time as function of  $J_1$  for the two set-ups shown in Fig. 1.

We have also studied the synchronization between master and receiver systems as well as message encoding showing that this scheme provides a more chaotic carrier while synchronization is still good and message decoding can be done in a reliable manner.

# Dynamics of electro-optic delay oscillators pumped with two lasers

Romain Modeste Nguindo<sup>1</sup>, Pere Colet<sup>1</sup>, Yanne Chembo Kouomou<sup>2</sup>, Laurent Larger<sup>2</sup>

<sup>1</sup>IFISC (CSIC-UIB), Campus Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain

<sup>2</sup> Institut FEMTO-ST, Dép. d'Optique P. M. Duffieux, U. de Franche-Comté, 25030 Besançon cedex, France  
 modeste@ifisc.uib-csic.es, pere@ifisc.uib-csic.es, ckyanne@yahoo.fr, laurent.larger@univ-fcomte.fr

**Abstract:** We study the synchronization of optoelectronic delay oscillators pumped with two lasers with different wavelengths. While only one of them is transmitted, the receiver can still synchronize.

Opto-electronic oscillators (OEOs) can generate a broad range of dynamical regimes from of spectrally pure microwaves to chaos for optical encoded communications. A typical OEO is composed of a Mach-Zehnder interferometer pump by a CW laser, a fibre delay line, a photo-detector and a gain amplifier. The refractive index in one of the arms of the MZ depends on the emitted light after fibre propagation. In the chaotic regime a message can be encoded on top the chaotic carrier and decoded by an appropriate receiver. To increase privacy, we consider here an OEO which is pumped by two lasers with slightly different wavelength ( $\lambda_0, \lambda_1$ ), both playing a role in the generation of the chaotic carrier, but only  $\lambda_0$  is transmitted using a demultiplier.

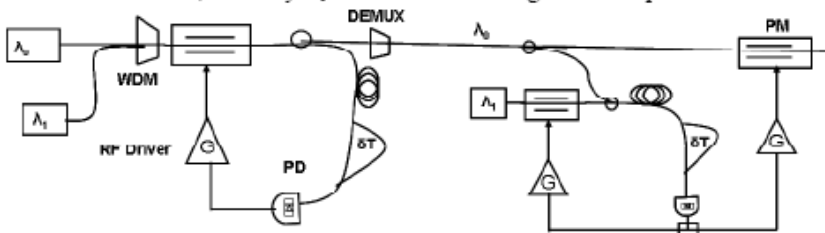


Fig. 1. Set-up.

The dimensionless voltage of the emitter operating in phase modulation, is governed by

$$x + \tau_1 \frac{dx}{dt} + \frac{1}{\theta_1} \int_{t_0}^t x(s) ds = \beta_0 \cos^2(x(t - T_1) - x(t - T_1 - \delta T) + \phi_1) + \beta_1 \cos^2(x(t - T_2) - x(t - T_2 - \delta T) + \phi_2)$$

Where  $\delta T$  is the time-imbalanced interference between the arms of the MZ,  $T_1$  and  $T_2$  are the time delays for  $\lambda_0$  and  $\lambda_1$  which differ due to fibre dispersion,  $\phi$  is the delay phase and  $\beta_0$  and  $\beta_1$  are related to the power of the lasers emitting at  $\lambda_0$  and  $\lambda_1$ . The receiver is operating in open loop for  $\lambda_0$  but in close loop for  $\lambda_1$ , which is generated locally.

$$y + \tau_2 \frac{dy}{dt} + \frac{1}{\theta_2} \int_{t_0}^t y(s) ds = \beta'_0 \cos^2(x(t - T'_1) - x(t - T'_1 - \delta T) + \phi'_1) + \beta_1 \cos^2(z(t - T'_2) - x(t - T'_2 - \delta T) + \phi'_2)$$

$$z + \tau_3 \frac{dz}{dt} + \frac{1}{\theta_3} \int_{t_0}^t z(s) ds = \beta'_0 \cos^2(x(t - T'_1) - x(t - T'_1 - \delta T) + \phi'_1) + \beta_1 \cos^2(z(t - T'_2) - x(t - T'_2 - \delta T) + \phi'_2)$$

We have studied chaos generated in this form as well as the synchronization between emitter and receiver. For typical parameter values we find that chaos entropy increases with  $\beta_1$  as shown in (Fig.(1, left)). Despite the increase in entropy and the fact that the receiver has now to generate its own  $\lambda_1$  synchronization is still good for  $\beta_1 < 1.5$  (Fig.(1, left)). Beyond this value, instabilities occur in the system and therefore, the synchronization is seriously degraded. The threshold for  $\beta_1$  depends slightly on the value of the main gain  $\beta_0$ , and increasing  $\beta_0$  to 5.0, synchronization occurs up to 1.75.

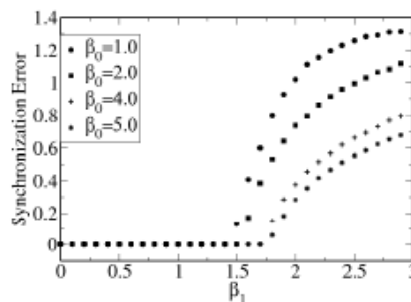
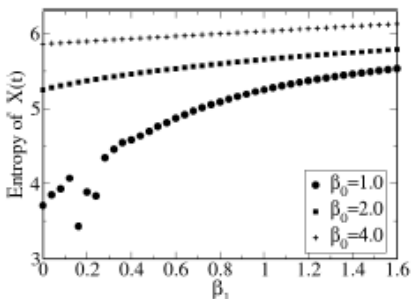


Fig. 2 Entropy of the transmitter (left) and synchronization error between transmitter and receiver (right) as function of  $\beta_1$ .  $T_1 = 31.7$  ns,  $T_2 = T_2' = 32$  ns,  $\phi_1 = \phi_1' = 0.3$ ,  $\phi_2 = \phi_2' = 0.35$

# Dynamics and Chaos Synchronization of TE-TM Orthogonal Optical Feedback in Semiconductor Lasers

Junji Ohtsubo, Yasutoshi Takeuchi, and Rui Shogenji

Faculty of Engineering, Shizuoka University, 3-5-1 Johoku, Hamamatsu, 432-8561 JAPAN  
tajohs@ipc.shizuoka.ac.jp

**Abstract:** Anti-phase oscillations without time delay between TE and TM modes are experimentally and theoretically discussed in orthogonal polarization-rotated optical feedback in semiconductor lasers. The scheme is applied to chaos synchronization.

## 1. Introduction

Chaotic dynamics in edge-emitting semiconductor lasers with optical feedback have been extensively studied for those two decades not only for fundamental interests as a chaotic model but also for high-speed transmitter and receiver systems in chaotic communications [1]. However, almost those works are for the configuration of transverse electric mode (TE mode) optical feedback in TE-mode operating semiconductor lasers. In this report, we present chaotic dynamics of semiconductor lasers subjected to polarization-rotated optical feedback from TE-mode to transverse magnetic mode (TM mode). We first show the TE-TM chaotic dynamics for the system of polarization-rotated optical feedback [2]. Then chaos synchronization between two semiconductor lasers with polarization-rotated optical feedback and polarization-rotated injection is demonstrated. Synchronous oscillations are observed only for lower chaotic signals less than the solitary relaxation oscillation frequency.

## 2. Dynamics of polarization-rotated feedback

We conducted experimental investigations for a semiconductor laser subject to TE-TM polarization-rotated optical feedback. An edge-emitting single-mode laser of a wavelength of 780 nm and a maximum power of 50 mW was used. The fundamental TE mode was rotated 90° by a Faraday rotator together with some polarization optics and then fed back into the laser cavity for the direction of the TM-mode oscillation. Then both TE and TM modes showed chaotic oscillations at the intensity feedback fraction of 13 %. The TE and TM chaotic signals showed an anti-phase correlation without time delay for the frequency components less than the relaxation oscillation, while the chaotic signals covering higher frequency component over the relaxation oscillations showed no correlation. The phenomena are well reproduced by the numerical simulation for the corresponding rate equations by taking into account the small frequency detuning between the TE and TM modes.

## 3. Chaos synchronization

The polarization-rotated systems are applied to chaotic transmitter and receiver and the dynamic characteristics of the chaos synchronization systems are investigated. Fig. 1 shows an experimental example of synchronous waveforms

for the low-pass filtered TE-mode signals of the transmitter and receiver lasers, when the transmitter laser is subjected to polarization rotated feedback and the receiver laser is injected by the polarization-rotated (to the TM-mode direction) signal from the transmitter. From the correlation, we can see anti-phase correlation peak at -5 ns, which is equal to the time of flight for the optical injection from the transmitter to the receiver. This is explained by a simple optical injection. Namely, the TM mode of the receiver is injected by the polarization rotated TE mode from the transmitter, and then the TM-mode of the receiver laser is injection-locked by this mode at in-phase. Then the TE-mode immediately oscillates at anti-phase manner with the TM-mode in the receiver laser. Also we cannot observe any significant correlations for the full frequency band including the main chaotic oscillations of the semiconductor lasers. The results are well reproduced by the numerical simulations using rate equations.

## 4. Conclusions

We have investigated TE-TM dynamics of semiconductor lasers with polarization-rotated optical feedback and found a new correlation scheme of the TE-TM mode dynamics. We have also applied the system as transmitter and receiver for chaos synchronization. The experimental results have been well reproduced by the theoretical model using the rate equations. However, the origin of the frequency dependent correlations between the TE and TM mode oscillations are left for a future issue.

## 5. References

- [1] J. Ohtsubo, Semiconductor Lasers: Stability, Instability and Chaos, 2nd Edition, Springer-Verlag, Berlin (2008).
- [2] Y. Takeuchi, R. Shogenji, and J. Ohtsubo, Appl. Phys. Lett. Vol.93, 181105 (2008).

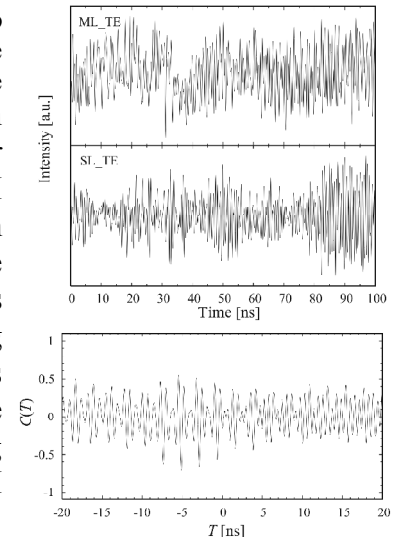


Fig. 1 Upper two traces: chaotic signals of transmitter and receiver lasers less than the relaxation oscillation frequency. Lower plot: correlation of two waveforms.

# Long-Delay Self-Synchronization of a Chaotic Semiconductor Laser

M. Benedetti<sup>1</sup>, V. Annovazzi-Lodi<sup>1</sup>, C. Antonelli<sup>2</sup>, and A. Mecozzi<sup>2</sup>,

<sup>1</sup>Università degli Studi di Pavia, Dipartimento di Elettronica, Via Ferrata 1, I-27100, Pavia, Italy

<sup>2</sup>Università dell'Aquila, Dipartimento di Ingegneria Elettrica e dell'Informazione and CNISM, I-67040, Poggio di Roio, L'Aquila, Italy

Author e-mail address: mauro.benedetti@unipv.it

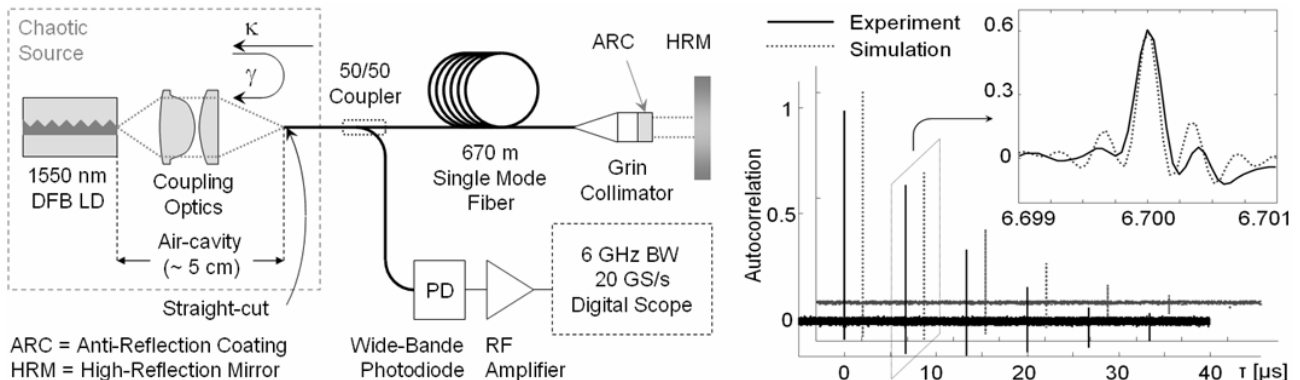
**Abstract:** We show theoretically and experimentally that a chaotic semiconductor laser (CSL) may be self-synchronized by re-injecting a delayed replica of its own output. The ensuing quasi-periodic dynamic is analyzed.

## 1. Introduction

Synchronization of CSLs subject to external optical injection has been widely studied in recent years [1]. When the external source is replaced by a delayed replica, from a distant mirror, of the same laser optical output, we expect the laser to synchronize upon itself [2]. In principle, a perfect self-synchronization would select in the chaotic attractor a periodic trajectory appearing, on a short time scale, indistinguishable from a genuine chaotic trajectory. In this paper, we investigate this regime both experimentally and by numerical simulations based on the Lang-Kobayashi model [3], finding that the CSL achieves imperfect synchronization, whose quality we quantify by observing how the output autocorrelation function peaks decay over the round-trips.

## 2. Self-synchronization experiment and numerical analysis

The experimental set-up is shown in the left part of Fig. 1. The light emitted by a DFB laser diode at 1550 nm is focused into one arm of a 50/50 coupler through a system of optics in a  $\sim 5$  cm air-cavity, and is then back-reflected by a high-reflectivity mirror placed at the other arm, at the end of a 670 m single mode fiber. The laser is led to chaos by means of the Fresnel reflection of the straight-cut fiber tip, which acts as a first partial mirror. The backward delayed replica coming from the long fiber forces the laser to continuously synchronize upon itself (over the round-trip time  $T \approx 6.7 \mu\text{s}$ ), giving rise to a quasi-periodic chaotic waveform. Indeed, as shown in the right side of Fig. 1, measurable autocorrelation peaks appear up to about 5-6 periods.



**Figure 1:** (left) Experimental set-up; (right) normalized laser output autocorrelation function: experimental (solid line), numerical (dotted line); (inset) 2-ns-span direct comparison of the correlation peaks at  $6.7 \mu\text{s}$ .

By computer simulations we have verified that the level of the correlation peaks, hence the quality of the self-synchronization, is independent of the period  $T$ , as long as this remains sufficiently larger than the typical timescales of the standalone laser dynamics (i.e., while working with incoherent injection), whereas it is very sensitive on the relative strength of the two optical injections, namely on the ratio  $\kappa/\gamma$ , where  $\gamma$  is the short-cavity field reflection coefficient, and  $\kappa$  is the injection coefficient of the delayed external field.

## 3. Conclusions

We have experimentally demonstrated that a chaotic semiconductor laser can be synchronized upon itself. Moreover, simulations reproducing the main features of the experiments have confirmed it. Applications simultaneously requiring the noise-like character of a chaotic signal and the regularity of a periodic source can be envisaged (e.g., target displacements measurements, chaotic cryptography).

## 4. References

- [1] S. Donati and C. Mirasso, eds. "Feature section on optical chaos and applications to cryptography," JQE 38-9, 1137-1196 (2002).
- [2] F.T. Arecchi et al., "Delayed self-synchronization in homoclinic chaos," Phys. Rev. E, 65, 046237 (2002).
- [3] R. Lang and K. Kobayashi, "External Optical Feedback Effects on Semiconductor Injection Laser Properties", IEEE JQE, 16, 347 (1980).

# Open vs Closed Loop Receivers in all-Optical Chaos-Based Communication Systems: the Final Round

Miguel C. Soriano, Pere Colet, and Claudio R. Mirasso

IFISC(CSIC-UIB) Instituto de Física Interdisciplinar y Sistemas Complejos, Campus Universitat Illes Balears, E-07122 Palma de Mallorca, Spain  
 Author e-mail address: miguel@ifisc.uib-csic.es

**Abstract:** Our numerical results show that higher privacy and security in chaos-based communications can be achieved when the closed-loop scheme is used in the receiver architecture, instead of the open-loop scheme.

## 1. Introduction

One of the main questions that remains open in chaos-based communications [1] is how much security can this technique offer?

Security aspects are often associated, by many researchers, directly to the receiver architecture although the security is related only indirectly with the receiver characteristics. Security is related to the difficulty of extracting the message from the chaotic carrier without using the authorized receiver.

It is our aim to show that privacy and security in all-optical chaos-based communication systems can only be achieved when small amplitude messages are used, which can be only recovered with a closed-loop receiver. To that end, we have performed numerical simulations using the standard rate equations model for two emitter and receiver lasers unidirectionally coupled [2].

## 2. Main results

To quantify the degree of correlation between the master laser (ML) and the slave laser (SL) we use the average mutual information (MI). MI is a non-linear measure of the similarities between two quantities  $x, y$  and is defined as

$$J_{xy} = -\sum_{i,j} p_{ij} / \log_2 [p_{ij} / (p_i p_j)], \quad (1)$$

where  $p_{ij}$  is the joint probability of  $x = x_i$  and  $y = y_j$ ,  $p_i$  ( $p_j$ ) is the probability of  $x = x_i$  ( $y = y_j$ ). This quantity essentially measures the extra information one gets from a signal when the outcome of the other signal is known. For two independent signals  $p_{ij} = p_i p_j$ , and  $J_{xy}$  is zero. Otherwise,  $J_{xy}$  will be positive, taking its maximum for identical signals.

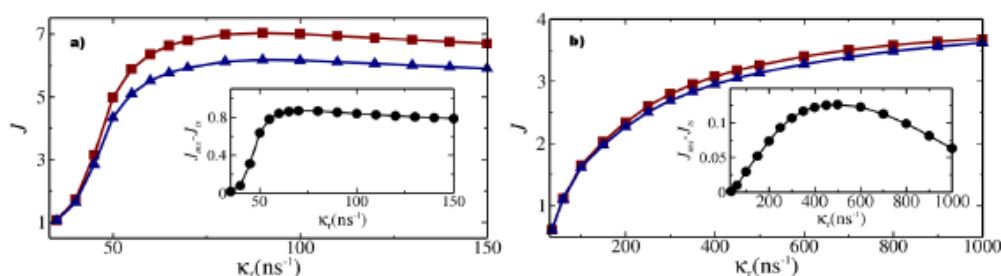


Fig 1: Average mutual information between the ML and SL in the a) closed-loop and b) open-loop scheme vs. coupling strength (triangles for  $J_{tz}$  and squares for  $J_{ms}$ ). The insets show the difference between  $J_{ms}$  and  $J_{tz}$  in both schemes.

Figure 1 shows the MI between the optical intensity of the ML ( $P_m(t)$ ) and SL ( $P_s(t)$ ), denoted as  $J_{ms}$  and the MI between the transmitted signal,  $P_t(t)$ , and the slave signal  $P_s(t)$  ( $J_{tz}$ ), for the closed and open-loop schemes. Both quantities,  $J_{ms}$  and  $J_{tz}$ , are evaluated when a binary message of 1Gbit/s is codified in the ML output. The scheme we choose to encode the information is chaos modulation (CM). In the synchronization regime  $J_{ms} > J_{tz}$  and the receiver is able to filter out the message. It can be seen that the discrimination between the master output and the transmitted signal, i.e.,  $J_{ms} - J_{tz}$  (shown in the insets of the figures), is larger for the closed-loop scheme than for the open one. The better chaos-pass filtering properties of the closed-loop allows for the use of small amplitude encoded messages.

## 3. Conclusions

Our numerical results show that the best and most efficient way to transmit and recover small amplitude messages, which guarantees a certain degree of security in all-optical chaos-based communication systems, is to operate with the closed-loop scheme in the receiver. On the contrary, the open-loop scheme requires large amplitude messages that compromise the security.

## 4. References

- [1] A. Argyris, D. Syvridis, L. Larger, V. Annovazzi-Lodi, P. Colet, I. Fischer, J. Garcia-Ojalvo, C. R. Mirasso, L. Pesquera, K. A. Shore., "Chaos-based communications at high bit rates using commercial fiber-optic links", *Nature* **438**, 343-346 (2005).
- [2] R. Vicente, T. Perez and C. R. Mirasso, "Open versus Closed Loop Performance of Synchronized Chaotic External-Cavity Semiconductor Lasers", *IEEE Journal of Quantum Electronics* **38**, 1197-1204 (2002).



# Synchronization and Message Transmission Using Coupled Semiconductor Lasers with Filtered Optical Feedback

Flavio Ruiz-Oliveras<sup>1,2</sup>, Miguel C. Soriano<sup>2</sup>, Pere Colet<sup>2</sup> and Claudio R. Mirasso<sup>2</sup>

1. Instituto de Física Interdisciplinar y Sistemas Complejos IFISC (CSIC-UIB),  
Campus Universitat Illes Balears, E-70122 Palma de Mallorca Spain.

2. Centro de Investigaciones en Óptica, A.C., Loma del Bosque 11, 37150, León Mexico.  
Author e-mail address: flavio@ifisc.uib-csic.es

**Abstract:** We study numerically the dynamics of two unidirectionally coupled semiconductor lasers subject to optical feedback. We find that this scheme improves the performance in optical chaosbased communication systems when compared with the conventional feedback one.

## 1. Introduction

Synchronization of chaotic semiconductor lasers (SCL) has great research interest due to its potential application in secure communication systems [1]. To transmit information the message has to be encoded in the chaotic output of the emitter system. Up to now, the full wide bandwidth generated by the emitter has been transmitted to the receiver to achieve synchronization. However, most communication channels suffer from band width limitations, which can degrade the synchronization properties of chaotic systems [2]. Consequently, sources generating chaos with narrower spectrum are desired. A major advantage of filtered feedback system is that they can produce chaotic emission of narrow bandwidth [2], which could reduce the synchronization degradation due to bandwidth limitations. Furthermore, the fact that high frequencies are suppressed favours the synchronization between emitter and receiver [3] and the quality of transmission increases.

## 2. Main body

SCL subject to FOF can be modelled via rate equations for slow varying amplitude of the electric field. This situation can be modelled using a modification of the Lang-Kobayashi equations [4], which account for a single reflection from the external mirror. A proper manipulation of these equations is needed to add the characteristics of the filter mirror [5]. To measure the synchronization between the emitter and the receiver, we calculate the cross-correlation between them for different filter bandwidths ( $\Lambda$ ). Figure 1 shows the cross-correlation as a function of the coupling parameter between the emitter and the receiver for different filter bandwidths in a closed loop scheme. For narrower filters the coupling required to obtain synchronization is smaller. To evaluate the message quality in the receiver we compute the Q-factor. Figure 2 shows the Q-factors as a function of the coupling parameter for a transmission rate of 1Gb/s and different bandwidths.

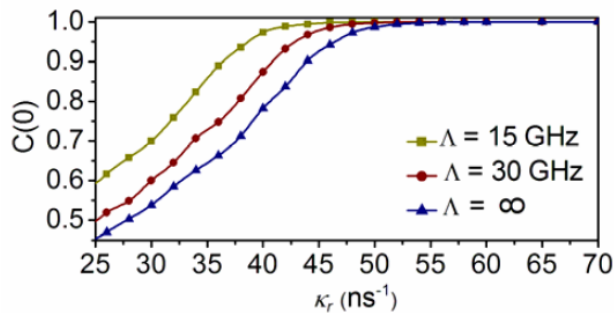


Figure 1. Cross-correlation between emitter and receiver as a function of the coupling strength.

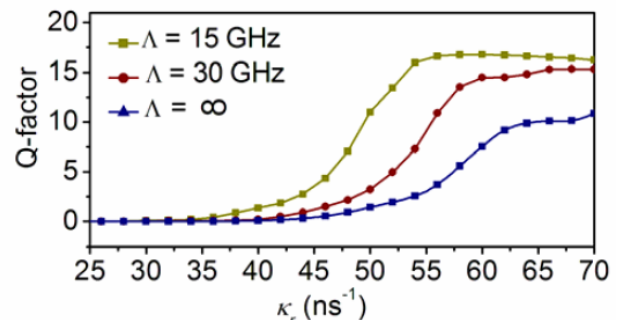


Figure 2. Q-Factor of the recovered message as a function of the coupling strength.

## 3. Conclusions

The reduction in complexity of the chaotic waveform by filtering high frequencies leads to a better synchronization between emitter and receiver. With the bandwidth reduction smaller coupling strengths are required and the higher cross-correlations yield better message extractions, making this new scheme very attractive for practical applications.

## 4. References

- [1] S. Donati et al., "Feature sections on optical chaos and applications to cryptography," IEEE JQE **38**, 1138- 1140 (2002).
- [2] M. Kim et al., "Synchronization of unidirectionally coupled Mackey-Glass analog circuits with frequency bandwidth limitations," Phys. Rev. E, **74**, 016211 (2006).
- [3] M. C. Soriano et al., "Synchronization properties of coupled semiconductor lasers subject to filtered optical feedback," Phys. Rev. E, **78**, 046218 (2008).
- [4] Roy Lang et al., "External optical feedback effects on semiconductor injection laser properties," IEEE JQE **16**, 347- 355 (1980).
- [5] M. Yousefi et al., "Dynamical behavior of a semiconductor laser with filtered optical feedback," IEEE JQE **35**, 970-976 (1999).

# Closed-loop synchronization in photonic-integrated chaos emitters

A. Argyris<sup>(1)</sup>, A. Hamacher<sup>(2)</sup>, A. Bogris<sup>(1)</sup>, K.E. Chlouverakis<sup>(1)</sup>, D. Syvridis<sup>(1)</sup>  
(1) Department of Informatics and Telecommunications, University of Athens, Ilisia, Athens, 15784, Greece  
(2) Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institute, 10587, Berlin, Germany  
Corresponding author e-mail: [argiris@di.uoa.gr](mailto:argiris@di.uoa.gr)

**Abstract:** The synchronization of closed-loop receiver architecture to a chaotic signal emitted by a photonic integrated chaotic oscillator is studied. A phase matching condition and precise temperature control are prerequisites for stable synchronized operation.

## 1. Introduction

Photonic integrated devices that employ semiconductor lasers with additional controllable sections that perturb the solitary laser operation prove to be efficient in terms of their potential to generate non-linear dynamics [39-42]. The device presented very recently in [43] exhibits a fully-controllable rich dynamical behavior, providing a broad chaotic spectrum under specific operating conditions. In the present work a matched pair of such devices is evaluated in terms of their ability to synchronize in a closed-loop receiver configuration, which means that the receiver is an identical device to the emitter, operating in optimized conditions.

## 2. Results and discussion

Closed-loop synchronization can be achieved with very precise matching of the external cavity lengths between the emitter and the receiver. The monolithic fabrication process can guarantee identical cavity lengths for all devices; nevertheless, even if a small fine tuning in the round trip time of the electric field is needed within a cavity for accomplishing the optimal synchronization conditions, the appropriate biasing of the active phase section that is included in the device will provide that.

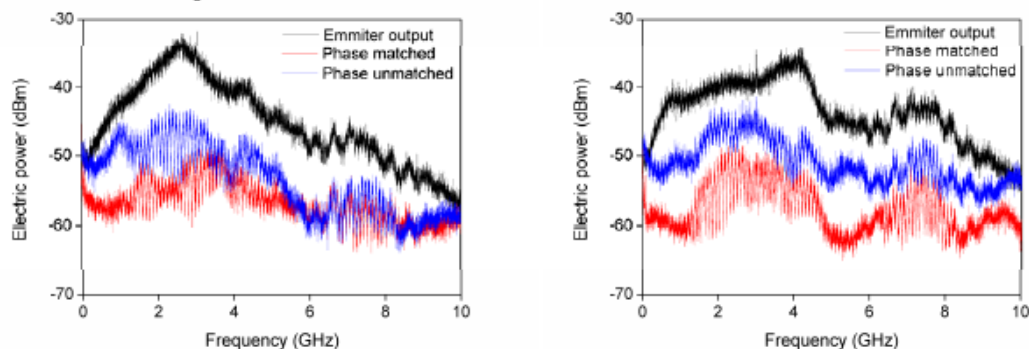


Fig. 1: Experimental microwave spectra of the monolithic integrated emitter optical output (black) and the subtraction signal between the hybrid emitter and the synchronized closed-loop receiver for phase-matched (red) and phase-unmatched (blue) conditions, for a feedback strength  $k_f$  of  $\sim 3.3\%$  (left) and  $\sim 5\%$  (right).

The dependence of the phase matching condition in the synchronization process of short-cavity devices is presented, after considering two different feedback conditions for both emitter and receiver devices, which are determined by accordingly biasing a gain/absorption section ( $G/A_s$ ) that is also integrated in the device. When  $G/A_s$  is positively connected but biased with 0mA, the feedback strength lays in adequate levels to generate powerful chaotic dynamics gathered around the laser's relaxation frequency (fig. 1, left). Cancellation maximum reaches up to 20dB in the most powerful spectral regions, when a phase matched condition is applied. On the contrary, unmatched phase conditions will result in severe synchronization efficiency deterioration. When feedback is increased (fig. 1, right) the spectral distribution of the chaotic carrier is changed as a result of the much different dynamics that prevail in the device. Under appropriate phase matching, a good synchronization performance is recorded, with a cancellation maximum over 20 dB. As it can be also observed, the cancellation error in some spectral regions emerges from intense fringes. These fringes are attributed to the local reflection of the emitter's injected field at the receiver's laser-fiber interface and are caused by the correlation that exists between the emitter's output and the same delayed chaotic signal reflected at the receiver's laser. A better performance should be expected in terms of synchronization if minimization of this back-reflection could be achieved.

- [1] T. Franck et al, "Synchronization phase diagrams of monolithic colliding pulse mode-locked lasers," IEEE Phot. Techn. Lett. 8, 40-42 (1996)
- [2] S. Bauer et al, "Nonlinear dynamics of semiconductor lasers with active optical feedback," Phys. Rev. E, 69, 016206 (2004).
- [3] O. Ushakov et al, "Self-organization in semiconductor lasers with ultrashort optical feedback," Phys. Rev. Lett. 92, 043902 (2004)
- [4] M. Yousefi et al, "New role for nonlinear dynamics and chaos in integrated semiconductor laser technology," Phys. Rev. Lett. 98, 044101 (2007)
- [5] A. Argyris, et al, "A photonic integrated device for chaos applications in communications", Phys.Rev. Lett., 100, 194101, (2008)

# Security of chaos encryption in photonic integrated circuits

A. Bogris<sup>(1)</sup>, A. Argyris<sup>(1)</sup>, K.E. Chlouverakis<sup>(1)</sup> and D. Syvridis<sup>(1)</sup>

<sup>(1)</sup> Department of Informatics and Telecommunications, University of Athens, Ilisia, Athens, 15784, Greece

Corresponding author e-mail: [abogris@di.uoa.gr](mailto:abogris@di.uoa.gr)

**Abstract:** In this report we try to clarify significant issues regarding the security provided by telecommunication systems incorporating chaotic encryption.

## 1. Introduction

In this paper we try to explore theoretically the effect of codification method and the receiver's architecture on the sensitivity of message extraction to parameter mismatch. Our perception is that FEC (Forward Error Correction) or other techniques can not be omitted since security must be enhanced and investigated more thoroughly due to the analogue nature of our configuration. However, the concept of chaos synchronization is meaningful in the case where parameter mismatch is affecting significantly the message extraction. In that way, FEC or other techniques will more easily discriminate arbitrary receivers from matched ones. Our report studies the closed and open loop configurations in terms of baseband and subcarrier modulation [1] as a function of message amplitude considering significant parameter deviations.

## 2. Results and discussion

In real life situations the transmitter and receiver devices will not be perfectly matched to each other. Moreover, other parameters such as noise and transmission effects will further worsen the synchronization between transmitter and receiver. In any case, this will lead to the requirement of higher message amplitudes for the achievement of the required SNR performance. Therefore it is helpful to calculate SNR of the decoded message in a noisy environment for both matched and deviating devices in open and closed loop configurations and for baseband and subcarrier modulation techniques [2]. Open loop is evidently less efficient for such low message amplitudes.

Utilizing subcarrier technique, the message decoding efficiency is worse compared to the baseband scenario, expected due to the encryption of the message inside the most powerful part of the chaotic spectrum. The SNR difference between the matched and deviating devices is greater than 4dB and at low amplitudes reaches up to 8dB. This is an indication that deviating devices manifest less efficient synchronization at higher frequencies. Indicatively we report that for message amplitude equal to 22% and subcarrier frequency equal to 7GHz, the SNR for matched devices is 16dB while for unmatched devices is 9.5dB. Since  $\text{SNR} > 10\text{dB}$  are large enough to provide BER less than  $10^{-3}$ , we observe (fig. 1) that for modulation depth equal to 12% and subcarrier frequency 6.2GHz, the matched pair SNR is above threshold (12.2dB) while the slightly unmatched pair SNR is far below threshold (4.5dB, or  $\text{BER} > 10^{-1}$ ).

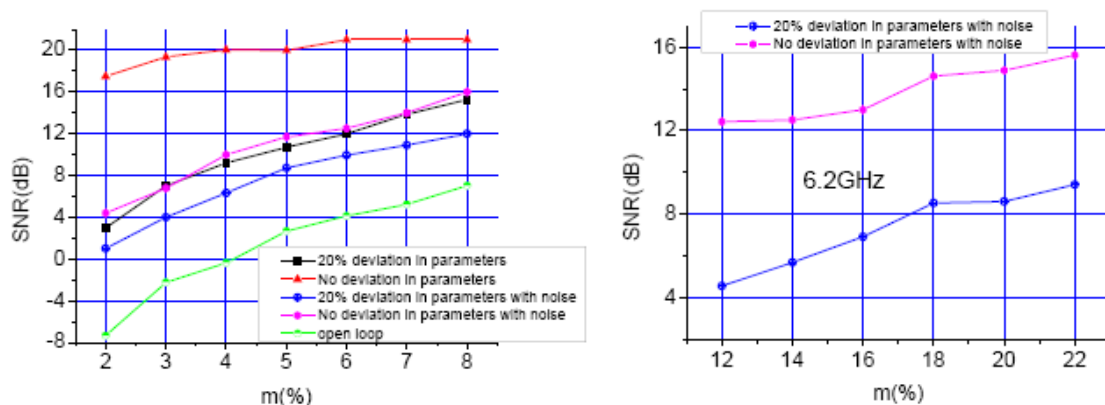


Fig.1 SNR of the decoded message for closed loop receiver as a function of message amplitude. Left: For chaos modulation, baseband and right: For chaos modulation, subcarrier.

## 3. Conclusions

Closed loop is the appropriate scheme in order to exploit the concept of chaos synchronization. The parameter mismatch affects the message extraction. As the mismatch increases, the amplitude of the message for which adequate SNR performance is achieved should be analogously increased. Additionally, subcarrier modulation technique has the ability to discriminate in a larger extend matched from deviating devices in terms of SNR performance of the decoded message compared to baseband modulation.

## 4. References

- [1] A. Bogris *et al.*, "Subcarrier Modulation in All-optical Chaotic Communication Systems," *Opt. Lett.*, vol. 32, pp. 2134-2136 (2007).
- [2] A. Argyris *et al.*, "Subcarrier modulation boosts chaotic optical systems to error-free performance", *Optical Fiber Communications Conference OFC2009*, JWA-41, San Diego, California, U.S.A. (2009).

# Breaking Chaotic Encryption using PDE's

A. Jacobo, M. C. Soriano, R. M. Nguimdo, P. Colet, C. Mirasso

Instituto de Física Interdisciplinar y Sistemas Complejos IFISC (CSIC-UIB), E-07122, Campus Universitat de les Illes Balears, Palma de Mallorca, Spain

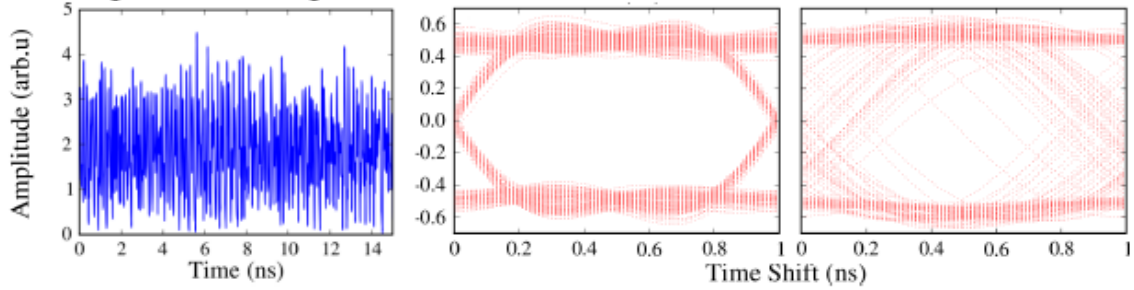
**Abstract:** We show how, using the Ginzburg-Landau Equation, it is possible to decrypt a message encoded using Chaos Modulation. Then we introduce a new encoding method invulnerable to this attack.

In the context of chaotic communications using semiconductor lasers in many instances the message is codified such that the mean power of a bit 1 differs from that of bit 0. For example, in Chaos Modulation the transmitted signal is  $P_t(t) = (1 - \varepsilon m(t))P_m(t)$ , where  $\varepsilon$  is the message modulation amplitude,  $m(t)$  is the message being transmitted and  $P_m(t)$  is the chaotic carrier.

We explore the possibility of using PDE's to filter the chaos and recover the message. In particular we consider the Ginzburg Landau Equation (GLE) in one dimension with an external forcing as a filter to find changes on the mean value and to recover the message:

$$\partial_t \psi(x) = d \cdot \partial_x^2 \psi(x) + \psi(x) - \psi(x)^3 + b \cdot h(x)$$

where  $\psi$  is the field,  $d$  is the diffusion constant and  $b$  is the forcing strength and  $h(x)$  is the forcing, which here is directly related to the transmitted signal. Applying the GLE dynamics to  $h(x)$  is possible to recover the encrypted message, as shown in Fig. 1.



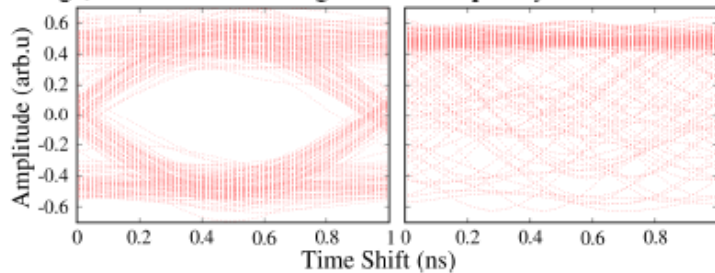
**Fig. 1** From left to right: Transmitted signal ( $\varepsilon=0.04$ ). Eye diagram of the recovered message by the authorized receiver. Eye diagram of the recovered message by the CGLE filter ( $d = 1$ ;  $r = 0.65$ ).

Despite that the eye diagram of the recovered message using the GLE is not as good as the eye diagram obtained by the authorized receiver, it still good enough to recover the message. The GLE method works because it is capable of detecting the changes on the mean value of the signal because of the presence of the bits '0' and '1'.

To improve the security, we propose a new encoding method, where the transmitted signal is formed according to the expression:

$$P_t(t) = (1 - \delta m(t))P_m(t) + \delta m(t)\bar{P}_m,$$

where  $\bar{P}_m$  is the mean of the chaotic carrier. The last term in this equation compensates for the changes in the mean value of the transmitted signal due to the message. The compensation term is chosen in such a way that  $\langle P_t(t) \rangle = \langle P_m(t) \rangle = \bar{P}_m$  at any given time. In Fig. 2 we show how with this method the authorized receiver is able to recover the message, but the GLE filtering method completely fails to decode the message.



**Fig. 2** Left: Eye diagram of the recovered message by the authorized received with the new encryption method. Right: Eye diagram of the message recovered by the GLE filter.

Finally, we also analyze the performance of an electro-optic encoding scheme against attacks performed with this method.

# Unmasking chaotic cryptosystems based on delayed optoelectronic feedback

S. Ortín<sup>(1)</sup>, M. Jacquot<sup>(2)</sup>, L. Pesquera<sup>(1)</sup>, M. Peil<sup>(2)</sup>, L. Larger<sup>(2)</sup>

(1) Instituto de Física de Cantabria (CSIC-Universidad de Cantabria), Avda. Los Castros s/n, E39005, Santander, Spain.

[pesquerl@ifca.unican.es](mailto:pesquerl@ifca.unican.es)

(2) UMR CNRS FEMTO-ST 6174/Optics Dpt, Université de Franche-Comté, 25030 Besançon Cedex, France

**Abstract:** A message encoded in a high-dimensional ( $D>100$ ) chaotic transmitter based on delayed optoelectronic feedback is recovered by using a neural network model extracted from experimental time series.

Recent results provide a convincing proof-of-practical-concept for optical chaos communications technology [1]. However, security of these systems remains the key issue to be addressed. We have recently shown [2] that the nonlinear dynamics of a chaotic transmitter based on delayed optoelectronic feedback [3] can be reconstructed from experimental data. In this work we show that the message can be recovered by using the nonlinear model extracted from experimental time series as a receiver. The nonlinear dynamics can even be reconstructed from a transmitted signal that includes the message.

The transmitter consists of a DBR laser with a feedback loop formed by a delay line and an optical device with a nonlinearity in wavelength [3]. The number of oscillations of the nonlinear function depends on the feedback strength  $\beta$  that also determines the strength of the nonlinearity. The response time of the loop is  $8\mu\text{s}$ . Data acquisition is performed with a 8 bits resolution oscilloscope. We have first estimated the delay time  $T=476\mu\text{s}$ . Then a new type of modular neural network (MNN) is used to obtain the transmitter nonlinear dynamics. The MNN has two modules: one for the non-feedback part with input data delayed by the sampling time  $\Delta=1\mu\text{s}$ , and a second one for the feedback part with input data delayed by the feedback time  $T$ . We use 25000 points to train the NN. A training error around 5% is achieved for all the available values of the nonlinear strength  $\beta$ . The noise level mainly determines the training error. The nonlinear function of the type  $\sin^2$  is extracted by the MNN. This recovery deteriorates when the number of oscillations increases with  $\beta$ . It is checked using chaotic synchronization that the MNN describes correctly the transmitter nonlinear dynamics, although the dimension of the chaotic attractor is very high ( $>10^2$ ). Similar results are obtained when the MNN is trained from a transmitted signal that includes a 2 kHz square function message with a message-to-chaos ratio of  $-8\text{dB}$ . This message can be recovered by using the MNN model as an unauthorized receiver. Figure 1 shows the transmitted signal and the recovered message for a moderate-to-strong nonlinearity (5 maxima in the nonlinear function). Similar results are obtained when the MNN is trained by using the transmitted signal without and with message. The power spectrum of the recovered message displays a strong peak at 2 kHz with a signal-to-noise ratio of 27 dB.

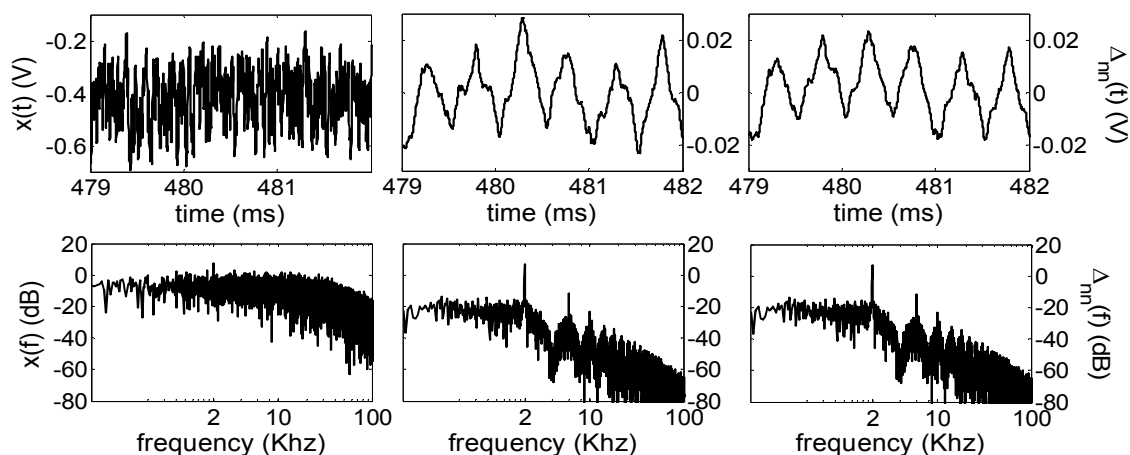


Fig. 1 Left: Transmitted signal with message (top) and its power spectrum (bottom). Middle (right): recovered message (top) and its power spectrum (bottom) when the NN model is extracted from the experimental time series without (with) message.

In conclusion, chaotic cryptosystems based on optoelectronic feedback with one fixed delay are not safe. We have shown that the message can be recovered by using a NN model as an unauthorized receiver. This model can even be extracted from a transmitted signal that includes the message.

[1] A. Argyris et al., Nature **438**, 343-346 (2005).

[2] S. Ortín et al., Proceedings CLEO-E/IQEC, JS11-3-THU (2007).

[3] J. Goedgebuer et al., Phys. Rev. Lett. **80**, 2249-2252 (1998).

# Multiplexing Information Using Chaotic Oscillators with Multiple Feedback Loops

D. Rontani<sup>1,2,3</sup>, A. Locquet<sup>1</sup>, M. Sciamanna<sup>2</sup>, D.S. Citrin<sup>1,3</sup>

1. UMI 2958 GeorgiaTech-CNRS, Georgia Tech Lorraine, 2-3 Rue Marconi, F-57070 Metz, France

2. Supélec LMOPS CNRS UMR 7132, 2 Rue Edouard Belin, F-57070 Metz, France

3. School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia 30324-0250, USA

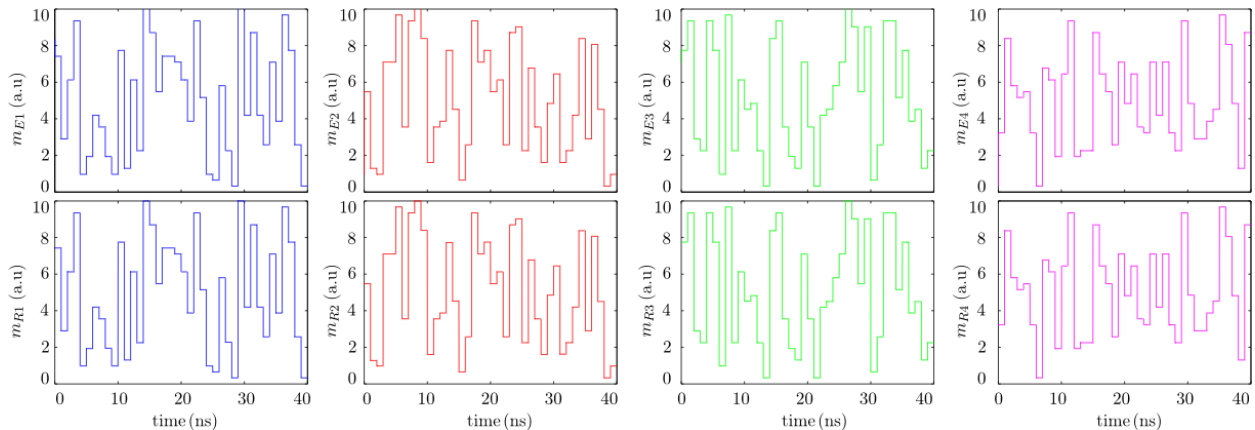
**Abstract:** We propose a general method for constructing multi-message chaos-based communications schemes based on the use of a single nonlinear oscillator subjected to multiple delayed feedbacks.

Chaotic dynamics produced by nonlinear oscillators can be used to convey [1] or encrypt [2] information-bearing messages. In particular, optical chaos has proven to be a practical way of encrypting, at the physical level, a multi-Gbit/s information-bearing message [3].

One aspect of chaos-based communications that deserves further attention is the simultaneous transmission of several independent messages. The solutions that have been proposed so far either require the use one different chaotic oscillator per message [4,5], or involve complex computations at the receiving end to decode the message [6].

We propose a general method for constructing a multi-message communications scheme, based on a single nonlinear oscillator, which allows for simple message decoding. The emitter is built by adding to the nonlinear oscillator as many feedback loops as there are messages to be sent. The messages are inserted into these feedback loops leading to a chaotic oscillator dynamics to which the various messages participate. A scalar function of the chaotic state is sent to an array of open-loop receivers which exploit synchronization to recover the different messages efficiently.

We apply our method to a numerical model of an optoelectronic oscillator exploiting the nonlinear regime of a Mach-Zehnder intensity modulator [7]. The resulting chaotic fluctuation of modulated light intensity is used to convey several messages at the same time. At the receiving end, the messages are extracted by exploiting synchronization phenomena between the chaotic light and receiver Mach-Zehnder modulators. Figure 1 represents the transmission of four pseudo-random digital messages, encoded on 32 levels at a rate of 1 giga symbol per second. It is seen that the levels are correctly decoded for all four messages.



**Fig. 1** The first row represents four 32-level digital messages  $m_{Ei}$  at 1 Gsymbol/s which are used to drive the nonlinear dynamics of a Mach-Zehnder modulator. The second row represents the decoded messages  $m_{Ri}$  at the receiving side.

Because of its simplicity, we are hopeful that our method will prove helpful in building multi-user and high-bit-rate chaos-based communication and encryption systems.

## References

- [1] L.M. Pecora and T.L. Carroll, "Synchronization in chaotic systems", *Phys. Rev. Lett.* **64**, 821 (1990).
- [2] K.M. Cuomo and A.V. Oppenheim, "Circuit implementation of synchronized chaos with applications to communications", *Phys. Rev. Lett.* **71**, 65 (1993).
- [3] A. Argyris, D. Syvridis, L. Larger, V. Annovazzi-Lodi, P. Colet, I. Fischer, J. García-Ojalvo, C. R. Mirasso, L. Pesquera and K. A. Shore, "Chaos-based communications at high bit rates using commercial fibre-optic links", *Nature* **438**, 343 (2005).
- [4] T. Matsuura, A. Uchida, and S. Yoshimori, "Chaotic wavelength division multiplexing for optical communication", *Opt. Lett.* **29**, 2731 (2004).
- [5] S. Sano, A. Uchida, S. Yoshimori, and R. Roy, "Dual synchronization of chaos in Mackey-Glass electronic circuits with time-delayed feedback", *Phys. Rev. E* **75**, 016207 (2007).
- [6] W.M. Tam, F.C.M. Lau, and C.K. Tse, "Exact analytical bit error rates for multiple access chaos-based communication systems", *IEEE Trans. Circ. Syst. II* **51**, 1868 (2004).
- [7] J.-P. Goedgebuer, P. Levy, L. Larger, C.-C. Chen, and W. T. Rhodes, "Optical communication with synchronized hyperchaos generated electrooptically", *IEEE J. Quantum Electron.* **38**, 1178, 2002.

# Experiment on fast random bit generation using chaotic semiconductor lasers

Atsushi Uchida<sup>1</sup>, Kazuya Amano<sup>2</sup>, Masaki Inoue<sup>2</sup>, Kunihito Hirano<sup>2</sup>, Sunao Naito<sup>2</sup>, Hiroyuki Someya<sup>2</sup>,  
Isao Oowada<sup>2</sup>, Shigeru Yoshimori<sup>2</sup>, Kazuyuki Yoshimura<sup>3</sup>, and Peter Davis<sup>3</sup>

1. Department of Information and Computer Sciences, Saitama University, 255 Shimo-Okubo, Sakura-ku, Saitama city 338-8570, Japan

2. Department of Electronics and Computer Systems, Takushoku University, 815-1 Tatemachi, Hachioji, Tokyo 193-0985, Japan

3. NTT Communication Science Laboratories, NTT corporation, 2-4 Hikaridai, Seika-cho, Soraku-gun, Kyoto 619-0237, Japan

**Abstract:** Random bit sequences that pass standard tests of randomness are generated at fast rates of up to 1.7 Gbps by directly sampling the output of two chaotic semiconductor lasers.

## 1. Introduction

Random numbers are used in transactions on the internet to ensure confidentiality, authentication, and data integrity. Future deployments of quantum cryptography systems will require the generation of trusted random numbers to select photon detection parameters. Efforts are being made to develop faster and more reliable random-number generators and establish better standards for random number generation based on stringent tests of randomness. Random phenomena such as photon noise, thermal noise in resistors, and frequency jitter in oscillators have been used as physical entropy sources for non-deterministic random-number generators. However, previous implementations of non-deterministic generators have been limited to much slower rates than pseudo-random generators due to limitations of the mechanisms for extracting bit sequences from physical noise without degrading statistical properties. Typical rates are 10 Mbps using electronic oscillator jitter and 4 Mbps using quantum optical noise [1]. Here, we report success in generating random bit sequences at rates up to 1.7 Gbps using high-band chaotic semiconductor lasers [2]. Chaotic systems generate large-amplitude random signals from microscopic noise by nonlinear amplification and mixing mechanisms. We make use of chaos in lasers to achieve efficient and stable generation of random bits at high frequencies.

## 2. Experimental results

We use two semiconductor lasers with chaotic intensity oscillations for generating random bit sequences. The output intensity of each laser is converted to an a.c. electrical signal by photo detectors, amplified and converted to a binary signal using a 1-bit analog-to-digital converter (ADC) driven by a fast clock. The ADC first converts the input analog signal into a binary signal by comparing with a threshold voltage, and then samples the binary signal at the rising edge of the clock. The binary bit signals obtained from the two lasers are combined by a logical exclusive-OR (XOR) operation to generate a single random bit sequence. No other digital postprocessing is required. The parameters of the two lasers are adjusted to detune their chaotic oscillations and the threshold levels of the ADC adjusted to equalize the ratio of 0 and 1 at the XOR output. The temporal waveforms of two chaotic laser output, the 1.7-GHz clock and the corresponding random bits sequences with the NRZ (Non-return to zero) format are shown in Fig.1.

To evaluate the statistical randomness of digital bit sequences we used the standard statistical test suite for random number generators provided by the National Institute of Standard Technology (NIST) and the Diehard test suite [3]. Bit sequences obtained from the experiment passed all of the NIST and Diehard tests.

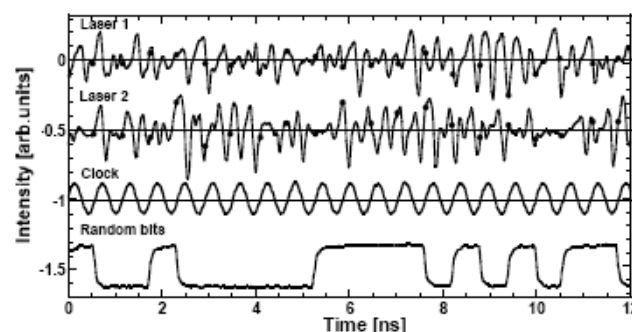


Fig. 1 Temporal waveforms of chaos, clock and random bits.

## 3. Conclusions

We have demonstrated that continuous streams of random bit sequences that pass standard tests of randomness are generated at fast rates of up to 1.7 Gbps by directly sampling the output of two chaotic semiconductor lasers. The performance of random number generation can be greatly improved by using chaotic laser devices as physical entropy sources.

## 4. References

[1] M. Bucci, et al., *IEEE Trans. Comput.* 52, 403-409 (2003); J. F. Dynes, et al., arxiv/0801.4111v1 (july 2008).

[2] A. Uchida, et al. *Nature Photonics* 2, 728-732 (2008).

[3] A. Rukhin, et al. NIST, Special Publication 800-22. <http://csrc.nist.gov/mg/>; G. Marsaglia, DIEHARD: <http://www.stat.fsu.edu/pub/diehard/>.

# Correlation Chaotic Optical Time-Domain Reflectometry

Yun-Cai Wang\*, An-Bang Wang

Department of Physics, College of Science, Taiyuan University of Technology, 79 West Yingze Street, Taiyuan, 030024, China  
Corresponding author: wangyc@tyut.edu.cn

**Abstract:** A correlation chaotic optical time domain reflectometry is proposed and experimentally demonstrated for detecting reflection events. The results show it has the merit of range-independent spatial resolution of 6cm.

## 1. Introduction

The developing FTTH and RoF bring a mass of local fiber networks, and thus give a challenge to high-spatial-resolution optical time-domain reflectometry (OTDR). For the conventional OTDR probing fiber with single optical pulse, the trade-off between resolution and dynamic range limits its resolution to about tens of meters [1]. Although the trade-off can be overcome by the correlation OTDR using pseudorandom pulse sequences (PNS), but the resolution is also limited by the electronic bandwidth [2]. By adding a degree of freedom, a laser diode can emit chaotic light with  $\sim$ GHz bandwidth. Utilizing the correlation of chaotic laser light, Liu *et al.* proposed a concept of chaotic lidar [3]. In this paper, we exploit the application of chaotic laser in OTDR and a correlation chaotic OTDR is proposed and demonstrated experimentally.

## 2. Experimental setup and results

The experimental setup of the proposed OTDR is shown in Fig.1. The chaotic light source is a 1.55- $\mu$ m DFB laser with optical feedback from a 6-m fiber ring cavity, and its output features true randomness and 6.2-GHz bandwidth, as shown in Fig.2(a) and (b). The chaotic output is split into two beams after an amplifier: one serves as the probe light and the other serves as reference light. Both the echo and reference light are converted to electrical signals by two identical photodetectors and recorded by a real-time oscilloscope, and their correlation can be calculated by using a computer.

We used fiber endpoint as reflection event for demonstration. The tested fibers were 1550nm single-mode fibers with loss coefficient 0.2 dB/km. After amplified by EDFA, the average power of the probe and the reference light are 11.2dBm and -8.76dBm, respectively. We firstly calibrated the zero point by adjusting fiber delay-line in the reference channel. Depicted in Fig.2 (c), three correlation traces clearly show each reflection distance from the launching port. Further, the detection of dual-reflection event is demonstrated by injecting the probe light simultaneously into two open-ended fibers with 0.8-m length difference via a 3dB coupler, and the result is shown in Fig.2 (d).

The spatial resolution is only 6cm shown in Fig.2 (e), experimentally examined by using a tunable fiber delay-line with 0.05-mm step. Actually, the resolution only depends on the bandwidth of probe light and is independent of the measuring distance. Note that the 6-cm resolution is limited by the oscilloscope bandwidth of 0.5GHz, and the broadband advantage of chaotic light was not effectively utilized. In fact, it is already enough for diagnoses in small sized network.

To evaluate the actual dynamic range, we studied the effect on the correlation trace's sidelobe level (PSL) of the probe light power loss, which is equivalent to the fiber attenuation or length. Shown in Fig.2 (f), the power loss below 7dB has no effect on the PSL, and when the power loss increases to 17dB, the PSL increases to -3dB. This indicates that the dynamic range of the chaotic OTDR can reach 17dB. The dynamic range can be enhanced by developing a method (like Gray code) which will reduce significantly the sidelobe level.

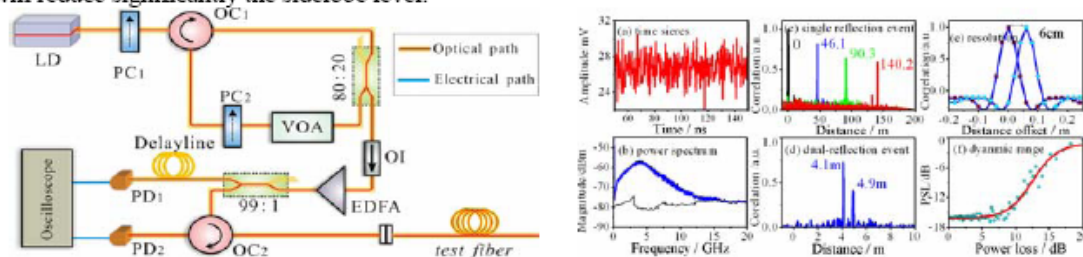


Fig.1 Experimental setup of the proposed chaotic OTDR

Fig.2 (a, b) time series and spectrum of chaotic probe light; (c, d) detection of single- and dual-reflection events; (e, f) resolution and dynamic range

## 3. Conclusions

We proposed a correlation chaotic OTDR and experimentally achieved measuring reflection events. A range-independent high resolution of 6cm and a dynamic range of 17dB were obtained. We believe it can also measure the fiber loss and Rayleigh scatters just like the conventional correlation OTDR does.

## 4. References

- [1]. P. Healey, "Instrumentation principles for optical time domain reflectometry," *JPhysE* 19, 334-341 (1985).
- [2]. D. Lee et al., "SNR enhancement of OTDR using biorthogonal codes and generalized inverses," *IEEE PTL* 17, 163-165 (2004).
- [3]. F. Lin et al., "Chaotic lidar," *IEEE JSTQE* 10, 991-997 (2004).
- [4]. A. B. Wang et al., "Enhancing the bandwidth of the optical chaotic signal generated by semiconductor laser with optical feedback," *IEEE PTL* 20, 1633-1635 (2008).





# Evaluating Free Space, Optical Injected Chaotic Steganography

Marco Corà, Leonora Ursini, Marco Santagiustina

Dipartimento di Ingegneria dell'Informazione, via Gradenigo 6/B, 35131, Padova, Italy  
e-mail:ursinile@dei.unipd.it

**Abstract:** The hiding and recovering quality of a free space, optical injected chaotic transmission system are numerically evaluated; impairments due to path attenuation are overwhelming and cause synchronization loss.

Free space optics links (FSOL) are communication systems with a great potential owing to their great capacity, low cost, simplicity of deployment and the absence of license requirements [1]. The overall security of a FSOL, whose signal is diffused might be highly enhanced by hardware techniques based on the physical principles of photonics like the optical chaotic steganography (OCS) method, based onto the synchronization of the slave laser (SL) to the master laser (ML); encouraging experimental results have been recently obtained [2].

The FSOL is affected by three main impairments: the attenuation, the multiple path dispersion and the amplification and environmental noise [1]; here, the effects of the first term are numerically evaluated in a OCS based on optical injection of the received signal into SL.

The model of the ML and SL emission is based on the Lang-Kobayashi rate equations with parameters similar to those that can be found in [3]; the synchronization process is based on a pure optical injection of the received signal into the SL, much similarly to what is usually performed in fiber optics systems [3]. Before SL injection, the received signal, at 1550nm, is optically amplified by an Erbium doped fiber amplifier. The OCS is obtained by modulating the ML waveform [3] by an information message that is a 128-bit long, non-return-to-zero (NRZ) or Manchester coded (MC) [3] sequence at different bit rates from 200 to 900Mbit/s. The multiple path dispersion, the amplification and environmental noise are not considered, in order to determine only the effects of attenuation. The model of the wireless infrared channel is that of ref. [4] and it is better described as follows. The transmitter and receiver are placed at a distance  $d=1\text{m}$  on the line of sight (LOS), perfectly pointed one toward the other though light emission is spread by  $120^\circ$ . The model of [4] was used to calculate the transfer function for the power of the wireless infrared channel.

The quality of information signal hiding is very good, as shown in Fig. 1 where the Q-factor is evaluated for the coded (TX) and decoded (RC) signals at different bit rates for MC. Hidden signal condition ( $Q < 6\text{dB}$ , [3]) is always well attained; results for NRZ format are similar. The Q-factor of the received signal is maximum for perfect path loss compensation, but achieving a good quality of the recovered signal ( $Q > 15\text{dB}$ ) is very critical; slightly larger or smaller gain causes lack of synchronization. This is shown in Fig. 2 where the dependence of the Q-factor on the receiver amplifier gain is presented for a MC signal at 900Mbit/s. Note that losses are very large, even at short distances, due to the beam diffraction and so the required optical gain can be too large for being practical. So, the simple optically injected scheme is not practical and electro-optical schemes should be preferred [2].

## References

- [1] J.M. Kahn, J.R. Barry, "Wireless infrared communications", Proc. IEEE 85, 265-298 (1997).
- [2] V. Annovazzi-Lodi, G. Aromataris, M. Benedetti, S. Merlo, "Secure Chaotic Transmission on a Free-Space Optics Data Link", IEEE Journal of Quantum Electronics 44, 1089-1095 (2008).
- [3] L. Ursini, M. Santagiustina, V. Annovazzi-Lodi, "Enhancing Chaotic Communication Performances by Manchester Coding," IEEE Phot. Techn. Lett. 20, 401-403 (2008).
- [4] J.B. Carruthers, P. Kannan, "Iterative site-based modeling for wireless infrared channels", IEEE Trans. Antenna and Propagation 50, 759-765 (2002).

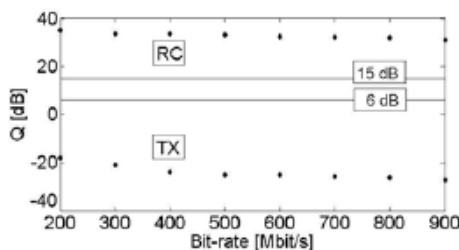


Fig.1: Q-factor as a function of the bit rate for MC. Amplifier gain is set in order to maximize Q,  $d=1\text{m}$ .

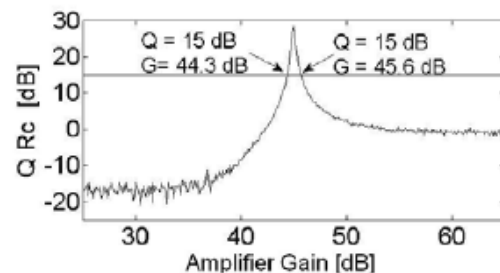


Fig.2: Q-factor as a function of the amplifier gain for MC, bit rate 900Mbit/s,  $d=1\text{m}$ .

# Impairments due to Fiber Random Birefringence in Optical Chaotic Steganography

Leonora Ursini<sup>1</sup>, Marco Santagiustina<sup>1</sup>, Cristian Antonelli<sup>2</sup>, Antonio Mecozzi<sup>2</sup>

1. Dipartimento di Ingegneria dell'Informazione, via Gradenigo 6/B, 35131, Padova, Italy

2. Dipartimento di Ingegneria Elettrica e dell'Informazione, Poggio di Roio, 67040, L'Aquila, Italy

e-mail: ursinile@dei.unipd.it

**Abstract:** The PMD effects on chaos-encrypted transmission are numerically investigated. Performances are evaluated in terms of synchronization error and Q-factor. A compensation scheme is proposed which reduces the PMD influence.

The chaotic steganography of information in fiber optics systems is realized by superposing the chaotic emission of the Master Laser (ML) at the transmitter to the message [1]. At the receiver, the message recovering entails the synchronization of the Slave Laser (SL), a process that is highly affected by fiber impairments [2]. Previous studies considered a scalar model for the propagation, thus neglecting any effect related to the signal polarization. However, real fibers are affected by the random birefringence, also called Polarization Mode Dispersion (PMD) [3]. This effect causes random fluctuations of the signal state of polarization (SOP) propagating through the fiber and waveform distortions; PMD statistical properties are fully characterized by the mean Differential Group Delay (DGD) [3]. In order to fully account for PMD effects in an optical chaotic transmission system a set of vectorial LK equations [4] must be considered to describe the ML and SL dynamics. In fact, though the dominant emitted mode in chaotic DFB lasers is the TE, an orthogonally TM mode can be also excited and participates to the dynamics. Under the hypothesis that all other fiber impairments are absent (mitigated or compensated [5]), the effects of the PMD on the system performance can be evaluated by performing Monte Carlo simulations, over a large set (more than 1000) of statistical realizations of the random fiber transfer unitary matrix [3]. The ML-SL synchronization is quantified in terms of mean synchronization error  $\langle S \rangle$ , where  $S$  is the time-averaged absolute difference between the normalized optical intensity impinging upon the SL and that emitted by the SL. The benefits of a first order PMD compensator, aligning the mean SOP at the fiber output to the SL TE mode, are also assessed. In Fig. 1,  $\langle S \rangle$  is plotted as a function of the mean DGD: squares (circles) refer to the uncompensated (compensated) system. The impact of PMD on the chaotic steganography of a NRZ signal, at 2.5Gb/s, is also determined. In Fig. 2 (in which the same symbols of Fig.1 are used), the estimated Q-factor is presented as a function of the mean DGD. PMD severely affects both synchronization efficiency and message recovering. Considering as an error-free condition the reference value  $Q=15.6$  dB [5] (dashed line in Fig. 2), the

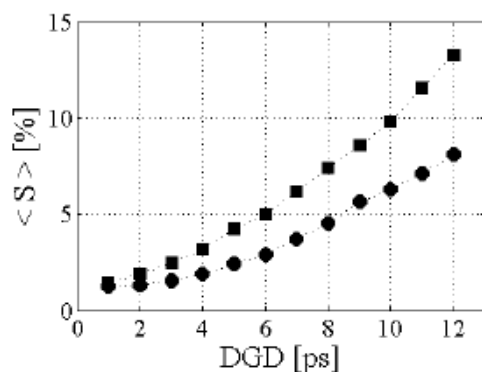


Fig.1:  $\langle S \rangle$  vs DGD. Squares (circles): scheme without (with) PMD compensator. The parameters are defined as in ref. [4].

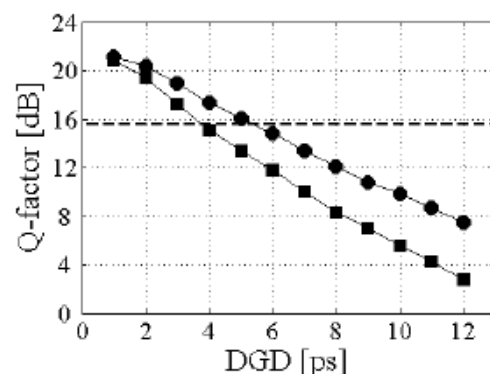


Fig.2: Q-factor vs DGD. Squares (circles): scheme without (with) PMD compensator. Dashed line: error-free reference value ( $Q=15.6$  dB).

first order compensator enhances the synchronization performance and eventually can extend the PMD system margin from  $DGD=3.75$  ps to 5.5 ps.

In conclusion, fiber PMD introduces SOP random fluctuations and distortion on the signal injected into the SL, finally causing loss of synchronization and Q-factor penalties. First order PMD compensation effectively reduces the impairments.

## References

- [1] A. Argyris et al., "Chaos-based communications at high bit-rates using commercial fiber-optic links," *Nature* **438**, 343-346 (2005).
- [2] A. Bogris et al., "Performance Characterization of a Closed-Loop Chaotic Communication System Including Fiber Transmission in Dispersion Shifted Fibers," *IEEE J. Quantum Electron.* **40**, 1326-1335 (2004).
- [3] J.P. Gordon, H. Kogelnik, "PMD fundamentals: Polarization mode dispersion in optical fibers" *Proc. Natl. Acad. Sci. USA* **97**, 4541 (2000).
- [4] T. Heil et al., "TE-TM dynamics in a semiconductor laser subject to polarization-rotated optical feedback," *Phys. Rev. A* **68**, 033811 (2003).
- [5] L. Ursini et al., "Enhancing Chaotic Communication Performances by Manchester Coding," *IEEE Phot. Techn. Lett.* **20**, 401-403 (2008).



**Authors' Index**

Abdulla, H. D.	1	Bell, M. C.	27
Astapova, E.S.	93	Belyakov, S. L.	9
Atsalakis, G.	4	Belyakova, M. L.	9
Veselova, E.M.	93	Belyi, V.V.	9
Adamopoulos, M.	48	Ben Jemaa, Z.	32, 38
Adams, M. J.	63, 102, 104, 108	Benedetti, M.	107, 112, 122
Adzhemyan, L.Ts.	1	Bergman, L. A.	90
Aidanpää, Jan-Olov	1	Bettayeb, F.	10
Akhmanova, D.M.	3	Beuler, M.	10
Akkaya, E.E.	25	Binder, B.	11
Alasty, Aria	26	Blömer, D.	105
Alomari, M. M.	1	Bogris, A.	115, 116,
Amabili, M.	2, 3	Bonath, W.	10
Amangaliyeva, M.M.	3	Bondarets, A.Ya.	12
Amano, Kazuya	120	Boussiha, K.	10
Ambika, G.	3, 4	Boutalis, Y. A.	15, 88
Amritkar, R E	4	Braun, H. A	12, 60
Aniszewska, D.	4	Brazaitis, M.	13
Anninos, P. A.	4	Brianzoni, S.	13
Annovazzi-Lodi, V.	107, 112, 122	Bunyakova, Yuliya Ya.	22
Antonelli, C.	112, 124	Buyadzhi, V.	34
Antoniou, P. E.	4	Byrne, G	42
Arapis, G.	50	Byrtus, M.	14
Argyris, A.	115, 116	Castellano, G.	89
Aromataris, G.	122	Charge, P.	30, 96
Athanasίου, M.A.	59	Chelidze, T. L.	49
Atsalakis, G.	5	Chin, Chou Hsin	53
Attarsharghi, S.	5	Chlouverakis, K.E.	115, 116
Avlonitis, M.	5	Choi, Han-Lim	15
Awrejcewicz, J.	6, 39	Chou, Chia-Yi	51
Aybar, O.O.	25	Christodoulou, M. A.	15, 88
Babkin, A. V.	6	Chuprov, Vladimir	99
Baehr, C.	7	Citrin, D.S.	119
Bagdov, A.G.	7	Coca, D.	8
Bai, Lianjun	8	Coculescu, C.	16
Bauch, S.	42	Colet, P.	19, 107, 109,
Becerra-Alonso, D.	8		110, 113, 114,
Beckwith, A.	8		117
Belegri-Roboli, A.	50	Corà, M.	123
Belghith, S.	32, 39	Cordente Martínez, C.A.	98

Cornejo, M.D.	90	Folcut, O.	16
Corradi, A.	106	Fort, I.	26
Cveticanin, L.	16	Fournier-Prunaret, D.	30, 96
D'Huys, O.	18	Frenkel, Zeev M.	21
Danckaert, J.	18, 19	Frias Bustamente, M. P.	21
Daniels, S	42	Garcia Guirao, J. L.	24
Das, P.	16	Gelens, L.	19
Davis, P.	120	Gliozzi, A.	17
De Campos, C.	17	Glushkov, A.V.	22, 34, 86
Delsanto, P. P.	17	Gopar, V. A.	50
Despa, R.	16	Goswami, P.	23
Dikpati, M.	24	Gouda, K. C.	23
Dimotikalis, Y.	18	Gouveia Dal Pino, E.M.de	24
Dingwell, D. B.	17	Grigoras, C.	24
Dobrescu, L. I.	18	Grigoras, V.	24
Dodson, C.T.J.	19	Gue Zhu, Jian	1
Dolgenkov, I.V.,	91	Guerrero, G.	24
Dolgikh, A.P.	91	Gurses, S.	25
Donges, J.	40	Hacinliyan, A.S.	25
Dowling, D P	42	Hajkarami, H.	25
Drakopoulos, V.	47	Haller, George	73
Dubinín, N.E.	19	Hamacher, A.	115
Dushenin, D.	83	Hamacher, M.	107
Efremidis, G.	5	Hanslien, M.	25
El ASSAD, S.	53	Harikrishnan, K P	4
Elsäßer, W.	105	Hasal, P.	26
Ermakov, I. V.	19	Hatami, Arash	26
Ertel-Ingrisch, W.	17	Heiss, WD	26
Fahimnia, B.	20	Hil, G.	27
Fasoulas, J.	31	Hirano, Kunihito	120
Fedchuk, A.	45	Hnatich, M.	1
Feigin, A.	52	Ho, Ming-Chung	29, 51
Feigin, A.M.	46	Honkonen, J.	1
Fernandez Pascual, R.	20, 58	Hsieh, Ying-Hen	16
Feudel, U.	20	Hul, O.	42
Fiksen, Ø.	59	Hurtado, A.	63, 102
Filippaki, E.	95	IANA, V. G.	69
Filippov, V.V.	19	Iasemidis, L. D.	27
Finke, C.	20	Ibrahim, Ahmed	28
Fischer, I.	18	Ignatenko, A. V.	28
Flunkert, V.	18	Iliopoulos, A.C.	59

Inoue, Masaki	120	Kotti, A.	39
Inselberg, A.	29	Kouomou, Y. C.	110
Ivanauskas, F.	29	Kozelov, B.	71
Ivashchenko, N.N.	81	Kreerenko, O.D.	12
Jacobo, A.	117, 118	Krylov, A. L.	91
Jafri, H. H.	79	Krysko, V.A.	39
Jahed-Motlagh, M. R.	5	Kugiumtzis, D.	57
Jan, H.	29	Kurths, J.	40
Jasaitis, V.	29	Kusbeyzi, I.	25
Jenaliyev, M.T.	3	Kuzmenko, A. A.	38, 40
Jevtic, N.	30	Kuznetsov, N.V.	40
Jiang, I-Min	29	Kuznetsova, E.S.	39
Kaddoum, G.	30	Labukhin, D.	104, 108
Kalashnikov, V. L.	31	Laktyunkin, A.V.	40
Kalpakas, A.	31	LALOUM, M.	41
Kalvouridis, T. J.	31	Lampart, M.	24
Kanellopoulos, G.	92	Lan, B. L.	41
Kapustina, A. S.	39	Larger, L.	110, 118
Karagiozis, K.	3	Law, V. J.	42
Karakatsanis, L.P.	59	Ławniczak, M.	42
Karami, M.	31	Lawrance, A. J.	43
Karapetyan, D.R.	7	Leonov, G.A.	40
Karim, A.	32	Lermusiaux, P.	73
Karim, T.	32	Li, Han	94
Kasyanov, A.O.	33	Liang, Shiuan-Ni	41
Keller, K.	33	Liljenstrom, H.	44
Khaki-Sedigh, A.	5	Liu, Chia-Ju	51
Khetselius, O.	34	Livshits, M. A.	55
Khokhlov, Valery	22	Loboda, A. V.	44, 45
Khots, B.	35	Locquet, A.	119
Khots, D.	35	López Díaz de Duran, A.	98
Kirzhner, V. M.	21	Lopez, J. L.	45
Klenov, V. I.	35	Lopez-Ruiz, R.	59
Knyazeva, I.	35	Loskutov, E.	52
Kolesnikov, Alexander A.	36	Loskutov, E.M.	46
Kolesnikov, Anatoly A.	36, 37, 38, 40	Loudon, R.	104, 108
Kolesnikova, N. A.	38	Lovett, L.	34
Kolesnikova, T. A.	38	Lu, Ming-Chi	51
Kononov, A. F.	39	Lukash, T.	86
Korol, A. B.	21	Luong, L.	20
Kotini, A.	4	Mahdavian, L.	46

Makarenko, N.	35	Naito, Sunao	120
Maksimova, M.	47	Neamtuy, M.	18
Mamma, C.	13	Nepomnyashchy, A. A.	51
Manneville, P.	47	Nguimdo, R. M.	109, 110, 117
Manousopoulos, P.	47	Nguyen, P.	38
Margaris, A.	48, 74	Ni, D. C.	53
Marian, R.	20	Nikishov, A. Yu.	53
Marin, D.	48, 67	Nimsch, J. E.	105
Marinescu, D.	48, 67	Nötzel, R.	106
Marini, S.	55	Noura, H. N.	53
Martirosyan, H.A.	7	Novokshenov, V.Yu.	54
Marwan, N.	40	Obukhovets, V.A.	33
Mataliotakis, G.	49	Ohtsubo, Junji	111
Matcharashvili, T. N.	49	Omelchenko, V.	83
Matveev, E.N.	61	Oommen, B. J.	64
Mavraki, E.	4	Oowada, Isao	120
McFarland, D. M.	90	Oprisz, D.	18
Mecozzi, A.	112, 124	Orman, G. V.	54
Mello, P. A.	50	Ortín, S.	118
Mendez-Bermudez, J. A.	50	Osokin, A. R.	55
Mepharidze, E. V.	49	Oti, W. J.O	95
Merlo, S.	120	Pahomov, A.A.	62
Michaelides, P. G.	50	Païdoussis, M. P.	2, 3
Michetti, E.	13	Pakter, R.	55
Mikaelyan, G.S.	7	Pannekoucke, O.	7
Mikishev, A.	51	Pantelidis, L.	56
Mirasso, C. R.	19, 107, 109, 113, 114, 117	Papageorgiou, C. D.	56
Misra, R	4	Papamarkou, T.	56
Mitskevich, S.	39	Papana, A.	57
Moghani, A.	31, 51, 82	Paraskevopoulou, M.	31
Mohanakumar, K.	52	Patidar, V.	58
Molkov, Ya.	46, 52	Pavlos, E. G.	59
Montejo Gamez, J.	45	Pavlos, G. P.	59
Moreno, E.	60	Pechernyi, V.	78
Mudraya, N.V.	45	Pécseli, H. L.	59
Mukhin, D.	52	Peil, M.	118
Mukhin, D.N.	46	Pellicer-Lostao, C.	59
Munoz, V.	90	Perelygina, T.	45
Mushenko, A. S.	53	Perez-Villegas, A.	60
Muvasharkhan J.	3	Perugini, D.	17
		Pesquera, L.	63, 102, 118



Pichardo, B.	60	Rypdal, K.	71
Piperidou, H.	4	Sadrinasab, M.	72
Poli, G.	17	Safaryan, Yu.S.	7
Polikarpov, V.S.	60	Sakellariou, M. G.	85
Polovincak, M.	1	Salarieh, H.	26
Postnova, S	12, 60	Samandari, H.	25
Potapov, A.A.	40, 61, 62	Samoilov, D. S.	73
Poulou, M.	62	Samoylov, L. K.	72, 73
Pozo, J.	106	Sampedro Molinuevo, J.	98
Prants, S. V.	62	Sampedro, J.	84
Prokopiev, E.P.	63	Santagiustina, M.	123, 124
Prucha, J.	90	Sapsis, T.	73
Purohit, G.	58	Saraidaris, A.	74
Qin, Ke	64	Schöll, E.	18
Quirce, A.	63, 102	Schweitzer, J.S.	30
Rachieru, O.	65	Schwartz, T.	74
Radomir, I.	54	Sciamanna, M.	119
Rajendran, K.	65	Scirè, A.	19
Ramaswamy, R.	79	Seledzhi, S.M.	40
Ramazanov, M.I.	3	Selvam, A.M.	74
Ramm, A.G.	66	Semenov, V.N.	91
Ramniceanu, I.	48, 67	ȘERBĂNESCU, A.	69
Raptis, T. E.	56	Serbov, N.	22
Refoyo, I.	84	Serbov, Nikoly	86
Rega, G.	68	Serga, I. N.	75
Resmi, V.	3	Shapovalov, V. I.	75
Rincon, M. M.	69	Sharko, Yu.	76
RÎNCU, C.I.	69	Shermenev, A.	77
Rizzato, F.B.	55	Sherpa, K.S.	79
Roberts, E. P. L.	70	Shibata, Kazunari	28
Rodriguez Romo, G.	98	Shogenji, Rui	111
Rogan, J.	90	Shvets, A. Yu.	78
ROHACS, J.	70	Silchenko, A. N.	78
Rontani, D.	118	Sillero Quintana, M.	98
Rosa, E.	71	Singh, A.K.	79
Roviras, D.	30	Singh, Th. U.	79
Rovithakis, G.	31	Sinn, M.	33
Ruiz Medina, M. D.	20, 21, 69	Sirko, L.	42
Ruiz-Oliveras, F.	114	Skavhaug, O.	25
Rybaczuk, M.	4	Skiadas, C.	49, 79
Rypdal, M.	71	Skiadas, C. H.	5, 79, 80

Skurvydas, A.	13	Tronciu, V. Z.	19, 107
Slotine, J.J. E.	15	Trulsen, J. K.	59
Smalbrugge, E.	106	Tsakalaki, K.	5
Smit, M.K.	106	Tsakiridis, O.	89
Smorodin, B. L.	51	Tsiavos, C.	92
Snasel, V.	1	Tsoutsouras, V.G.	59
Sokolov, V. V.	80	Tuimebayeva, A.E.	3
Soldatov, V.	39	Tynan, J	42
Someya, Hiroyuki	120	Uchida, A.	120
Somsikov, V. M.	81	Umut, O.	89
Sonechkin, D. M.	81	Urbanek, J. F.	90
Soriano, M. C.	113, 114, 117	Ursini, L.	122
Sorouhesh, M. R.	82	Ursini, L.	124
Sotiropoulos, A. D.	82	Vakakis, A. F.	90
Sotiropoulos, V. D.	82	Vakulenko, N.V.	81
Srisuchinwong, B.	83	Valdivia, J.A.	90
Staden, J. von	105	Valenzuela, O.	60
Starchenko, I.	83	Valle, A.	63, 103
Stavrakakis, N.	62	Valyaev, A.N.	91
Stefanidis, V.	89	Van der Sandea, G.	19
Stirling, J. R.	84, 98	Van der Weele, Ko	92
Stoian, N. M.	84	Vanina, E.A.	93
Stolz, C. A.	104, 108	Varas, A.	90
Stratakos, I. L.	85	Vargas-Hernández, J. G.	93
Sud, K K	58	Vasegh, N.	5
Sudheer, S.	85	Vatolin, N.A.	19
Svinarenko, A. A.	22, 86	Vercesi, V.	122
Svirina, L.	86	Veselov, G. E.	94
Sweilam, N. H.	87	Villalobos, J.	90
Syvridis, D.	115, 116	Vries, T. de	106
Takeuchi, Yasutoshi	111	Wang, Yun-Cai	121
Talagrand, O.	87	Wang, An-Bang	121
Tass, P. A.	78	Wang, Shuang-xin	94
Tereshko, V.	8	Wang, Zhi-qin	94
Theodoridis, D. C.	15, 88	Weihong, Huang	27
Theoharis, T.	47	Xaplanteris, C. L.	95
Thorpe, N.	27	Xu, Y.	96
Tkachova, P. P.	88	Yilmaz, L.	96
Toda, M.	88	Yoshimori, Shigeru	120
Toledo, B.	90	Yoshimura, Kazuyuki	120
Torrens, F.	89	Zaeembashi, A.	82

Zakhleniuk, N.	104, 108
Zakovorotny, V. L.	97
Zakynthinaki, M.	84, 98
Zarama, R.	90
Zavalishin, N. N.	98
Zeman, V.	14
Zenkina, O.	53
Zervas, E.	89
Zepeda Nunez, L.A.	47
Zhang, Xiu-xia	94
Zhigalov, M.	39
Zhong, Huaying	99
Zhukova, N. N.	49
Ziaei-Rad, S.	25
Zivkovic, T.	71
Zou, Y.	40
Zubok, Y.	99

