Universität Potsdam

Jürgen Kurths | Alexander Fradkov | Guanrong Chen (eds.)

The 3rd International IEEE Scientific Conference on Physics and Control (PhysCon 2007)

September 3rd-7th 2007 at the University of Potsdam

Universitätsverlag Potsdam 2007

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Abstract Collection

Edited by
Jürgen Kurths
Alexander Fradkov
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The 3rd International IEEE Scientific Conference on Physics and Control - PhysCon 2007

Sept. 3rd-7th 2007 at the University of Potsdam

	PhysCon 2007: 3 - 7 September 2007	PhysCon 2007: 3 - 7 September 2007	PhysCon 2007: 3 - 7 September 2007	PhysCon 2007: 3 - 7 September 2007	PhysCon 2007: 3 - 7 September 2007
Sep-02	**Monday Sep-03**	**Tuesday Sep-04**	**Wednesday Sep-05**	**Thursday Sep-06**	**Friday Sep-07**
6:00PM Registration & Ice breaker	8:00 AM **Registration** 8:45 AM **Opening**	8:00 AM **Registration**	8:00 AM **Registration**	8:00 AM **Registration**	8:00 AM **Registration**
	9:00 AM - 10:30 AM **Plenary Session** **Grebogi** **Schuster** ***A (Audimax)***	9:00 AM - 11:00 AM **Concurrent** **MS05 – part II (2h) *G*** **MS08 – part III (2h) *D*** **MS09 – part III (2h) *B*** **MS12 – part II (1.5h) *A*** **MS13 – part III (1.5h) *C*** **MS20 – part I (2h) *E***	9:00 AM - 11:00 AM **Concurrent** **MS12 – part III (1.5h) *A*** **MS26 – part II (2h) *B*** **MS29 (1h) *F*** **CP – part I *C*** **CP – part II *G*** **CP – part III D**	9:00 AM - 11:00 AM **Concurrent Sessions** **MS07 – part I (2h) *A*** **MS20 – part II (2h) *B*** **MS21 – part I (2h) *G*** **CP – part IV *C*** **CP – part V *F*** **CP – part VI D**	9:00 AM - 11:30 AM **Concurrent** **MS01 (3h) *A*** **MS02 (2.5h) *C*** **MS17 – part III (2.5h) *B*** **CP – part VII *G*** **CP – part VIII D** **CP – part IX *F***
	10:30 AM **Coffee**	11:00 AM **Coffee**	11:00 AM **Coffee**	11:00 AM **Coffee**	11:30 AM **Coffee**
	11:00 AM - 1:00 PM **Concurrent Sessions** **MS08 – part I (2h) *D*** **MS10 – part I (1.5h) *G*** **MS13 – part I (2h) *C*** **MS17 – part I (2h) *B*** **MS26 – part I (2h) *A***	11:30 AM - 1:00 PM **Plenary Session** **Ott** **Showalter** ***A (Audimax)***	11:30 AM - 1:00 PM **Plenary Session** **Wünsche** **Lai** ***A (Audimax)***	11:30 AM - 1:00 PM **Concurrent Sessions** **MS18 – part III (1.5h) *B*** **MS19 – part III (1.5h) *G*** **MS23 – part I (1.5h) *C*** **MS24 – part II (1.5h) *A*** **MS28 – part II (1.5h) *F***	12:00 AM - 12:45 PM **Plenary Session** **Sharkovsky** ***A (Audimax)***
	1:00 PM **Lunch + Poster Session 1**	1:00 PM **Lunch + Poster Session 1**	1:00 PM **Lunch + Poster Session 2**	1:00 PM **Lunch + Poster Session 2**	12:45 PM **Lunch**
	2:30 PM - 4:00 PM **Concurrent Sessions** **MS03 – part I (1.5h) *G*** **MS04 – part I (1.5h) *A*** **MS08 – part II (1.5h) *D*** **MS09 – part I (1.5h) *B*** **MS25 – part I (1.5h) *C*** **MS28 – part I (1.5) *E***	2:30 PM - 4:00 PM **Concurrent** **MS03 – part II (1.5h) *G*** **MS04 – part II (1.5h) *A*** **MS13 – part IV (1.5h) *C*** **MS19 – part I (1.5h) *D*** **MS22 – part I (1.5h) *B*** **MS30 – part I (1.5h) *E***	2:30 PM - 4:00 PM **Concurrent** **MS03 – part III (1.5h) *G*** **MS05 – part III (1.5h) *B*** **MS11 – part I (1.5h) D** **MS13 – part V (1h) *C*** **MS16 – part I (1.5h) *F*** **MS24 – part I (1.5h) *A***	2:30 PM - 4:00 PM **Concurrent Sessions** **MS04 – part IV (1.5h) *A*** **MS07 – part II (1.5h) *B*** **MS12 – part IV (1h) *G*** **MS16 – part II (1h) *F*** **MS23 – part II (1h) *C***	**End of the Conference**
	4:00 PM **Coffee+Poster Session 1**	4:00 PM **Coffee+Poster Session 1**	4:00 PM **Coffee+Poster Session 2**	4:00 PM **Coffee+Poster Session 2**	**Poster Sessions** **Haus 8, Rooms 0.60, 0.61** **(Foyer)**
	4:30 PM - 6:30 PM **Concurrent Sessions** **MS05 – part I (2h) *G*** **MS09 – part II (2h) *B*** **MS12 – part I (2h) *A*** **MS13 – part II (2h) *C*** **MS17 – part II (2h) *D*** **MS18 – part I (2h) *E***	4:30 PM - 6:30 PM **Concurrent** **MS04 – part III (2h) *A*** **MS08 – part IV (2h) *D*** **MS10 – part II (1.5h) *G*** **MS15 (1h) *E*** **MS22 – part II (1h) *B*** **MS27 – part I (1.5h) C**	4:30 PM - 6:00 PM **Concurrent** **MS06 – part I (1.5h) *A*** **MS11 – part II (1h) D** **MS18 – part II (1.5h) *B*** **MS19 – part II (1.5h) *G*** **MS25 – part II (1.5h) *C*** **MS30 – part II (1.5h) *F***	4:30 PM - 6:30 PM **Concurrent Sessions** **MS06 – part II (2h) *A*** **MS07 – part III (2h) *B*** **MS21 – part II (2h) *G*** **MS26 – part III (1.5h) *F*** **MS27 – part II (2h) *C***	
		7:00 PM **Barbecue**	6:00 PM - 8:00 PM **General Assembly**		

Room symbols

Symbol	Location
A	Haus 8, Room 1.45 (Audimax)
B	Haus 8, Room 0.58
C	Haus 8, Room 0.59
D	Haus 11, Room 2.03
E	Haus 11, Room 2.27
F	Haus 11, Room 0.09
G	Haus 12, Room 0.39

Minisymposia (MS) presentations are 25 minutes with an additional 5 minutes of discussion. Contributed Presentations (CP) are 15 minutes with an additional 5 minutes of discussion. (MS26=IS01, MS27=IS02, MS28=IS03, MS29=IS04, MS30=IS05)

Monday Sep-03			
8:00 AM	Registration		
8:45 AM	Opening		
9:00 AM	**Plenary Session**		
-	A (Audimax)	Grebogi, C	Chaos and complexity
10:30 AM		Schuster, Heinz-Georg	Control of sleep: theory and experiments
10:30 AM	Coffee		
11:00 AM	**Concurrent Sessions**		
	MS08 – part I (2h)	Álvarez, Gonzalo	Application of gray code to the cryptanalysis of chatic cryptosystems
		Barajas, Ramirez G. Juan	Towards an encryption scheme based on hybrid systems
	D (Haus 11, Room 2.03)	Cervantes, Ilse	Breathing in a class of switched linear systems with complex eigenvalues
-		Zhou, Changsong	Structure-function relationship in complex brain networks expressed by hierarchical synchronization
	MS10 – part I (1.5h)	Eiswirth, Markus	Geometric constaints in electrochemical pattern formation
		Garcia-Ojalvo, Jordi	Manipulating excitable dynamics in gene-regulatory networks
1:00 PM	G (Haus 12, Room 0.39)	Ramaswamy, Ram	Using time delay for phase control in coupled nonlinear systems
	MS13 – part I (2h)	Agafonov, A.S.	On the stability and stabilization of mechanical systems of general type
		Akbari, Samin	Shape control of smart structures using fluidic actuators
	C (Haus 8, Room 0.59)	Belyakov, O.A.	Dynamics of a swing
		Garcia-Planas, I.M.	Bifurcation diagrams of families of regularizable singular systems under proportional and drivative feedback
	MS17 – part I (2h)	Van Leeuwen, Peter	Effect of maternal respiratory rates on fetal-maternal heart rate coordination
		Malberg, Hagen	Analysis of cardiovascular oscillations: new approach to the early prediction of pre-eclampsia
	B (Haus 8, Room 0.58)	Porta, Alberto	Entropy-based complexity of short-term heart period variability is linked to cardiac autonomic modulation
		Wessel, Niels	Cardiovascular dynamics during normal and pathological sleep
	MS26 – part I (2h)	Ananiev, Boris	Multistage stochastic inclusions of special type and their multiestimates
		Filippova, Tatiana	State estimation problems for differential inclusions
	A (Haus 8, Room 1.45)	Gusev, Mikhail	On experimental design for nonlinear guaranteed identification problems
		Nikonov, Oleg	On game-theoretical modeling with applications to the problems of large-scale competitive projects
1:00 PM	Lunch + Poster Session 1		
2:30 PM	**Concurrent Sessions**		
	MS03 – part I (1.5h)	Carriegos, Miguel	A study of linear control systems from the geometry of the ring of scalars
		George, K.R.	Controllability of matrix second order systems - a trigonometric matrix approach
-	G (Haus 12, Room 0.39)	Hermida-Alonso, Á.José	Assignable polynomials to a single input weakly reachable linear system
	MS04 – part I (1.5h)	Ivanchenko, V.Mikhail	A network mechanism for high-and low-frequency oscillations in neuronal ensembles
		Kanakov, I.Oleg	Q-breathers in nonlinear lattices: normal mode concept and its breakdown
4:00 PM	A (Haus 8, Room 1.45)	Matrosov, V.Valery	Chaotic regimes in coupled phase systems
	MS08 – part II (1.5h)	Barajas, Ramirez G. Juan	On the controlled synchronization of dynamical networks with non identical nodes
		Li, Shujun	Analog chaos-based secure communications and cryptanalysis: a brief survey
	D (Haus 11, Room 2.03)	Li, Chengqing	On the security of a chaos-based encryption method for color image
	MS09 – part I (1.5h)	Beta, Carsten	Controlling chemical turbulence in surface reactions
		Engel, Harald	Feedback-mediated control of spiral waves
	B (Haus 8, Room 0.58)	Fenton, Flavio	N. N.
	MS25 – part I (1.5h)	Behre, Joern	Structural robustness of netabolic networks on the basis of elementary flux modes
		Wolf, Jana	Analysing the robustness of cellular rhythms
	C (Haus 8, Room 0.59)	Kollmann, Markus	Design principles of noise suppression in biological networks
	MS28 – part I (1.5)	Pavon, Michele	Controlled markov chains for controlled n-level quantum systems
		Romano, Raffaele	Indirect control of the asymptotic states of a dynamical semigroup
	E (Haus 11, Room 2.27)	Schirmer, G.Sonia	Comparative analysis of control strategies

4:00 PM	**Coffee+Poster Session 1**		
4:30 PM	**Concurrent Sessions**		
	MS05 – part I (2h)	E. Schöll / W. Just	Introduction to time-delayed feedback control methods
		Pyragas, Kestutis	Delayed feedback control of periodic orbits without torsion in nonautonomous chaotic systems: theory and experiment
	G (Haus 12, Room 0.39)	Benner, Hartmut	Observing global properties of time-delayed feedback control with an unstable control
-		Schoell, Eckehard	Refuting the odd number limitation of time-delayed feedback control
	MS09 – part II (2h)	Grigoriev, Roman	Boundary control of reaction-diffusion systems
		Loskutov, Alexander	Suppression of complex reentrant activity in a realistic model of cardiac tissue by a weak external pacing
	B (Haus 8, Room 0.58)	Nepomnyashchy, Alexander	Structures in subcritically unstable pattern-forming systems under global control
6:30 PM		Parlitz, Ulrich	Controlling spatio-temporal systems using multiple delayed feedback
	MS12 – part I (2h)	Macau, Elbert	Controlling chaotic transient and the improvement of system flexibility
		Meucci, Ricardo	Phase control of chaos
	A (Haus 8, Room 1.45)	Litak, Grzegorz	Pulsive feedback control for stabilizing unstable periodic orbits in a nonlinear oscillator
		Pickert, Volker	Control of bifurcations in power electronic dc-dc converters through manipulation of the saltation matrix
	MS13 – part II (2h)	Georgievskii, V.Dimitri	Some spectral problems on hydrodynamical stability of non-newtonian and plastic flows
		Irtegov, D.Valentin	On application of first integrals in analysis of conservative systems
	C (Haus 8, Room 0.59)	Karapetyan, V. Alexander	Invariant sets of dynamical systems with symetries: existence, stability and bifurcations
		Kliem, Wolfhard	Indefinite damping in mechanical systems and gyroscopic stabilization
	MS17 – part II (2h)	Bär, Markus	Propagation properties and onset of alternans in a realistic model of the rabbit heart
		Buchner, Teodor	Dynamics of the blood pressure control system during head up tilt test
	D (Haus 11, Room 2.03)	Żebrowski, Jan	Properties of a nonlinear oscillator model of the conduction system of the heart
		Hoyer, Dirk	Interactions between short-term and long-term cardiovascular control mechanisms
	MS18 – part I (2h)	Witt, Susanne	1. The 20s proteasome: 2. towards understanding substrate uptake
		Busch, Hauke	Unraveling the dynamics of gene regulation in cell migration using neural networks as a tool for reverse engineering
	E (Haus 11, Room 2.27)	Fernandez, Nelson	Antigen presentation via mhc class ii: study of the association
		Harrison, Andrew	The variety of genomic output in homo sapiens between hla dr and the invariant chain cd74 isoform expressed at the cell surface

Tuesday Sep-04			
8:00 AM	Registration		
9:00 AM	**Concurrent Sessions**		
	MS05 – part II (2h)	Parlitz, Ulrich	Stabilizing steady states using multiple delayed feedback
		Sieber, Jan	Non-invasive feedback with discrete updates
	G (Haus 12, Room 0.39)	Huybrechts, Henri	Anticipating synchronization of chaotic Lure systems
-		Kyrychko, Yuliya	Delay effects in a periodically forced beam-oscillator system
	MS08 – part III (2h)	Li, Ping	Chaotification of cmls
		Li, Wie	Stability analysis of swarms with a general topology
	D (Haus 11, Room 2.03)	Lu, Jinhu	Emerging collective behaviors of animal groups
11:00 AM		Triandaf, Ioana	A collective motion control algorithm for targeting time-dependent boundaries
	MS09 – part III (2h)	Rosenblum, Michael	Controlling collective dynamics in oscillator ensembles
		Rudzick, Oliver	Trapping of waves and twisted spirals in forced oscillatory media: results for the catalytic co oxidation on pt(110) and the …
	B (Haus 8, Room 0.58)	Schatz, Michael	N.n.
		Luther, Stefan	N.n.
	MS12 – part II (1.5h)	Ott, Edward	Estimating the state of large spatio-temporally chaotic systems
		Zambrano, Samuel	Safe sets for horseshoe maps
	A (Haus 8, Room 1.45)	Loskutov, Alexander	Separation of particles in velocities in breathing billiards
	MS13 – part III (1.5h)	Mailybaev, A.Alexei	Bifurcations in potential systems at bimodal critical points
		Salmina, A.Maria	Stability, bifurcations, control in dynamics of three-wheels robots
	C (Haus 8, Room 0.59)	Seyranian, A. A.	Solution to the chelomei problem
	MS20 – part I (2h)	Lewerenz, J.H.	Photoactive device by electrochemical processing of silicon
		Lublow, Michael	Fractal photocorrosion of silicon
	E (Haus 11, Room 2.27)	Parmananda, Punit	Noise invoked order in electrochemical systems
		Mikhailov, Alexander	Sudden onset of corrosion on stainless steel as a cooperative critical phenomenon
11:00 AM	Coffee		
11:30 AM	**Plenary Session**		
-	A (Audimax)	Ott, Edward	Estimating the state of large spatio-temporally chaotic systems
1:00 PM		Showalter, Kenneth	Collective behavior in addressable excitable media
1:00 PM	Lunch+Poster Session 1		
2:30 PM	**Concurrent Sessions**		
	MS03 – part II (1.5h)	Loo, K.C.	Particle swarm optimization of pd controller for cargo ship steering
		Nandakumaran, K.A.	Carleman estimate and exact controllability
-	G (Haus 12, Room 0.39)	Saéz-Schwedt, Andrés	Linear algebra techniques in stability problems of systems over rings
	MS04 – part II (1.5h)	Mishagin, G.Konstantin	Control of phase distributions in arrays of locally coupled oscillators
		Paleari, Simone	Fpu phenomenon for generic initial data
4:00 PM	A (Haus 8, Room 1.45)	Penati, Tiziano	Q-breathers, tail resonances and metastability in the fpu lattice
	MS13 – part IV (1.5h)	Shpilevaya, Y.Olga	Adaptive stabilization of dynamic systems with periodic coefficients
		Tureshbayev, T.A.	On the stability of the families of the libration points in gravitational-repulsive force-field of a binary star-systems
	C (Haus 8, Room 0.59)	Wagner, Nils	Optimization procedures for generalized eigenvalue problems and their applications in structural dynamics
	MS19 – part I (1.5h)	Dedkov, Yuriy	Electron spin-control and manipulation in micro- and nanostructures
		Fedin, Dmitry	Method of measurements with random perturbation
	D (Haus 11, Room 2.03)	Granichin, Oleg	Architecture for artificial intelligence hybrid computing
	MS22 – part I (1.5h)	Braun, A.Hans	Interdependencies of mental disorders and autonomous dysfunctions
		Conrad, Matthias	Implications of positive and negative feedback loops for the control of the cortisol "stress" axis: modelling and parameter …
	B (Haus 8, Room 0.58)	Penzel, Thomas	Dynamics of sleep stages and vegetative parameters in normals and patients with sleep apnea
	MS30 – part I (1.5h)	Makeev, Ivan	Robust features of tokamak plasma stabilization systems
		Ovsyannikov, Alexander	Linear control models for gutta tokamak
	E (Haus 11, Room 2.27)	Ovsyannikov, Dmitri	Plasma control problems investigation on gutta tokamak

4:00 PM	Coffee+Poster Session 1		
4:30 PM	**Concurrent Sessions**		
	MS04 – part III (2h)	Meucci, Riccardo	Synchronization of bursting in lasers
		Osipov, Grigory	Cluster synchronization in oscillatory networks
	A (Haus 8, Room 1.45)	Korneev, Alexey	Controlled synchronization-desynchronization transitions in oscillatory networks
-		Petrov, Valentin	Synchronization in networks of cardiac cells
	MS08 – part IV (2h)	Wang, Xiaofan	Collective behaviors in multi-agent systems
		Kwok, Bernie Sin-Hung	An efficient diffusion approach for chaos-based image encryption
	D (Haus 11, Room 2.03)	Wang, Yiming	Early detection of locust swarming-- behavioral indices for phase transformation
6:30 PM		Zhang, Hai-Tao	Network-based coordinated predictive control of flocks
	MS10 – part II (1.5h)	Sinha, Sudeshna	Exploiting chaos to design flexible hardware
		Mahara, Hitoshi	Double turing structures in the reversible gray-scott system
	G (Haus 12, Room 0.39)	Hauser, Marcus	Scroll wave instabilities in a chemical excitable medium
	MS15 (1h)	Gielen, C.Stan	Synchronization and propagation of oscillatory activity: multi-stability and hysteresis
		Surovyatkina, Elena	Multistability of cardiac excitation: a simulation study of a model of ventrical cardiac action potential
	E (Haus 11, Room 2.27)		
	MS22 – part II (1h)	Postnova, Svetlana	A neuron based model of sleep-wake cycles: control and effects of orexin
		Schiff, Steven J.	Model based spatiotemporal control of cerebral cortex dynamics
	B (Haus 8, Room 0.58)		
	MS27 – part I (1.5h)	Afanasyev, N.V.	The identification of uncertain time-variant plant
		Bakhshiyan, Boris	Least absolute value method under linear constraints for estimated parameters
	C (Haus 8, Room 0.59)	Matasov, I. Alexander	On an application of the filtering theory for delayed dynamic systems to plants without delay
7:00 PM	**Barbecue**		

	Wednesday Sep-05		
8:00 AM	**Registration**		
9:00 AM	**Concurrent Sessions**		
	MS12 – part III (1.5h)	Talagaev, Yuri	Modification of chaotic systems limit sets by multiparametrical optimal correction
		Marino, P.Inés	Phase control method for nonlinear systems
	A (Haus 8, Room 1.45)	Guran, Ardeshir	Control of chaos in a spinning kelvin type gyrostate satellite under the influence of gravitational force field
-			
	MS26 – part II (2h)	Pereira, Fernando	Necessary conditions of optimality for measure driven differential inclusions
		Sesekin, N. Alexander	Singular linear-quadratic problem for distributed delay systems
	B (Haus 8, Room 0.58)	Shorikov, F. Andrey	Optimal terminal control problem for discrete-time dynamical system
11:00 AM		Vostrikov, Ivan	Ellipsoidal techniques for closed-loop control of oscillating system that approximates the telegraph equation
	MS29 (1h)	Cao, Jinde	An adaptive chaotic secure communication scheme with channel noise and time delay
	F (Haus 11, Room 0.09)	Xia, Yuan-Qing	Performances and stability analysis of networked control systems
	CP – part I	Fradkov, Alexander	Slow motions in systems with inertially excited vibrations
		Kurdyukov, Alexander	Propagation of mean anisotropy of signals in filter connections
		Ryashko, Lev	Mean square stability and control for invariant manifolds of nonlinear stochastic systems
		Suzuki, Masayasu	A study on global stabilization of a class of discrete-time systems by using symbolic dynamics
	C (Haus 8, Room 0.59)	Ustinov, Pavel	Efficiency estimation of iterative control system design method: theoretical and experimental aspects
		Zemlyakov, Stanislaw	Precise control of complex lagrangian systems
	CP – part II	Tessone, Claudio Juan	control mechanism of phase synchronisation in oscillators of different kind: experimental results
		Mirasso, Claudio	Diversity induced resonance in dynamical systems
		Mirasso, Claudio	Predict prevent control method for perturbed excitable system
		Siemenikhin, Konstantin	on minimax estimating hilbert random elements
	G (Haus 12, Room 0.39)	Bartolozzi, Frederico	Suspension aseismic construction with elastic tie-rods
		Chernousko, Felix	Progressive motions of two-mass systems in resistive media
	CP – part III	Khodja, Djalal Eddine	Vectorial control of asynchronous machine presenting the defective bars rotor
		Gonik, Mark	Design of control system for growing crystals with desired properties
		Lukyanov, Gennadi	Interaction of semiconductor plate with the self-affine relief of surface with the electromagnetic radiation
		Mamikonyan, Boris	Research of physical phenomena occurring in complicated dynamic systems at seismic loads
		Orlik, Marek	Oscillations and multistability in the electrode processes of pseudohalogenide complexes of nickel(ii) - experiment and theory.
	D (Haus 11, Room 2.03)	Zielinski, Bartlomiej	A comparison of collision avoidance methods effectiveness in a mobile ad-hoc network
		Rutkovsky, Vladislav	Movement control of flexible mechanical systems with variable parameters and variable degrees of freedom
11:00 AM	**Coffee**		
11:30 AM	**Plenary Session**		
-	**A (Audimax)**	Wünsche, Hans J.	Noninvasive optical control of semiconductor lasers
1:00 PM		Lai, Ying-Cheng	Phase synchronization and applications to stochastic resonance and biomedical signal analysis
1:00 PM	**Lunch + Poster Session 2**		

2:30 PM	**Concurrent Sessions**		
	MS03 – part III (1.5h)	Sonia, Tarragona	Estimating the sensivity of the structure of the singular systems under proportional and derivative feedback and proportional and …
		Garcia-Planas, I. Maria	Structural stability of singular systems under proportional and derivative feedback
-	**G (Haus 12, Room 0.39)**	Garcia-Planas, I. Maria	Canonical local forms for holomorphic families of singular systems under proportional and derivative feedback
	MS05 – part III (1.5h)	Friedrich, Rudolf	Disentangling trends and fluctuations; applications to stochastic time-delayed systems
		Pototskyy, Andriy	Two-state model of excitable systems with time delayed feedback: renewal theory approach
4:00 PM	**B (Haus 8, Room 0.58)**	Tass, P.	Long-term therapeutic effects of desynchronizing deep brain stimulation
	MS11 – part I (1.5h)	Leonov, Gennady	Global stability of phase-locked loops
		Reitmann, Volker	Estimation of dynamic buckling loads in approximate shell models via frequency-domain methods
	D (Haus 11, Room 2.03)	Vavilov, Sergey	Specification of control problems under uncertainty in finances
	MS13 – part V (1h)	Burlakova, A.Larissa	On D-stability of mechanical systems
		Guran, Ardeshir	Buckling of a column as a benchmark nonlinear control design problem
	C (Haus 8, Room 0.59)		
	MS16 – part I (1.5h)	Kazantsev, Victor	Associative memory and information retrieval in a two-layer oscillatory network of spiking neurons
		Gong, Pulin	Dynamical and computational aspects of a spiking neural network with long-range spatiotemporal coherence
	F (Haus 11, Room 0.09)	Ghosh, Anandamohan	How does a heterogeneous large-scale connection topology influence the local and global dynamics of neural systems?
		Crommelin, Daan	Data-based estimation of generators formarkov processes, using convex optimization
	MS24 – part I (1.5h)	Dolaptchiev, Stamen	Automated generation of stochastic weather prediction models from time series exhibiting metastability
	A (Haus 8, Room 1.45)	Franzke, Christian	A hidden markov model perspective on regimes and metastability in atmospheric flows
4:00 PM	**Coffee+Poster Session 2**		
4:30 PM	**Concurrent Sessions**		
	MS06 – part I (1.5h)	Boccaletti, Stefano	Detecting complex network modularity by dynamical clustering
		Timme, Marc	Inferring network topology via driving the dynamics
-	**A (Haus 8, Room 1.45)**	Gil, Santiago	Control of chaos in network dynamics
	MS11 – part II (1h)	Kuznetsov, Nikolay	Realization theory methods for the construction of positively-invariant sets
		Leonov, Gennady	Shukovsky stability in dynamical systems. Generalization of andronov-witt theorem
	D (Haus 11, Room 2.03)		
6:00 PM	**MS18 – part II (1.5h)**	Holzhuetter, H.G.	Computational studies on the role of proteasomes in antigen presentation
		Mishto, M.	Proteamalg: a new tool for prediction of the substrate degradation and fragment production by the 20s proteasome and pa28
	B (Haus 8, Room 0.58)	Reynolds, Christopher	Self organization in protein folding
	MS19 – part II (1.5h)	Molodtsov, Serguei	Recent experimental developments of hardware for solid-state hybrid computers
		Scherbakov, Pavel	Stochastic approach to a class of convex optimization problems
	G (Haus 12, Room 0.39)	Shalymov, Dmitry	New breed stochastic hybrid computers
	MS25 – part II (1.5h)	Kartal, Önder	The evolutionary design of signalling networks in the light of signal-off rebustness
		Hoffmann, Sabrina	Introduction to robustness of biological systems
	C (Haus 8, Room 0.59)		
	MS30 – part II (1.5h)	Snopok, Pavel	Recent progress in muon collider storage ring lattice design
		Svistunov, Yuri	Development of roentgen and nuclear-physical contraband detection systems of the efremov institute
	F (Haus 11, Room 0.09)	Yudin, I	Optimization of the beam transport line for the customs cyclotron
6:00 PM	**General Assembly**		
-			
8:00 PM			

Thursday Sep-06			
8:00 AM	Registration		
9:00 AM	**Concurrent Sessions**		
	MS07 – part I (2h)	Akulin, M.V.	Nonholonomic control of the quantum evolution, decoherence, and entanglement
		Alicki, Robert	Dynamical and statical quantum memories
-	A (Haus 8, Room 1.45)	Bayer, Manfred	Coherent electron spin dynamics in quantum dots
		Eberly, J.H.	Quantum entanglement – a disappearing asset
	MS20 – part II (2h)	Baba, Nilüfer	Sudden onset of pitting corrosion on stainless steel as a critical phenomenon
11:00 AM		Claussen, Jens Christian	Underetching from simple reaction kinetics
	B (Haus 8, Room 0.58)	Föll, Helmut	Electrochemical pore formation in semiconductors: oscillations, structure formation and control
		Garcia, Morales Vladimir	Stochastic analysis of nonlinear electrochemical systems
	MS21 – part I (2h)	Altmann, G. Eduardo	Recurrences of long-term correlated
		Letellier, Christophe	Recurrence plots and shannon entropy for a dynamical analysis of asynchronisms in noninvasive mechanical ventilation
	G (Haus 12, Room 0.39)	Marwan, Norbert	Detection of climate transitions in Asia derived from speleothems
		Romano, Mamen	Estimation of the direction of the coupling by conditional probabilities of recurrence
	CP – part IV	Blekhman, I. I.	Vibrational mechanics in the problem of the control of physical properties of nonlinear media
		Kuznetsov, Sergey	Manipulating with phases of alternately excited self-oscillators: a way to organize hyperbolic chaos and other phenomena of …
		Landa, Polina	Geyser as a self-oscillatory system. Randomness or dynamical chaos?
		Roy, Prodyot	Multiscroll chaos in coupled double scroll type oscillators
	C (Haus 8, Room 0.59)	Tamasevicius, Arunas	Taylor predictor improves chaos controller
		Isao K. Tokuda	Estimating phase equations from multivariate time series
	CP – part V	Da Silva Baptista, Murilo	Transmission of information in active channels
		Dana, Syamal	Phase-flip bifurcation: theory and experiment
		Ezersky, Alexander	Bound states of topological defects in the system of non-linear coupled ginzburg-landau equations
		Buscarino, Arturo	Synchronization in a distributed system of moving chaotic agents
	F (Haus 11, Room 0.09)	Hoevel, Philipp	Stabilization of fixed points by extended time-delayed feedback control
		Kheowan, On-Uma	Wave mediated synchronization of nonuniform oscillatory media
	CP – part VI	Bashkirtseva, Irina	Stochastic sensitivity and control of chaos
		Ananievskiy, Igor	Control of mechanical systems under uncertainty by small forces
		Astrov, Yuri	negative differential conductivity of a system due to development of turing structure
		Bachelard, Romain	Stabilizing a wave amplified by a beam of particles with test-waves
	D (Haus 11, Room 2.03)	Khalid, Saifullah	Shell model of open-loop optical control for atomic beam focusing in momentum space
		Yalcin, Mustak, E.	Autowawes on locally coupled relaxation oscillators
11:00 AM	Coffee		
11:30 AM	**Concurrent Sessions**		
	MS18 – part III (1.5h)	Selbig, J.	Computational tools for the optimization of antiretroviral drug therapies
		Ullner, Ekkehard	Noise-induced rhythmicity in an ensemble of circadian oscillators
-	B (Haus 8, Room 0.58)	Koseska, Aneta	Variety of dynamical regimes in synthetic genetic oscillators
	MS19 – part III (1.5h)	Vyalikh, Denis	Characterization of electronic structure of dna molecules immobilized on gold surface
		Vakhitov, Alexander	Architecture for hybrid computing for artificial intelligence based on blackboard approach
1:00 PM	G (Haus 12, Room 0.39)	Shcherbakov, Pavel	Optimal control of a mechanical two-mass-spring system using invariant ellipsoids technique
	MS23 – part I (1.5h)	Feudel, Ulrike	Uncertain destination dynamics: multistability, synchronization, and control
		Goswami, K. Binoy	Crisis resonance in multistable regime
	C (Haus 8, Room 0.59)	Masoller, Cristina	Multistability induced by delay and controlled by delay
	MS24 – part II (1.5h)	Meerbach, Eike	Parameter distribution of maximum-likelihood estimators for time series with hidden states
		Metzner, Philipp	Generator estimation of markov jump processes based on incomplete observations non-equidistant in time
	A (Haus 8, Room 1.45)	Riegert, Anja	Stochastic modelling of fast hamiltonian chaos
	MS28 – part II (1.5h)	Ticozzi, Francesco	Finding quantum noiseless subsystems: a linear-algebraic approach
		Vitali, David	Dynamical decoupling schemes for inhibiting decoherence in the propagation of single-photon polarization qubits
	F (Haus 11, Room 0.09)	Viola, Lorenza	N.n.

1:00 PM	**Lunch + Poster Session 2**		
2:30 PM	**Concurrent Sessions**		
	MS04 – part IV (1.5h)	Averyanova, Liubov	Suppressing chaos in cardiac models using overdrive pacing
		Komarov, Maxim	Connectivity induced multistability in ensembles of neuron-like oscillators
-	**A (Haus 8, Room 1.45)**	Kryukov, Alexey	Multistabilibty of synchronous regimes in oscillatory ensembles
	MS07 – part II (1.5h)	Hartmann, Lorenz	Weighted graph states and applications to spin chains, lattices and gases
		Imamoglu, A.	Quantum control of quantum dot spins
4:00 PM	**B (Haus 8, Room 0.58)**	Kurizki, Gershon	Dynamical control of decoherence and thermodynamics
	MS12 – part IV (1h)	Dzhanoev, Arsen	A new mechanism for the chaos suppression
		Ando, Hiroyasu	An automatic feedback adjustment control in chaotic systems
	G (Haus 12, Room 0.39)		
	MS16 – part II (1h)	Steur, Erik	Reconstructing dynamics of spiking neurons from input-output measurements in vitro
		Rijlaarsdam, David	Synchronization of nonlinear neural oscillators with diffusive coupling: does the leakage of neurotransmitters matter?
	F (Haus 11, Room 0.09)		
	MS23 – part II (1h)	Pisarchik, Alexander	Control of multistability in lasers
		Janson, Natalia	Delayed feedback control of chaos: bifurcations in a large range of feedback parameters
	C (Haus 8, Room 0.59)		
4:00 PM	**Coffee+Poster Session 2**		
4:30 PM	**Concurrent Sessions**		
	MS06 – part II (2h)	Kiss, Istvan	Dynamical order and complexity in rhythmic chemical systems
		Kobayashi, J.Tetsuya	Population-level singularity behavior of mammalian circadian clock driven by desynchronization of multi-cellular clocks
	A (Haus 8, Room 1.45)	Kori, Hiroshi	Collective dynamical response to external forcing in complex oscillator networks
-		Meyer-Ortmanns, Hildegard	Synchronization of kuramoto oscillators determined by the depth of the networks
	MS07 – part III (2h)	Nest, Mathias	Exact benchmark calculations for system-bath type quantum dynamics with very largewave functions
		Oberthaler, Markus	Two weakly-coupled condensates
	B (Haus 8, Room 0.58)	Schumm, Thorsten	Interference and coherence in 1-d bose-einstein-condensates
6:30 PM		Viola, Lorenza	Dynamical decoupling techniques for coherent quantum control: recent developments
	MS21 – part II (2h)	Thiel, Marco	On recurrence matrices - solved and open problems
		Schelter, Björn	Multivariate analysis of oscillatory signals
	G (Haus 12, Room 0.39)	Malinowska, Katarzyna	Using recurrence plots to detect pomeau-manneville intermittencies and the related bifurcations
		Zou, Yong	Distinction between quasiperiodic and sticky orbits from a recurrence perspective
	MS26 – part III (1.5h)	Vzdornova, Oxana	Ellipsoidal techniques in state estimation problem for linear impulsive control systems
		Yunt, Kerim	Optimal impulsive control of structure-variant rigidbody mechanical systems
	F (Haus 11, Room 0.09)	Zavalishchin, Dmitrii	Problems of dynamic optimization of flow
	MS27 – part II (2h)	Siemenikhin, V.Konstantin	On minimax estimation in uncertain-stochastic models with probability criteria
		Taragna, M.	Virtual sensors for linear systems: structure and identification
	C (Haus 8, Room 0.59)	Timofeeva, Galina	Properties of confidence estimates for statistically uncertain systems
		Miller, Gregory	Separation principle for linear quadratic control in statistically uncertain stochastic hybrid system

Time	Friday Sep-07	Speaker	Title
8:00 AM	Registration		
9:00 AM	**Concurrent Sessions**		
	MS01 (3h)	Brockmann, Dirk	The structure of human transporation networks and how to divide the us into 10 parts
		Hilker, Frank	Regulating chaotic population dyanmics
		Jansen, Vincent	The interaction between transmission of disease and information on social networks
		Meron, Ehud	Pattern formation and rehabilitation of dryland vegetation
	A (Haus 8, Room 1.45)	Petrovskii, Sergei	Biological control of invasive species
-		Ryabov, Alex	Competition and coexistence in an incompletely mixed environment
	MS02 (2.5h)	Fischer, Ingo	Synchronization of delay-coupled lasers and neurons via dynamical relaying
		Kinzel, Wolfgang	Spiking optical patterns
		Mirasso, Claudio	Synchronization and correlation properties of n delay-coupled semiconductor lasers in a ring configuration
	C (Haus 8, Room 0.59)	Larger, Laurent	Chaos synchronization phenomena in delayed shared feedback coupled electro-optical oscillators
11:30 AM		Shaw, Leah	Isochronal synchronization of delay-coupled lasers
	MS17 – part III (2.5h)	Steinhoff, Uwe	Magnetocardiography of mice using a standalone multichannel squid device
		Fischer, Robert	Non-invasive cardiac magnetic field mapping detects early alterations in cardiac
		Schirdewan, Alexander	Comparison between body surface potential mapping and magnetic field mapping of the repolarization sequence in patients …
	B (Haus 8, Room 0.58)	Voss, Andreas	How and which non-linear measures of cardiovascular oscillations contribute to risk stratification?
		Chen, Jin-Long	Fractal analysis of heart rate dynamics in hyperthyroid patients
	CP – part VII	Ryabchenko, Vladimir	The spectra and pseudospectra of electric power systems
		Sieniutycz, Stanislaw	A variational principle for steady frictional flow in nonlinear porous media
		Kulish, V.V.	Application of the theory of hierarchic wave and oscillations to nonlinear
		Kulish, V.V.	A new approach to the theory of hierarchic wave-oscillation dynamic systems
		Kulish, V.V.	Multi-harmonic two-stream free electron laser as an example of the wave-oscillation hierarchic system
	G (Haus 12, Room 0.39)	Blyuss, Konstantin	Master equation approach to modelling multi-state memories and processors
	CP – part VIII	Daryin, Alexander	Closed-loop impulse control of oscillating systems
		Ben Chouikha, Wiem	Time evolution and pure dephasing of entangled states of two electrons in coupled quantum dots
		Kim, Jung-Su	Nonlinear observer-based synchronization of neuron models
		Krishchenko, Alexander	Id 68: estimation of the domain containing all compact invariant sets of the viral infection model
		Krishchenko, Alexander	virtual outputs with uniformly asymptotically stable zero dynamics and feedback design
	D (Haus 11, Room 2.03)	Moiola, J.	The complex non-resonant double Hopf degeneracy: An alternative approach
	CP – part IX	Rybalko, Sergei	A generalized model of active media with a set of interacting pacemakers: application to the heart beat analysis
		Donner, Reik	Dynamic stabilization and control of material flows in traffic and manufacturing networks by means of phase synchronization
		Frisman, Efim	Mosaic structure of biologic diversity: A result of autocontrol and synchronization of complex spatiotemporal dynamics of biological …
		Flunkert, Valentin	Supressing noise-induced intensity pulsations in semiconductor lasers by means of time-delayed feedback
		Starkov, Konstantin E.	Localization of Compact Invariant Sets of the Coupled Laser System
	F (Haus 11, Room 0.09)	Manuylovich, Elizaveta	Optimization of the proportional navigation law with time delay
		Khalid, Saifullah	Atomic probability amplitude stabilization with feedback control optical field
		Gadomski, Wojciech	Control of chaos and homoclinic dynamics of the vibronic laser
11:30 AM	Coffee		
12:00 AM	**Plenary Session**		
-	A (Audimax)	Sharkovsky, Aleksandr N.	One-dimensional maps, nonlinear dynamics and winnerless competition of patterns
12:45 PM			
12:45 PM	Lunch		
	End of the Conference		

Poster Session 1

Poster ID		
1	Recurrence plots in the analysis of icd heart rate recordings	Katarzyna Malinowska
2	Qualitative Behavior Prediction of Transition States in a Convection Loop	Mario Alberto Jordan
3	Oscillation Control of a Pendulum with Sliding Mass and Perturbation in the Pivot	Mario Alberto Jordan
4	On the Possibility of Combined Control Synthesis for Transient Processes Rate in Frequency Synthesizer Working in Wide Band	Olga G. Antonovskaya
5	Noise- and Delay-Induced Dynamics near a Global Bifurcation	R. Aust
6	Lie Algebra on Synchronization of Different Systems: A Generalized Function for Hodgkin-Huxley Neurons	Juan Gonzalo Barajas Ramirez
7	An Adaptive Fuzzy Sliding Mode Controller Applied to a Chatoic Pendulum	Wallace M. Bessa
8	Dissipative Processes at Phase Synchronization in the Nonlinear Oscillators' Lattice and Heat Emission at the Premelting Stage	Evgeniy Bogatikov
9	Feedforward Stabilization of Kapitza Oscillator Driven by Periodical Kicking Pulses	Sergei Borisenok
10	Control of an Active Damper Based on Magneto-Sensitive Fluid and Rubber	Igor A. Brigadnov
11	Stabilization of the Desired Uniform Rotation in Underactuated Systems	Ilya Burkov
12	"Channel" and "Jokers" Revealing at Reconstruction of the Chaotic Systems	Oleg Butkovskii
13	Transition to Chaos in Plasma through a Cascade of Spatio-Temporal Period-Doubling Bifurcations	S. Chiriac
14	On the Mechanism of Type I Intermittency in Nonlinear Current Driven Double Layers Dynamics	S. Chiriac
15	Efficient Neuromodulation of Excitability to Prevent the Spread of Pathological Activity	Markus Dahlem
16	Control of Unstable Steady States in Semiconductor Lasers by Time-Delayed Feedback Methods	Thomas Dahms
17	Evaluation of Traffic Control Strategies in Scale Free Networks Using a Parallel Processing Simulator	Radu Dobrescu
18	Mathematical Models of Control by the Interconnected Mechanical and Thermal Processes in Nonlinear Dynamic Systems Disturbed by Temperature Effects	V. E. Dzhashitov
19	General Synchronization Dynamics of Coupled Van der Pol–Duffing Oscillators	H.G. Enjieu Kadji
20	The Effect of Higher Order Hopping Integrals on Persistent Current of a Mesoscopic Normal Metal Ring	E.Faizabadi
21	The Modeling and Optimizing of Front Contact Metallization Grid Pattern for Multi Crystalline Silicon Solar Cell	E.Faizabadi
22	One Side Invertibility for Implicit Hyperbolic Systems with Delays	Haddouchi Faouzi
23	All-Optical Noninvasive Control of Unstable Steady States in a Semiconductor Laser	Valentin Flunkert
24	Practically Stable Observer-Based Synchronization of Discrete-Time Chaotic Systems over the Limited-Band Communication Channe	A.Fradkov
25	Synchronization of 4 Identical Chaotic Systems	Ioan Grosu
26	Studying the Stability of Magnetic Islands in a Nonlinear Dynamical System: Ergodic Magnetic Limiter in TOKAMAK	Ali Heidari
27	Open Loop Control of Lyapunov Exponents in Fixed Points of Nonlinear Ocillator	Nayyer Iqbal
28	Variable Structure MRAC for a Class of MIMO Systems	Ardeshir Karami Mohammadi
29	Compensation for the Iron loss Effect in EKF-based Speed Estimation of Vector Controlled Induction Motors	A. Kheldoun
30	Wave Mediated Synchronization of Nonuniform Oscillatory Media	On-Uma Kheowan
31	Estimates of control times for some classes of control systems of neutral type	Sergey Khryashchev
32	Adequate Control in Hierarchical Systems during Self-Adjusting Processes	Vadim Kleparskiy
33	Identification of Operating Periodic Process Braking-Up Regarding the Nonstationary Pulse Systems	Yu.V. Kolokolov
34	Stability Analysis of the "Thyristor Voltage Converter – Induction Machine" Model	Yu.V. Kolokolov
35	Variational Formulation for the Optimal Control Problems of Elastic Body Motions	G.V. Kostin
36	Influence of intrinsic noise on the progression of procaryotic gene expression	Busch, Hauke
37	A new Strategy of Defibrillation: Supression of the spiral wave Turbulence by Moving Pacemakers	A.Loskutov
38	Excitation of Resonance Phenomena during the Magnetron Sputtering of Thin Metallic Fractal Films	Gennadi Lukyanov
39	From an Equilibrium to Quasiperiodicity in Non-Smooth Systems	Zhanybai T. Zhusubaliyev
40	Recurrence analysis of strange nonchaotic dynamics	E. Ngamga

Poster Session 2

Poster ID	Title	Author
41	Closed-Loop Simulation of Kelvin Probe Force Microscopy based on Reduced Finite Element Cantilever Modeling	J. Maess
42	Extended Time Delayed Feedback Control of Stochastic Dynamics in a Resonant Tunneling Diode	Niels Majer
43	Physical Quantities Sensors Parameters Measurer	B.M. Mamikonyan
44	The Research of Hyperbolic Motion of Bodies in Gravity Fields	B.M. Mamikonyan
45	The Research of Elliptic Motion of Bodies in Gravity Fields	B.M. Mamikonyan
46	Modelling, Active Vibration Control and Simulation of Piezoelectric Layer Structures	D. Marinova
47	Investigation of Self-Fields Effects on Dispersion Relation in a Helical Wiggler with Ion-Channel Guiding	Mohammad Mirzakhani
48	Curvature index failures in the dynamics of an electric coupled circuit	J.Moiola
49	Non-Holonomic Distributions and Dynamical Systems	Felipe Monroy-Perez
50	The Structure at Infinity and the Structure of the Interactor of Linear Multivariable Systems	Yasuhiko Mutoh
51	Flight Automatic Control System for Wing-in-Ground Effect Craft Buchon-1	V. Nebylov
52	Supressing noise-induced intensity pulsations in semiconductor lasers by means of time-delayed feedback	Frisman, Efim
53	Geometric Method for a Problem of Synthesis of the Robust Control on Linear Polyhedrons	Vladimir N. Pilishkin
54	Nonsynchronous Modes and Bifurcation of a Frequency-Phase-Feedback Oscillator with an Inverted Frequency Discriminator Charac	Valery P. Ponomarenko
55	Controlling Chaos in Spatially Extended Beam-Plasma System with the Help of Continuous Delayed Feedback	I.S. Rempen
56	Extended Kalman and Particle Filtering for Sensor Fusion in Mobile Robot Localization	Gerasimos G. Rigatos
57	Robust Elimination Lemma for Polytopic Systems	Danica Rosinova
58	Time-Delayed Control of Chaos in the Ikeda System	Nikita M. Ryskin
59	Reliable Beam Modeling in Control Problems	V.V. Saurin
60	A Comparison of Collision Avoidance Methods Effectiveness in a Mobile Ad-hoc Network	
61	Phase-Locking Phenomena and Excitation of Damped and Driven Nonlinear Oscillator	Arkadiy Shagalov
62	Experimental and Computer Modeling of Intelligent Polymeric Composite Structures with Neural-Network Based Control	Sergey Shevtsov
63	Cure Kinetics of Epoxy Resin and Distributed Thermal Control of Polymeric Composite Structures Moulding	Sergey Shevtsov
64	Neural Networks Approach to Blind Source Separation via Adaptive Independent Component Analysi	Viacheslav Shkodyrev
65	About the Problem of Cycle-Slipping in Discrete System with Periodic Nonlinear Vector Function	Vera B. Smirnova
66	Nonlinear Gyromoment Spacecraft Attitude Control with Precise Pointing the Flexible Ant	Yevgeny Somov
67	Nonlinear Dynamics of Phase Control System Modeling by Modified Circle Map	A.I. Tomashevskiy
68	Control of Passage through Resonance for the Two-Rotor Vibration Set-Up	Dmitry Tomchin
69	Algorithm of Multiple Synchronization for Two-Rotor Vibration Unit with Time-Varying Payload	Olga Tomchina
70	All-optical noninvasive control of unstable steady states in a semiconductor laser	
71	Entanglement generation by dispersive interactions	Luis Roa
72	Control of Turbulence Spectra by Acoustic Forcing	P. Landa
73	Recursive Active Control for Controlling Chaos in Nonlinear Bloch Equations	Uchechukwu E. Vincent
74	An Adaptive Chaotic Secure Communication Scheme with Channel Noise and Time Delay	Sun Yonghui
75	The Exploitation Effect on Both Genetic Variety and Dynamic Behavior of Mendelian Limited Population: Non-Stationary and Stationa	Oksana L. Zdanova
76	Microstructure and Magnetic Properties of Co-C and Co-Pd Films with the Internal Bend of a Lattice	Victor Zhigalov
77	Control of unstable steady states in semiconductor lasers by time-delayed feedback methods	Thomas Dahms
78	Reconstruction of System Dynamics from Short Data Sets	C. Komalapriya

University of Potsdam Complex 1: Am Neuen Palais

Locations of PhysCon2007:

Haus 12
Mensa,
Lectureroom 0.39 (G)

Haus 11
Lecturerooms 2.03 (D), 2.27 (E), 0.09 (F)

Haus 8
Lecturerooms Audimax 1.45 (A), 0.58 (B), 0.59 (C), Registration and Posters in Foyer (0.60, 0.61)

CHAOS AND COMPLEXITY

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A complex system is made up of many parts that are interrelated in a complicated manner. These intricate mutual relations result in the formation of coherent and random structures over a wide range of time and/or length scales. I will argue, following the tradition of the theory of dynamical systems, that these complex structures can be understood in terms of dynamical invariants. I will also argue that the ability of a complex system to access many different states, combined with its sensitivity, offers great flexibility in manipulating the system's dynamics to select a desired behaviour. In addition, I will discuss a paradigm that combines targeting type of control problem for chaotic systems with techniques used in system control theory.

E. E. N. Macau and C. Grebogi, Phys. Rev. E **59**, 4062 (1999)

PHASE SYNCHRONIZATION AND APPLICATIONS TO STOCHASTIC RESONANCE AND BIOMEDICAL SIGNAL ANALYSIS

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Phase synchronization has been an active area in applied nonlinear dynamics. The phenomenon occurs in weakly coupled nonlinear oscillators, where their phases tend to follow one another but the state variables remain uncorrelated. Studies of stochastic and/or chaotic phase synchronization have led to novel methods for signal processing and time-series analysis with significant applications in biomedical science and engineering.

In this talk, the basic dynamics of phase synchronization will be reviewed. Two problems will then be discussed: (1) characterization of stochastic resonance in terms of phase synchronization and (2) analysis of nonstationary signals. For the first problem, it will be shown that proper measures based on stochastic phase synchronization can provide orders-of-magnitude improvement in sensitivity to noise variation. This may be desirable for developing stochastic-resonance based devices. For the second problem, a method to detect phase synchronization in nonstationary dynamical systems will be introduced and applications to ECoG signal analysis for detecting and understanding epileptic seizures will be presented.

ESTIMATING THE STATE OF LARGE SPATIOTEMPORALLY CHAOTIC SYSTEMS

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State estimation is a general requirement for controlling a system or for predicting its future evolution. In this talk we will address the problem of estimating the state of a large spatiotemporally chaotic system from limited noisy measurement data and a knowledge of a system model. For large systems, state estimation can be particularly challenging because straightforward application of the conventional techniques is typically not feasible due to computational limitations. This problem has very general interest, *e.g.*, for weather forecasting, *etc*. This talk will present background material, a proposed solution for treating large systems, and illustrative results from application of our technique to weather forecasting and to a laboratory experiment.

CONTROL OF SLEEP: THEORY AND EXPERIMENTS

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We begin with an overview about the problem of sleep. Slow wave sleep is generated by the cortex, it influences the sleep spindles generated by the thalamus and both signals induce synaptic changes which influence our memory.

Next, slow wave sleep will be modelled by way of coupled threshold elements with self inhibition. These elements display a phase transition to an oscillating state which is noise activated and displays strong collectively enhanced stochastic resonances. For an exponentially decaying distribution of dead-times the transition to the oscillating state occurs, coming from high temperatures via a Hopf bifurcation and coming from low temperatures, via a saddle node bifurcation. These transitions can be triggered externally by noise and oscillating signals, offering new possibilities for controlling slow wave sleep.

Experiments show that spindle oscillations in the thalamus are synchronized via thalamo-cortical projections. We model the underlying control mechanism and show that it will lead to a control method that is applicable to a wide range of stochastically driven excitable units. Finally, we discuss the influence sleep on synaptic changes, the problem of homeostasis and the possibility of control by learning.

ONE-DIMENSIONAL MAPS, NONLINEAR DYNAMICS AND WINNERLESS COMPETITION OF PATTERNS

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In 60–70s of the last century the advancement of nonlinear dynamics was going on at a quickened pace owing to the emergence of such notions as chaos, strange attractor, fractal, *etc*. Developing the theory of one-dimensional dynamical systems has also made a considerable contribution to this situation. In the report, we will have to do with some stages of the creation of one-dimensional dynamical systems theory.

The use of this theory in modelling various nonlinear phenomena has allowed us to explain many mechanisms of the onset of spatio-temporal chaos, in particular, the cascade process of emergence of coherent structures of decreasing scales, up to fractal and stochastic ones. However basic achievements in this line of investigation are likely to be gained in the future.

One further line of considerable promise for the application of one-dimensional dynamical systems theory is modelling brain processes. Building dynamical models to study the neural basis of behavior has long history. Recently a dynamical principle, called winnerless competition, was suggested in works of several authors. In such models, given by multidimensional dynamical systems, spatio-temporal coding is realized in the form of deterministic trajectories moving along heteroclinic orbits that connect certain saddle fixed points and saddle limit cycles in the state space. For modelling information of this kind, it makes sense to use one-dimensional maps with positive topological entropy. Such maps, being very simple in form, have nevertheless a countable set of saddle cycles and an uncountable set of homoclinic and heteroclinic orbits connecting these cycles.

COLLECTIVE BEHAVIOR IN EXCITABLE MEDIA: DYNAMICAL NETWORKS AND INTERACTING PARTICLE-LIKE WAVES

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We discuss two topics of collective behavior in the context of excitable media: spatiotemporal networks and swarming behavior

A network of excitable nodes based on the photosensitive Belousov-Zhabotinsky reaction is studied in experiments and simulations. The addressable medium allows both local and nonlocal links between the nodes. The initial spread of excitation across the network as well as the asymptotic oscillatory behavior are described. Synchronization of the spatiotemporal dynamics occurs by entrainment to high-frequency network pacemakers formed by excitation loops. Analysis of the asymptotic behavior reveals that the dynamics of the network is governed by a subnetwork selected during the initial transient period.

We describe studies of interacting particle-like waves in the photosensitive Belousov-Zhabotinsky reaction. Unstable waves are stabilized by global feedback that affects the overall excitability of the medium, and the motion of these waves is controlled by imposing excitability gradients that are regulated by a secondary feedback loop. Waves interact via a Lennard-Jones type potential in which there are attractive forces at long distances and repulsive forces at short distances. Processional motion is the most common behavior, where waves align with one another to varying degrees depending on the strength of the potential. Rotational motion is also observed, which may occur for the same parameters as processional motion depending on initial conditions. We also discuss other modes of behavior and an analysis of the wave interaction in terms of the gradient of the potential.

*In collaboration with Aaron J. Steele and Mark Tinsley

Noninvasive Optical Control of Semiconductor Lasers

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Semiconductor lasers are key components of modern optical information technologies. Not only continuous-wave emission but also self-pulsations or even chaotic output on picosecond timescales are of interest. In this context, ultrafast all-optical control methods become important where the velocity of light sets the ultimate speed limit. After reviewing basic ideas as well as the state of the art in this field, we focus on the experimental configuration developed in our group [1]. A multisection laser is controled by phase-dependent optical feedback from a Fabry-Perot (FP) interferometer. The multisection laser provides reproducible access to numerous bifurcations within a codimension 4 parameter space spanned by 3 currents and temperature. Optical feedback from a Fabry-Perot represents a generalization of the well-known extended time-delayed feedback control [2] to the stabilization of periodically modulated waves. A complex control gain is the consequence. Its phase represents the optical round-trip phase shift providing an additional new control parameter. Phase-dependent noninvasive stabilization of unstable continuous and periodic emission is demonstrated experimentally at Hopf- and period-doubling bifurcations as well as in chaotic regimes of operation. Theoretical analysis, in both generic models of the bifurcations as well as device-specific simulations, points out the role of the control phase. In particular, there exist cases where modulated waves can be stabilized although the control of corresponding periodic orbits fails.

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THE STRUCTURE OF HUMAN TRANSPORATION NETWORKS &
HOW TO DIVIDE THE US INTO 10 PARTS

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Geographical boundaries are key determinants of various spatially extended dynamical phenomena. Examples are migration dynamics of species, the spread of infectious diseases, bioinvasive processes, and the spatial evolution of language. As political boundaries have become less important, it is difficult to quantify their impact on spatially extended human dynamics. The evolved complexity of contemporary human travel may exhibit intrinsic modularities and effective boundary structures, which not necessarily coincide with existing political boundaries. We investigate to what extend geographical boundaries are intrinsically encoded in the connectivity structure of human transporation networks. We investigate a large scale complex network of human travel between the approx. 3000 counties in the US. We construct the network by analyzing the flux of over 10 million dollar bills reported at the bill-tracking website wheresgeorge.com which extends the dataset of a previous study (Brockmann et al., Nature 2006) by a factor of 20. This dataset is supplemented by dispersal data of so-called "travel bug dog tags". These are items which play a key role in geocaching, a popular GPS treature hunt. Both datasets serve as a proxy for estimating human travel on global scales.

REGULATING CHAOTIC POPULATION DYANMICS

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Interactions in ecological communities are inherently nonlinear and can generate complex population dynamics including chaos -- leading to violent fluctuations in the sense that extremely small or large population abundances may cause extinction and recurrent outbreaks, respectively. A simple management method is presented that can prevent crashes, peaks or any other undesirable state. The control scheme is based on ideas from chaos anti-control and composed of two steps. First, we scan available time-series data and identify certain regions in state space that lead to undesired events. Second, we implement interventions to perturb the system whenever it is on such a crash path. The approach is illustrated by two examples: the simple Ricker model of populations with non-overlapping generations and a structured model of flour beetle populations. Ecological systems are typically characterized by a shortage of available data, noise and a limitation of possible interventions. It is shown that the method can be very effective even under these circumstances.

THE INTERACTION BETWEEN TRANSMISSION OF DISEASE AND INFORMATION ON SOCIAL NETWORKS

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Humans can protect themselves against contracting or transmitting a disease by changing their behaviour, for example, through vaccination or a reduction in the number of infectious contacts. To do so, one needs to have information that the disease is present. Just like a disease can spread in a social network, information about the presence of a disease can spread in a similar way. We investigate the interaction between the transmission of a disease and information about this disease and discuss the interplay between these two processes.

PATTERN FORMATION AND REHABILITATION OF DRYLAND VEGETATION

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Landscapes of water-limited systems are mosaics of patches that differ in resource concentration, biomass production and species richness. Two processes affecting their structure and dynamics have attracted considerable attention during the past decade, ecosystem engineering and self-organized patchiness. Ecosystem engineers are key species that modify the abiotic environment, redistribute resources and facilitate the growth of other species. A well studied example is provided by shrubs that concentrate soil water and form fertile patches where annuals, grasses and other species can grow. Self-organized patchiness is a pattern formation phenomenon whereby positive water-biomass feedbacks at the level of a single patch result in vegetation patterns at the landscape level. A striking example of this phenomenon is banded vegetation on hill-slopes. Biomass and resource patchiness may also be affected by climate fluctuations inducing desertification phenomena. Vegetation rehabilitation in desertified regions is commonly based on water harvesting techniques using landscape modifications, such as parallel contour ditches on hill slopes that capture runoff water.

In this talk I will describe studies of self-organized patchiness and ecosystem engineering along environmental gradients, using a mathematical model for plant communities in water-limited systems. Theoretical results predicted by the model will be compared and confronted with aerial photographs, field studies and laboratory experiments. I will conclude by discussing vegetation rehabilitation as a problem of resonant response to spatially periodic forcing.

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BIOLOGICAL CONTROL OF INVASIVE SPECIES

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Invasion of exotic species is currently regarded as a major threat to biodiversity and agriculture. Apparent importance of this issue has brought to life various strategies of invasive species management. The concept of biological control is based on the assumption that the impact of certain biological factors, such as predation or infectious disease, can slow down or block or even reverse the spread of pest species.

Mathematically, the problem is described by a system two nonlinear diffusion-reaction equations. We first study the problem analytically and show that predation normally slow down the species spread, although invasion blocking or reverse is only possible when the population growth is damped by the strong Allee effect. We then study the problem by means of extensive numerical experiments in one and two spatial dimensions and show that the impact of predation or infectious diseases can change the whole pattern of spread: in a certain parameter range, invasion can take place not via the intuitively expected circular expanding population front but via motion and interaction of separate patches. The population density appears to be on the order of carrying capacity inside the patches and it is virtually zero between the patches. We then show that this phenomenon of patchy invasion takes place 'at the edge of extinction' so that a small change of controlling parameters either brings the species to extinction or restore the travelling population fronts. Moreover, we show that the regime of patchy invasion in two spatial dimensions actually takes place when the species go extinct in the corresponding 1-D system. Similar dynamics is observed in the case when exotic species spread is affected by an infectious disease. Our results create a theoretical framework for species spread understanding and control.

COMPETITION AND COEXISTENCE IN AN INCOMPLETELY MIXED ENVIRONMENT

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Competition theory predicts that in a well mixed environment at equilibrium the number of coexisting species should be limited by the number of limiting resources. Nevertheless, usually in aquatic ecosystems biodiversity of phytoplankton species strongly exceeds the number of abiotic resources. It is well known as "paradox of the phytoplankton". Different mechanisms can provide it. For example, oscillations and chaotic dynamics of abundances give rise of time niches for each species. Another mechanism is based on a trade-off between colonization and competing abilities. In this case an offspring of the better colonizer can find an empty site rather the better competitor can colonize any site but with lower rate. However both mechanism and many others assume homogenous distribution of the resources. Here we consider a 1D spatio-temporal model of several populations which live on two essential spatially distributed resources, where the resource distribution depends on the population densities in a nonlinear way. We present a new method for analysis of the competition outcome in this environment and show that a trade-off between competing abilities for the two resources may provide coexistence of many species growing in two opposite resource gradients (e.g. light and a nutrient). The favorable patch for each species can not be arbitrary small, hence the number of coexisting species can be large, but it is limited by the number of possible patches in the environment. Moreover, addition of a new species may provide new niches and lead to coexistence of those, which could not coexist before.

Synchronization of Delay-Coupled Lasers and Neurons via Dynamical Relaying

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The study of the synchronization properties of delay coupled systems has relevance in different fields of science, including coupled semiconductor lasers and brain dynamics. In studies of the brain, both from microelectrodes and from EEG recordings (MEG EEG), zero-lag synchronization of neural firings and oscillations across separated cortical regions has been found, despite of considerable coupling delays. Complementary, also in studies of coupled semiconductor laser dynamics, zero-lag chaos synchronization has been observed. Thus the question arises, how two distant lasers or neural assemblies can synchronize their dynamics at zero-lag in the presence of non-negligible delays in the transfer of information between them? We introduce and discuss simple net-work modules that naturally account for zero-lag neural synchronization for a wide range of temporal delays. In particular, we discuss how isochronous (zero-lag) millisecond precise synchronization between two distant neurons or neural populations can be achieved by relaying their dynamics via a third mediating single neuron or population.

Spiking Optical Patterns

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The chaotic intensity fluctuations of a semiconductor laser consist of short spikes, (120 ps), and when two chaotic lasers are synchronized the pattern of these apparently random, short spikes precisely coincide. Here we analyze the statistics of spikes of a solitary and two mutually interacting chaotic semiconductor lasers on a sub-ns time scale and find a number of similar features in the spiking behavior of lasers and neurons. As for neurons, repulsion between two successive spikes is observed, resulting in a refractory period which is largest at laser threshold. For time intervals between spikes greater than the refractory period, the distribution of the intervals follows a Poisson distribution. In further analogy to neurons, the spiking pattern of the laser is highly periodic over time windows corresponding to the optical length of the external cavity, with a slow change of the spiking pattern as time increases. When zero-lag synchronization between the two lasers is established, the spike statistics are not altered and the mismatch in the timing of the spikes was found to be less than our detection bandwidth of 80 ps, and the typical relative difference between the heights of synchronized spikes was found to be around 10%. These results strongly suggest that the bar-code of the spiking pattern can be used as encoded information in novel communication systems based on synchronized chaotic lasers and may also play a central role as an information carrier in synchronized neuronal networks.

Chaos Synchronization Phenomena in Delayed Shared Feedback Coupled Electro-Optic Oscillators

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Synchronization phenomena of delay-coupled nonlinear oscillators have turned out to be of importance in various fields of science. Mathematically, the delayed coupling renders these systems infinite dimensional which often makes analysis challenging. In the last two decades, analysis methods have been developed and experiments realized to study their nonlinear dynamical behavior. Since then, manifold influences of delayed coupling have been identified, comprising multistability of synchronized and desynchronized solutions, amplitude death, and delay-induced instabilities in conjunction with symmetry breaking. For the latter, it has been shown that two coupled systems can synchronize, but with a relative time-lag roughly corresponding to the coupling delay [1]. This has been overcome recently by introducing a relay element in the coupling path [2].
We introduce a versatile system consisting of two mutually delay-coupled electro-optic oscillators. We have designed a coupling scheme, namely *delayed shared feedback coupling*, which allows for nonlinear dynamics and implementation of robust chaos synchronization. In our system we can experimentally and numerically demonstrate different types of chaos synchronization comprising identical synchronization, anti-synchronization and general synchronization. For identical synchronization, we demonstrate robustness, and identify an extremely fast synchronization process which we can relate to the occurrence of a common drive signal acting as stabilizing mechanism. Further more, by relatively detuning the nonlinearity of the oscillators, we can demonstrate anti-synchronization, exhibiting perfect anti-correlation and general synchronization with vanishing linear correlation. Therefore, the realized system represents an attractive model system for studying the transitions between different synchronization states. Such insight might be fruitful for the understanding of dynamical phenomena in various systems in nature.

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Synchronization and Correlation Properties of N Delay-Coupled Semiconductor Lasers in a Ring Configuration

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The study of the synchronization properties of delay coupled systems has recently been gaining considerable interest in the complex systems field due to the interesting behaviors that emerge. While mutually delay-coupled semiconductor lasers (DCSCLs) were studied for the first time only at the end of the last decade, the finding that delayed coupling induces instabilities and synchronization at the same time triggered significant activity in the field. One of the intriguing aspects is that the instabilities are not synchronized isochronously but exhibiting a leader-laggard phenomenon in the dynamics of the lasers. Thus, delayed coupling induces spontaneous symmetry breaking in the time domain. Recently it has been demonstrated that nevertheless identical zero-lag synchronization can be established, if an appropriate configuration of three mutually coupled semiconductor lasers in a chain is chosen. Actually, zero-lag synchronization then occurs between the two outer elements, while nearest-neighbors only synchronize in a generalized way with leader-laggard properties[1].

Here we study the configuration of N DCSCLs. We choose the ring configuration of unidirectionally coupled elements, the dynamics of which can be understood as two bidirectionally coupled systems with laser 1 being the first and laser $N/2+1$ the second element connected via $N/2$ other nonlinear elements. We concentrate on their correlation properties and compute the corresponding optical and power spectra. Analyzing the autocorrelation function for $N = 2$ we observe a significant reduction of the height of the first peak (at $t \neq 0$). We attribute this to the nonlinear response of the laser. Increasing the number of lasers in the path we find that the height of the first peak decays exponentially with the number of elements being almost negligible for $N \sim 10$ or larger. The cross correlation between 1 and $N/2+1$ is almost flat indicating a complete loss of correlation between these elements. However, when computing both optical and power spectra their shape is identical and appears to be unaffected except for the peaks associated with the external cavity that completely wash out. These results open new possibilities in chaos-based applications.

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Isochronal synchronization of delay-coupled lasers

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We consider models for small networks of delay-coupled lasers. We show analytically and numerically that for certain coupling architectures that involve delayed self-feedback to the nodes, the lasers become isochronally synchronized, meaning that the time series are completely synchronized with no time shift. Both fiber ring lasers, a spatiotemporal system, and incoherent pump-coupled semiconductor lasers are studied. We consider how to scale the coupling architecture to synchronize larger networks of lasers.

A STUDY OF CONTROL SYSTEMS FROM THE GEOMETRY OF THE RING OF SCALARS

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Linear systems over commutative rings have been studied from the late 1960's. There has long perceived the need for an extension of the framework of linear systems over the field C of complex numbers to an arbitrary commutative ring R. This extension allows us to consider as particular cases not only usual linear systems with constant coefficients over R or C but linear digital systems over finite fields F_q (coding) or the ring Z of integers. Delay systems over polynomial rings or Laurent series rings fit also in the definition.

Families of real linear systems parametrized in a topological space X can be studied by setting the R-algebra $R = \mathcal{C}(X)$ of real continuous functions defined on X. This is the case focused in this paper. In fact we review the pointwise approach to reachability (based on the evaluations at the points of βX, the Stone-Čech compactification of X. Feedback invariants are also reviewed and we state the conditions for a linear system to be ... locally of Brunovsky type. It is well known that in the case of $R = \mathcal{C}(X)$ is projectively trivial then locally Brunovsky = Brunovsky. But in general this is not the case.

Fixed the dimensions n and m of state space and input space, the problem of find all (m,n)-Brunovsky systems is in fact the combinatorial problem of studying all the partitions of integer n into pieces lower than m.

However the more general problem of finding all locally Brunovsky systems is shown to be characterized by the Grotendieck's K-group $K_0(\mathcal{C}(X))$ and by the problem of finding all possible decompositions of state space module into projective direct summands.

In fact we review the case of rings of continuous functions defined on a real sphere S^n and point out some examples of locally Brunovsky systems that are not globally of Brunovsky type.

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STRUCTURAL STABILITY OF SINGULAR SYSTEMS UNDER PROPORTIONAL AND DERIVATIVE FEEDBACK

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We consider quadruples of matrices (E,A,B,C), representing singular linear time invariant systems in the form $E\dot{x}(t) = Ax(t) + Bu(t)$, $y(t) = Cx(t)$ with $E,A \in M_n(C)$, $B \in M_{n\times m}(C)$ and $C \in M_{p\times n}(C)$, under proportional and derivative feedback, and proportional and derivative output injection.

In this work study the equivalence relation as a Lie group action that permit see the equivalence classes as differentiable manifolds and studying the tangent space to the orbits we obtain a characterization of the structural stability of quadruples of matrices, in terms of numerical invariants.

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CANONICAL LOCAL FORMS FOR HOLOMORPHIC FAMILIES OF SINGULAR SYSTEMS UNDER PROPORTIONAL AND DERIVATIVE FEEDBACK

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In this work we study the problem of finding canonical forms that are stable under small perturbations of the original entries. We solve the problem following ArnolThe author studies the problem of finding canonical forms that are stable under small perturbations of the original entries. He solves the problem d's techniques, and we obtain a local canonical form of a holomorphic family of triples of matrices $(E(\lambda), A(\lambda), B(\lambda))$ acted on by the state and derivative feedback group. We obtain an explicit formula to compute the dimension of the base space of any miniversal deformation of $(E(0), A(0), B(0))$. We make some applications to local perturbations of a triple of matrices.

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CONTROLLABILITY OF MATRIX SECOND ORDER SYSTEMS OF MATRIX. A TRIGONOMETRIC MATRIX APPROACH

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Many of the real life problems are modelled as Matrix Second Order Systems. Necessary and sufficient conditions for controllability of Matrix Second Order Linear(MSOL) Systems have been established by Hughes and Skelton. However, no scheme for computation of control was proposed. In this paper we first obtain another necessary and sufficient condition for the controllability of MSOL and provide a computional algorithm for the actual computation of steering control. We also consider a class of Matrix Second Order Nonlinear systems (MSON) and provide sufficient conditions for its controllability. In our analysis we make use of Sine and Cosine matrices and employ Pade approximation for the computation of matrix Sine and Cosine. We also invoke tools of nonlinear analysis like fixed point theorem to obtain controllability result for the nonlinear system. We provide numerical example to substantiate our results.

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ASSIGNABLE POLYOMIALS TO FEEDBACK CLASS OF A SINGLE INPUT LINEAR SYSTEM

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This work deals with the pole-shifting problem for non reachable single input linear systems. Let R be a Bezout domain (i.e. R is an integral domain with the property that every finitely generated ideal over R is principal). A single input n-dimensional linear system Σ over R is a pair of matrices $\Sigma = (A, \underline{b})$ where A is an $(n \times n)$-matrix and $\underline{b}$ is an $(n \times 1)$-matrix with entries in R. Two single input n-dimensional linear systems $\Sigma = (A, \underline{b})$ and $\Sigma' = (A', \underline{b}')$ are feedback equivalent if there exist a feedback $(1 \times n)$-matrix $\underline{f}^t$ and an invertible $(n \times n)$-matrix P such that

$$(A', \underline{b}') = (PAP^{-1} + P\underline{b}\underline{f}^t, P\underline{b}).$$

For $i = 1, 2, \ldots, n$ consider the block matrix

$$(A * \underline{b})_i = (\underline{b} \mid A\underline{b} \mid A^2\underline{b} \mid \ldots \mid A^{i-1}\underline{b}),$$

and recall that Σ is reachable (resp. weakly reachable) if the determinant of the reachability matrix $(A * \underline{b})_n$ is invertible (resp. non zerodivisor). The characteristic polynomial $\chi(A, X)$ of A is not an invariant by the feedback action. In fact, a classical result in Control Theory assures that $(A * \underline{b})_n$ is invertible if and only if Σ has the coefficient assignability property (i.e. for every monic polynomial $f(X)$ of degree n there exists a linear system $\Sigma' = (A', \underline{b}')$ feedback equivalent to Σ such that $f(X) = \chi(A', X)$). Let $\Sigma = (A, \underline{b})$ be a single input n-dimensional linear system over a Bezout domain R. In this work we characterize the monic polynomials $f(X)$ of degree n such that there exists an $(1 \times n)$-matrix $\underline{f}^t$ such that

$$f(X) = \chi(A + \underline{b}\underline{f}^t, X).$$

In other words, we characterize the assignable polynomials to feedback class of Σ . We give an algorithm to determine if a polynomial $f(X)$ is assignable to Σ.

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PARTICLE SWARM OPTIMIZATION OF PD CONTROLLER FOR CARGO SHIP STEERING

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This paper discussed the implementation of Particle Swarm Optimization (PSO) to optimize a PD-type autopilot for a cargo ship. The tuning of the PD controller parameters are considered to be difficult and tedious due to the high nonlinearity of the ship dynamic model and the external disturbances. However, PSO can provide a very promising technique for its simplicity and ease of use. Three variants of PSO model are evaluated and compared in the simulation experiment. Moreover, Centroidal Voronoi Tessellation (CVT) is implemented to select the starting positions of the particles strategically. The promising results from the experiment provide direct evidence for the feasibility and effectiveness of PSO for autopilot control of cargo ship.

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CARLEMAN ESTIMATE AND EXACT CONTROLLABILITY

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A nonlinear parabolic problem with memory effect is considered. We establish a Carleman type estimate for a linear problem which is the adjoint of a suitable linearization of the nonlinear problem. This is used to get an observability estimate. Then we establish the exact controllability of the linearized system with distributed control over a subdomain. Finally, we get the controllability of the nonlinear system via Kakutani fixed point theorem.

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LINEAR ALGEBRA TECHNIQUES IN STABILITY PROBLEMS OF SYSTEMS OVER RINGS

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A linear system over a commutative ring R is a pair (A,B), where A is an $n\times n$ matrix and B is an $n\times m$ matrix with coefficients in R. Systems over rings are a generalization of linear control systems, which are used in the study of evolution processes which can be modelled as differential or difference equations, with states, inputs and outputs.

We will study two different aspects of systems theory: (i) the problems of pole assignment (PA), coefficient assignment (CA) and feedback cyclization (FC), which basically consist of replacing A by a matrix of the form $A+BK$ such that the characteristic polynomial of $A+BK$ has some desired properties, and (ii) the 'feedback' classification of systems: the pair (A,B) is equivalent to $(PAP^{-1}+PBK, PBQ)$, for matrices P,Q,K of appropriate sizes and P,Q invertible.

After giving an outline of the main linear algebraic techniques used, we will present an almost-canonical form for systems with coefficients in rings for which the above mentioned FC problem is solvable.

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ESTIMATING THE SENSIVITY OF THE STRUCTURE OF THE SINGULAR SYSTEMS UNDER PROPORTIONAL AND DERIVATIVE FEEDBACK AND PROPORTIONAL AND DERIVATIVE OUTPUT INJECTION EQUIVALENCE

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Given quadruples of matrices (E,A,B,C) defining a singular linear systems $E\dot{x}(t) = Ax(t)+Bu(t)$, $y(t) = Cx(t)$ with $E,A \in M_n(\mathbb{C})$, $B \in M_{n\times m}(\mathbb{C})$ and $C \in M_{p\times n}(\mathbb{C})$. After defining an equivalence relation that it can be seen as the action under a Lie Group, permit us to use geometrical techniques to obtain a lower bound for the distance between a structurally stable quadruple of matrices and the nearest non-structurally one, in terms of the singular values of a certain matrix associated to the quadruple.

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SUPPRESSING CHAOS IN CARDIAC MODELS USING OVERDRIVE PACING

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Recent findings indicate that ventricular fibrillation can arise from spiral wave chaos. Our objective in this computational study was to investigate wave interactions in excitable media and to explore the feasibility of using overdrive pacing to suppress spiral wave chaos. This work is based on the finding that in excitable media, propagating waves with the highest excitation frequency eventually overtake all other waves. We analyzed the effects of two simultaneously applied low-amplitude forces: (i) constant current and (ii) high-frequency pacing in one-dimensional and two-dimensional networks of coupled, excitable cells governed by the Luo-Rudy model. In the one-dimensional cardiac model, we found narrow high-frequency regions of 1:1 synchronization between the input stimulus applied to single cell and the whole system's response. Importantly, the frequencies in this region were higher than those present in fibrillation episodes. When we locally paced the two-dimensional cardiac model with frequencies from this region, we found that spiral wave chaos could be suppressed. This happens because the influence of constant current on the action potential duration (APD): The application of positive current leads to decrease of APD. As a result of such doubled force, spiral waves behavior becomes more regular. This allows to suppress the spiral chaos more effectively. These findings suggest that low-amplitude, high-frequency overdrive pacing, in combination with low-amplitude positive constant current may be useful for eliminating fibrillation.

A NETWORK MECHANISM FOR HIGH- AND LOW-FREQUENCY OSCILLATIONS IN NEURONAL ENSEMBLES

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Bursting is a fundamental regime of neuronal behavior, exhibiting trains of spikes of the action potential mediated by periods of silence. Synchronized bursts from central pattern generators are known to coordinate movements. Experimentally observed synchronous high- (> 300Hz) or low-frequency (< 300Hz) bursting in cortical areas of the behaving or sleeping animal is hypothesized to participate in learning, cognition, motivation, movement control. Another possible role of bursting is increasing reliability of cortical synapses.

In recent years the problem of the origin of bursting in neural ensembles has received much attention. Beside being a result of intrinsic mechanisms or a response to external stimulus, these oscillations may originate due to interaction between neurons. Currently, there is a bunch of experimental and theoretical evidence of various network mechanisms of burst generation in ensembles of non-bursting neurons.

We report on the mechanism of burst generation by populations of intrinsically spiking neurons, when a certain threshold in coupling strength is exceeded. These ensembles synchronize at relatively low coupling strength and lose synchronization at stronger coupling via spatio-temporal intermittency. The latter transition triggers fast repetitive spiking, which results in synchronized bursting. We present evidence, that this mechanism is generic for various network topologies from regular to small-world and scale-free ones, different types of coupling and neuronal model.

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q-BREATHERS IN NONLINEAR LATTICES: NORMAL MODE CONCEPT AND ITS BREAKDOWN

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Recently q-breathers - time-periodic solutions which localize in the space of normal modes and maximize the energy density for some mode number - were obtained for finite nonlinear lattices. A q-breather in a nonlinear lattice is a continuation of a single-mode solution of the corresponding linear system. The localization length of a q-breather in the space of normal modes increases when the nonlinearity parameter is increased. When the localization of a q-breather is weak, the concept of a linear normal mode becomes meaningless: a single-mode solution is quickly destroyed and energy is redistributed among the modes . We study localization properties of q-breathers in a system size independent form in terms of intensive parameters: energy density and wavenumbers. Various particular cases (different boundary conditions and parts of the spectrum) are considered. Different approaches (general symmetry considerations, asymptotical methods, numerical calculation) are used.

CONNECTIVITY INDUCED MULTISTABILITY IN ENSEMBLES OF NEURON-LIKE OSCILLATORS

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We consider the Hodgkin-Huxley type model of pacemaker activiy in the bursting neurons of snail Helix pomatia. Mathematical model and various modes of activity of a single cell are shown. We present the results of numerical analysis of two electrically, excitatory and inhibitory coupled neurons in various initial regimes. Different effects of oscillatory death, in-phase and out of phase synchronization, chaos and collective burst generation are studied.

Further we show the results of numerical investigation of a chain of 50 nonidentical elements. Spatio-temporal structures of synchronous and asynchronous activity in spiking and bursting regimes are found. Phases and frequencis of different synchronus regimes are presented. Multistabilty in single neuron and connection berween neurons leads to the co-existence of different modes of dynamical activity and oscillation quenching.

Controlled synchronization-desynchronization transitions in oscillatory networks

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We present an automatic control method for synchronization - desynchronization phenomena in ensembles of diffusively coupled non-identical regular and chaotic oscillators. In our approach the swith between synchronosu and asynchronous states can be achieved with the help of a feedback loop performing automatic phase and frequency control. We demonstrate the effectiveness of our strategy for controlled synchronization - desynchronization transitions on several examples: (i) two coupled regular and chaotic oscillators, (ii) ensembles of locally coupled regular oscillators. This method can be used for control synchronization -desynchronization of oscillators of different nature (regular and chaotic), and different topology. The control of synchronization-desynchronization transitions sets in at very small values of control parameters.

MULTYSTABILIBTY OF SYNCHRONOUS REGIMES IN OSCILLATORY ENSEMBLES

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The understanding of principles of functioning of the oscillatory ensembles and algorithms of information processing in oscillatory based networks is an important actual challenge. Answers to these problems will have an immediate impact on the creation of highly efficient and low cost artificial neuron systems which are capable to solve tasks, apparent now as extremely complex. There are already first solutions in this direction demonstrating the potentials of artificial networks constructed by analogy with neuron systems.

We study synchronous behavior in ensembles of locally coupled non-identical oscillators, which can be considered as very simplified neuronal models. We show that in a chain of N elements 2^{N-1} different regimes of global synchronization are possible at the same values of parameters. There were two models under our consideration: system of coupled week and strong nonlinear Van der Pol oscillators. In both cases we considered (i) two coupled elements and found in-phase and anti-phase synchronous regimes, (ii) three coupled elements and found four different synchronous regime. In the chain of 50 locally coupled elements we found several different regimes of global synchronization.

In both studied models at weak coupling their behavior is characterized by the cluster synchronization. Increasing coupling causes decreasing number of clusters and then into one of synchronous regime of global synchronization. At further increasing coupling anti-phase synchronous regimes become unstable and brakes into another regime. At strong coupling any anti-phase regimes become unstable and only in-phase regime of global synchronization remains stable.

CHAOTIC REGIMES IN COUPLED PHASE SYSTEMS

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The idea of using chaotic self-oscillations as carriers in communication systems that was put forward in was recently intensively discussed in the literature. Dynamical chaotic oscillations are the kinds of wideband and ultrawideband signals. Chaotic oscillations provide rich opportunities for controlling and modulation. These are the reasons which make them highly promising in the communication field of research.

Traditional communication systems with regular oscillations as carriers are usually based on phase-locked loops (PLL). Such systems allow effective solution of the whole complex of problems arising at transmission and reception of information, namely, generation of stabilized carrier oscillations, modulation of carrier oscillations by information signal, optimal noise filtration, and others. There arises a question: Is it possible to construct PLL-based nontraditional promising communication systems with chaotic oscillations as carriers? Specifically, can PLL be a useful tool for generation and synchronization of carrier chaotic oscillations that is the key task in communication systems? This problem is very scantily considered in the literature. The present work is concerned with generation of carrier chaotic oscillations using PLL [1,2,3,4].

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SYNCHRONIZATION OF BURSTING IN LASERS

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We present experimental and numerical evidence of synchronization of burst events in two different modulated CO2 lasers bidirectionally coupled. Bursts appear randomly in each laser as trains of large amplitude spikes intercalated by a small amplitude chaotic regime. Experimental data and model show the frequency locking of bursts in a suitable interval of coupling strength. We explain the mechanism of this phenomenon and demonstrate the inhibitory properties of the implemented coupling focusing on the multiple time scale behavior. We have implemented a master - slave coupling by using a programmable function generator as master laser and a real laser as slave ; this way, we have demonstrated the capability of this scheme for communication. The analogy with neuronal bursting will be also discussed considering the importance of bursting synchronization for coding and cognitive functions.

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CONTROL OF PHASE DISTRIBUTIONS IN ARRAYS OF LOCALLY COUPLED OSCILLATORS

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It is known that effects of collective dynamics of coupled nonlinear oscillators operating in synchronous regime can be used for beam steering in active phased antenna arrays [1]. For coupling of oscillators we use phase-locked loops (PLLs) [2,3], which have many benefits from the practical point of view (enhanced synchronization range and increased bandwidth of modulating signal, phase noise reduction, robustness and practical feasibility in different frequency ranges, etc.) and give us possibility to implement effective control of parameters. We present different methods, which allows manipulating gradient and random phase distributions in arrays of PLL-coupled oscillators. These methods assume control of natural frequencies of the oscillators and coupling parameters (coupling strength and phase). The problems, related to the time of synchronization and the influence of random detuning of the system parameters on the phasing accuracy, are discussed. It is shown that the characteristic time of establishment of a synchronized gradient phase distribution and the accuracy of phasing substantially depend on the number of elements in the array and on the type of coupling. Effects of inertance of PLL couplings such as: existence of pull-in and hold-in ranges into synchronous regime, regular and chaotic auto-modulation regimes and possible applications of them are studied. The principle of control based on the nonlinear dynamics of PLL-coupled oscillators offers a promising solution to the problems of phasing and controlled beam scanning in antenna arrays operating in different frequency bands.

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CLUSTER SYNCHRONIZATION IN OSCILLATORY NETWORKS

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Synchronous behavior in networks of coupled oscillators is commonly observed phenomena which attracted a growing interest in physics, biology, communication and other fields of science and technology. Except of global synchronization, one observes spliting of full network into several clusters of mutually synchronized oscillators. We study conditions of such cluster partition. The most attention we pay at the existence and stability of unique *unconditional* clusters which rise does not depend on the origin of the other clusters.

We consider the phenomenon of clustering in an ensemble of nonlocally coupled identical oscillators described by the following system

$$\dot{V} = F(V) + (G \otimes P) f(V), V \in R^{dN}, \tag{1}$$

where $V = (v_1, ..., v_N)^T$ is the set of dynamical variables of N oscillators forming the array, v_i is the d-dimensional vector of i-th oscillator variables, $F(V) = (F(v_1), ..., F(v_N))^T$, and $f(V) = (f(v_1), ..., f(v_N))^T$ - coupling function. Elements of the $d \times d$ matrix P that are equal to 1 determine by which variables the oscillators are coupled, and the rest part of P is zero.

The conditions for cluster existence are expressed in terms of the $N \times N$ matrix G elements, e.g. zero-row sums of G provide the existence of the synchronization manifold (one cluster from N oscillators:

$$M(N,N) = \{v_1 = ... = v_N\} \tag{2}$$

with the dynamics in it defined by the single oscillator.

We present the conditions of cluster partition when l clusters of m^k elements exist simultaneously, and are related to the corresponding manifolds.

We present a stability condition of the nontrivial unconditional cluster. Different aspects of application of presented results to the problems of learning in oscillatory networks and design of the networks with desired cluster partitions are discussed.

FPU phenomenon for generic initial data

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The well known FPU phenomenon (lack of attainment of equipartition of the mode–energies at low energies, for some exceptional initial data) suggests that the FPU model does not have the mixing property at low energies.

We give numerical indications that this is actually the case. This we show by computing orbits for sets of initial data of full measure, sampled out from the microcanonical ensemble by standard Montecarlo techniques. Mixing is tested by looking at the decay of the autocorrelations of the mode–energies, and it is found that the high–frequency modes have autocorrelations that tend instead to positive values.

Indications are given that such a nonmixing property survives in the thermodynamic limit. It is left as an open problem whether mixing obtains within time–scales much longer than the presently available ones.

http://arxiv.org/abs/0705.1647

Q-BREATHERS, TAIL RESONANCES AND METASTABILITY IN THE FPU LATTICE

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Upon initial excitation of a few normal modes the energy distribution among all modes of a nonlinear atomic chain (the Fermi-Pasta-Ulam model) exhibits exponential localization on large time scales. At the same time resonant anomalies (peaks) are observed in its weakly excited tail for long times preceding equipartition. We observe a similar resonant tail structure also for exact time-periodic Lyapunov orbits, coined q-breathers due to their exponential localization in modal space. We give a simple explanation for this structure in terms of superharmonic resonances. The resonance analysis agrees very well with numerical results and has predictive power. We extend a previously developed perturbation method, based essentially on a Poincaré-Lindstedt scheme, in order to account for these resonances, and in order to treat more general model cases, including truncated Toda potentials. Our results give qualitative and semiquantitative account for the superharmonic resonances of q-breathers and natural packets.

SYNCHRONIZATION IN NETWORKS OF CARDIAC CELLS

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The cardiac muscle cells and tissues can be either oscillatory (also called pacemakers) or excitable. We observed various oscillating regimes that take place in ensembles of virtual coupled cells of both types. They were simulated accordingly to the Luo-Rudy model of membrane voltage potential.

Firstly, we studied dynamics of two coupled cells. By means of numerical simulation we have found the range of coupling parameter where the synchronous regime exists. Secondly, we considered a chain consisted of excitable cells forced by a single pacemaker. On the basis of the first results we have investigated the conditions of spread of oscillations from the pacemaker into the excitable region. After that we modified the chain by addition of one more pacemaker. During studies of that structure we have found different regimes of oscillating behavior such as cluster synchronization or interaction through the excitable region.

Finally, global and cluster synchronization regimes were studied in the lattice of coupled cells. Several available experimental results (formation of target and spiral waves in the cardiac cultures) were also reproduced in modeling.

Observing global properties of time-delayed feedback control with an unstable control loop

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Delayed feedback control is a convenient tool to stabilize unstable periodic orbits embedded in strange attractors of chaotic systems. We review recent developments for the control of chaos by time-delayed feedback methods focussing on two topical problems :

(i) We show, both analytically and experimentally [1], that the performance of time-delayed feedback control depends sensitively on the continuous or discontinuous type of transitions at the control boundaries. A subcritical transition at the control boundary gives rise to small basins of attraction and limits the control scheme considerably.

(ii) We demonstrate the feasibility of an unstable control loop to stabilize torsion-free orbits [2] not accessible by standard delayed-feedback control. Analytical normal form calculations and numerical simulations reveal a severe dependence of the control performance on the coupling scheme of the control force. These predictions are confirmed by experiments in electronic circuits and emphasize the importance of the coupling scheme for the global control performance.

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Disentangling Trends and Fluctuations: Applications to Stochastic Time-Delayed Systems

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We shall discuss methods which allow one to estimate drift vector fields and diffusion matrices for strongly fluctuating time series, which are generated by multivariate Langevin processes. Special emphasis will be layed on the consideration of time-delayed feedback systems.

Anticipating synchronization of chaotic Luré systems

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In this talk we consider the anticipating synchronization of chaotic time-delayed Lur'e-type systems in a master-slave setting. We introduce three scenarios for anticipating synchronization, and give sufficient conditions for the existence of anticipating synchronizing slave systems in terms of Linear Matrix Inequalities. The results obtained are illustrated on a time-delayed Rössler system and a time-delayed Chua oscillator.

Delay effects in a periodically forced beam-oscillator system

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This talk will be devoted to the study of time-delay effects on the dynamics of a coupled mechanical system. The system consists of a clamped-free cantilever beam with a mass-spring-damper attached to its free end. Because of the specifics of the coupling, there is a time delay arising in the connection between the beam and the mass-spring-damper. Mathematically, the system is modelled using partial delay differential equations. Finite mode truncation of the beam based on Galerkin approximation leads to a system of neutral delay differential equations. Applying a method of multiple scales we find amplitude response as a function of time delay and frequency of the perturbation. Stability issues of the system will be investigated using analytical studies and numerical simulations. Comparison between analytical and experimental findings will be presented. The results discussed in this talk can be found in

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Stabilizing steady states using multiple delayed feedback

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Multiple delay feedback control based on two or more independent delay times turned out to be an efficient method for stabilizing steady states (fixed points) of various chaotic dynamical system. We shall discuss the main features of this control scheme and compare it to Pyragas' single delay feedback control and related methods. Illustrations and examples are given including stability analyses, numerical simulations, and an experimental application for stabilizing the output power of a chaotic frequency-doubled Nd:YAG laser. Furthermore, we shall present theoretical and experimental results with an external multicavity semiconductor laser where multiple delays suppress chaotic oscillations.

Two-state model of excitable systems with time delayed feedback: renewal theory approach

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We present a two-state model of an excitable system with time delayed feedback control. The two-state stochastic process $s(t) = \pm 1$ can be interpreted as a renewal process with history-dependent residence time distributions (RTDs). We assume that the durations of the excited and the refractory phases are equally long and not affected by the noise. This reduces the problem to the only unknown RTD of the activation time.

Delayed Feedback Control of Periodic Orbits without Torsion in Nonautonomous Chaotic Systems: Theory and Experiment

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We demonstrate theoretically and experimentally that the unstable delayed feedback controller is an efficient tool for stabilizing torsion-free unstable periodic orbits in nonautonomous chaotic systems. To improve the global control performance we introduce a two-step control algorithm. The problem of a linear stability of the system under delayed feedback control is treated analytically. Theoretical results are confirmed by electronic circuit experiments for a forced double-well oscillator.

Refuting the odd number limitation of time-delayed feedback control

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We refute an often invoked theorem which claims that a periodic orbit with an odd number of real Floquet multipliers greater than unity can never be stabilized by time-delayed feedback control in the form proposed by Pyragas [1]. Using a generic normal form, we demonstrate that the unstable periodic orbit generated by a subcritical Hopf bifurcation, which has a single real unstable Floquet multiplier, can in fact be stabilized. We derive explicit analytical conditions for the control matrix in terms of the amplitude and the phase of the feedback control gain, and present a numerical example. Our results are of relevance for a wide range of systems in physics, chemistry, technology, and life sciences, where subcritical Hopf bifurcations occur [2].

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Non-invasive feedback with discrete updates

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We present a modification of the classical extended time-delayed feedback scheme (as introduced by Pyragas, Socolar and others). Instead of continuously updating the delayed term we suggest to update it only at discrete times keeping it periodic between updates. This approach relaxes the real-time constraints on the update of the delay term allowing for more complex operations than the filtering used in the original method. When the update of the delayed term follows the iterates of a Quasi-Newton iteration the scheme becomes robust in the sense that, if started near a periodic orbit, it always converges to the periodic orbit regardless of the linearization of the periodic orbit. We demonstrate that with this modification one can reliably continue a family of periodic orbits from stability to instability through a fold (saddle-node) bifurcation with non-invasive feedback control.

LONG-TERM THERAPEUTIC EFFECTS OF DESYNCHRONIZING DEEP BRAIN STIMULATION

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To overcome limitations of standard high-frequency (HF) deep brain stimulation, we have developed multi-site coordinated reset (MCR) stimulation, an effectively desynchronizing brain stimulation technique. Our method is based on a computational modelling approach, which specifically utilizes dynamical self-organization principles and plasticity rules. The goal is to unlearn pathological synchrony by therapeutically reshaping neural networks. We examined the effects of MCR stimulation in patients with severe PD or essential tremor during the first week after electrode implantation with our novel portable brain stimulator. According to our theoretical predictions, in all seven patients epochs of MCR stimulation caused pronounced therapeutic effects, which outlasted MCR stimulation during the whole post-MCR observation period prior to dismissal (i.e. during at least four days), even in patients with severe fluctuations. Energy consumption and current delivery of MCR stimulation were considerably smaller compared to HF stimulation.

Detecting complex network modularity by dynamical clustering

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Based on cluster desynchronization properties of phase oscillators, we introduce an efficient method for the detection and identification of modules in complex networks. The performance of the algorithm is tested on computer generated and real-world networks whose modular structure is already known or has been studied by means of other methods. The algorithm attains a high level of precision, especially when the modular units are very mixed and hardly detectable by the other methods, with a computational effort $O(KN)$ on a generic graph with N nodes and K links.

Control of Chaos in Network Dynamics

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It is known that, by applying feedbacks, one can control spatiotemporal chaos (turbulence) and induce various kinds of patterns in spatially extended systems (see [1]). Here, a similar control problem is studied for chaotic network dynamics. We consider random networks of phase oscillators with the interactions including phase shifts. Although behaviour of an individual oscillator is periodic, collective dynamics of oscillators in the network exhibits chaos. To control it, global feedback is introduced, so that the oscillators are also globally interacting one with another. If the feedback is strong enough, chaos is suppressed and synchronization is established. By going back, i.e. by decreasing the feedback intensity, the transition from synchronization to chaos is investigated. Our numerical studies show that the desynchronization begins when some elements lose the entrainment and develop phase slips. As the feedback intensity is further decreased, the number of such active elements grows and they start to interact. As a result, coherent groups and subnetworks, formed by active elements, emerge. At this stage, relatively regular collective dynamics of the system is observed. Only at weaker feedbacks, fully developed network chaos is found.

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DYNAMICAL ORDER AND COMPLEXITY IN RHYTHMIC CHEMICAL SYSTEMS

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The interaction and synchronization of populations of rhythmic processes is important in a variety of fields including chemistry (influence on overall rate of reaction), biology (circadian rhythm of suprachiasmatic nuclei, essential tremors), and engineering (lasers and microwave systems). The collective behavior of a population of somewhat dissimilar rhythmic processes depends on the dynamics of the individual elements and on the interactions among them.

In this talk laboratory experiments are presented on rhythmic chemical systems; the electrodissolution of nickel and iron electrode assemblies are studied in sulfuric acid solution. It is shown that several types of complex internal self-organization typically associated with biological systems, such as emerging coherence, dynamical differentiation, and co-operative behavior can occur in simple chemical systems. Thus, the experiments serve as a platform with which the effects of coupling, external forcing, and feedback can be thoroughly studied since in the electrochemical system elements of the array are addressable and individual rates of reaction can be obtained with high precision.

We also show that mutual entrainment in interacting oscillators can be characterized using phase models developed from direct and easily-performed experiments with a single oscillator. The phase models are used to predict order-disorder transitions in populations and the dependence of order on parameters in systems with positive or negative coupling.

Various external stimuli and feedback techniques are designed with the phase model methodology to control and engineer desired structures such as synchronized or desynchronized states and stable and itinerate clusters.

POPULATION-LEVEL SINGULARITY BEHAVIOR OF MAMMALIAN CIRCADIAN CLOCK DRIVEN BY DESYNCHRONIZATION OF MULTI-CELLULAR CLOCKS

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The singularity behavior of circadian clocks, the suppression of circadian oscillation driven by critical perturbation, was firstly predicted theoretically as the stop of oscillation of a limit cycle at the unstable fixed point, and then experimentally observed in various organisms such as bacteria, fungus, fly, and human.

While the singularity behaviors were frequently observed, its underlying mechanism has not yet been elucidated due to two reasons. One is that another theory predicted that singularity behavior was experimentally unobservable because of the infinitely small attractor of the unstable fixed point, apparently contradicting with experimental observations of singularity behaviors. The other is that the hierarchical structure of multi-cell-level circadian clocks exists behind the organism-level circadian rhythm, preventing us from directly examining the underlying mechanism by *in vivo* experiment.

In vitro light-responsible circadian system is, therefore, indispensable for revealing the underlying mechanism of the singularity behavior behind the hierarchical structure of multi-cell organisms.

To obtain such *in vitro* system, we synthetically constructed light-responsible mammalian clock cells by exogenously introducing a photo-responsible receptor. By using this synthetic system and population-level high-throughput promoter activity assay, we found that a light pulse with critical timing and strength can induce population-level singularity behavior of the light-responsible mammalian clock cells. Subsequent single-cell measurement revealed that desynchronization of multi-cellular clocks underlies the population-level singularity. The physiological relevance of this *in vitro* result was supported by the *in vivo* observation of desynchrony of clock-gene expression patterns in rat SCN.

A mathematical model consistently explains our population-level and single-cell-level experimental data, and also demonstrates that the synchronization and desynchronization of cellular clocks is the underlying mechanism of population-level response circadian clocks to external perturbation. The problem in the observability of singularity behavior can be also naturally explained by our model, which suggests that fluctuation in single-cell-level behavior of the clock cells is the key determinant of the observable singularity behavior.

Collective dynamical response to external forcing in complex oscillator networks

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The study of complex networks has applications in various fields ranging from biology to engineering and has attracted growing attention. Autonomous dynamical behavior taking place in a network determines functions of the networks, related, e.g., to information processing in the brain which is a network of neurons or to the production process in a factory which is a network of machines. In many applications, control of the dynamical behavior taking place in a complex network is a key issue. To get insight into the control principles of complex networks, it is essential, at first, to understand the dynamical response of each element and/or the whole network to external forcing applied to a subset of the network.

In this talk, we will present our recent studies concerning the dynamical response of complex networks. Those studies provide insight into the function and the structure of the brain clock (orchestrating our circadian rhythms) [1,2] and into the formation of a feedforward network via neural network plasticity [3].

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Synchronization of Kuramoto oscillators determined by the depth of the networks

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Abstract

We study Kuramoto oscillators entrained by different types of pacemakers, either acting as an impurity or a defect, or dynamically induced by a linear gradient in the natural frequencies. For the implementation as a defect we derive the critical pacemaker frequency, below which entrainment of all oscillators is possible; the derivation is performed for various network topologies and for various interaction range. In particular, for infinite-dimensional topologies, the critical frequency decreases exponentially with increasing depth of the network, that is, with increasing average distance of the oscillators from the pacemaker. Moreover, the entrainment possibility depends non-monotonically on the coupling range that is varied from next-neighbor to all-to-all coupling. For the linear gradient in the natural frequencies it turns out that the oscillator with the highest natural frequency dynamically becomes the pacemaker in the sense that it emits circular waves in phase space.

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Inferring Network Topology via Driving the Dynamics

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We present a method to infer the complete connectivity of a network from its stable response dynamics. As a paradigmatic example, we consider networks of coupled phase oscillators and study their long-term stationary response to temporally constant driving. The response depends characteristically on both the driving signals and the underlying network connectivity [1]. Thus, for a given driving condition, measuring the phase differences and the collective frequency reveals information about how the units are interconnected. Sufficiently many repetitions for different driving conditions yield the entire network connectivity (the absence or presence of each connection) from measuring the response dynamics only [2]. For sparsely connected networks we obtain good predictions of the actual connectivity even for formally under-determined problems. We explicitely show that the method works equally well for networks with lattice and random connectivity as well as in the intermediate small-world regime.

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NONHOLONOMIC CONTROL OF THE QUANTUM EVOLUTION, DECOHERENCE, AND ENTANGLEMENT

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Protection of the open quantum system coherence against the influence of their environment based on a non-holonomic control scheme is proposed. This method draws its inspiration from the standard error-correction ideas, that are adding of an ancilla, coding, decoding, which are combined with the Quantum Zeno Effect. One can protect a general quantum system from the action of a set of arbitrary uncontrolled unitary evolutions. We also apply the ideas of the nonholonomic control for creating multipartite entanglement among qubit, which we describe with the help of recently introduced technique, in terms of nilpotent variables.

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DYNAMICAL AND STATICAL QUANTUM MEMORIES

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The existence of a stable and scalable quantum memory is a necessary condition for the construction of a quantum computer or any other device used for the processing of quantum information on a large scale. Two strategies - the dynamical one, based on time-dependent control (gates) and the statical one employing self-correcting systems with constant Hamiltonians are compared. Using the general non-Markovian Born approximation for the error in a quantum device it is argued that both strategies are essentially equivalent. Then the recent results concerning stability of quantum memories based on the Kitaev models are discussed.

COHERENT ELECTRON SPIN DYNAMICS IN QUANTUM DOTS

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Electron spins in quantum dots (QDs) are promising building blocks for semiconductor based quantum information technologies. Due to the unavoidable inhomogeneities in a QD ensemble it is common believe that coherent manipulations ought to be performed on a single dot level. In this contribution we will show that by proper addressing by pulsed laser protocols it might be possible to perform corresponding studies on QD ensembles, with all the related benefits such as strong spectroscopic response. For our experiments we have primarily used a time-resolved Faraday rotation technique on (In,Ga)As/GaAs quantum dots singly charged with one electron. Using this methodology we have shown: (i) trains of circularly polarized laser pulses are extremely efficient to create spin coherence (spin initialization). (ii) Such pulse trains can be used to synchronize certain spin subsets within the ensemble. From the dependence of the synchronization on the pulse separation the electron spin coherence time can be measured to be 3 μs at cryogenic temperatures. (iii) The spins can be clocked by pulse doublet sequences such that they show periodic coherent responses. The period of these responses can be tailored by the details of the laser excitation. Finally we will also address the impact of the interaction of the electron spins with the background of nuclei, which is considered to be one of the prime reasons for spin dephasing. We will show that under specific conditions a strong interaction between electron and nuclear spins will be established leading to a drastic enhancement of the spin relaxation time.

WEIGHTED GRAPH STATES AND APPLICATIONS TO SPIN CHAINS, LATTICES AND GASES

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Weighted graph states naturally arise when spin systems interact via an Ising-type interaction. First, we abstractly define the class of weighted graph states and demonstrate its computational accessibility. We show how reduced density matrices of a small number of spins (about 10) can be computed from arbitrarily large systems using weighted graph techniques and projected entangled pairs techniques, and we discuss various entanglement measures accessible from these reduced density matrices. Second, we apply these findings to spin chains and lattices with long-range interactions and analytically derive area laws for the scaling of block-wise entanglement. Then, we turn to disordered spin systems, spin gases, which are connected to random weighted graph states and which share their entanglement properties. Finally, we use a spin gas as a bath that introduces decoherence in single as well as multipartite spin systems. The microscopic, exact decoherence model we obtain can operate in different regimes and exhibit non-Markovian features as well as spatially correlated noise effects.

QUANTUM CONTROL OF QUANTUM DOT SPINS

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Spins confined in semiconductor quantum dots (QD) offer new perspectives for realizing quantum optical systems with unique properties. Experiments in a number of different QD systems have demonstrated that the spin of a confined electron could have an ultra-long lifetime exceeding 20 msec. The spin-coherence time on the other hand, is limited by hyperfine coupling to the QD nuclear spin ensemble. In this talk, I will start by presenting experiments demonstrating QD electron-spin cooling using resonant optical pumping. Our measurements confirmed that the fundamental interactions that determine spin dynamics in QDs are hyperfine coupling to QD nuclear spin ensembles, spin-phonon coupling, and exchange-type interactions with a nearby Fermi sea of electrons. By controlling and suppressing these interactions via external dc electric and magnetic fields, we achieved an electron spin-state preparation with fidelity exceeding 99%.

The ability to read out the state of a single confined spin lies at the heart of solid-state quantum-information processing. In the second part of the talk, I will describe experiments demonstrating an all-optical dispersive measurement of the spin state of a single electron in a QD. We obtain information on the spin state through conditional Faraday rotation of a spectrally detuned laser, induced by the polarization- and spin-selective charged quantum dot transitions. These time-averaged single-spin measurements were made possible by our ability to prepare the electron-spin state with high-fidelity.

It is well known that optical pumping of the electron-spin could be used to polarize nuclear spins. Controlling the state of the QD nuclear spin ensemble could be key for suppressing electron-spin decoherence induced by hyperfine interactions. In the last part of the talk, I will review experiments demonstrating dynamical nuclear spin polarization in a single QD and discuss nonlinear dynamics of mesoscopic nuclear spin ensembles.

DYNAMICAL CONTROL OF DECOHERENCE AND THERMODYNAMICS

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We have developed the framework for universal dynamical control exerted by driving or modulating fields on two-level systems (TLS), aimed at suppressing or preventing their noise, decoherence or relaxation in the presence of a thermal bath. Its crux is the derivation of a general master equation (ME) for a multipartite system, weakly coupled to an arbitrary bath and subject to arbitrary temporal driving or modulation. The present ME does not invoke the rotating wave approximation and therefore applies at arbitrarily short times or for arbitrarily fast modulations [1].

The resulting universal convolution formulae provide intuitive clues as to the optimal tailoring of modulation and noise spectra. Our general analysis allows an optimal choice between spatiotemporal global and local control, based on the observation that the maximal suppression of decoherence is not necessarily the best one. Instead, we demand an optimal phase relation between different, but synchronous local modulations of each particle.

Local modulation can effectively decorrelate the different proper dephasings of the multiple TLS, resulting in equal dephasing rates for all states. For two TLS, the singlet and triplet Bell states acquire the same dynamically modified dephasing rate. This should be beneficial compared to the standard global 'bang–bang' (π-phase flips) if both states are used (intermittently) for information transmission or storage.

For different couplings to a zero-temperature bath, one can better preserve any initial state by using local modulation, than by using global modulation. Namely, local modulation which eliminates the cross-decoherence terms better preserves an initial Bell-state, compared to global π-phase flips [2].

We have also demonstrated that a TLS initially in a thermal (Gibbs) state will always increase in temperature, in the short time limit, irrespective of the initial temperatures of the system and the bath. This behavior can be traced to the quantum Zeno time-domain. At intermediate times, on the scale of the correlation time of the bath, we have shown that oscillatory relaxation rates, alternating between anti-Zeno and Zeno behavior, can give rise to transient heat transfers to and from the thermal bath. Then, an initial TLS in a Gibbs state with the same temperature as the bath's, can either decrease or increase its excitation.

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EXACT BENCHMARK CALCULATIONS FOR SYSTEM-BATH TYPE QUANTUM DYNAMICS WITH VERY LARGE WAVE FUNCTIONS

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Many physical systems can be seperated into a primary part of interest, and a secondary part, which plays the role of an environment/bath/reservoir. While the former has to be treated exactly, it is possible to represent the Hamiltonian of the latter by a (large) number of Harmonic Oscillators. This discretization of the bath allows, to treat the quantum dynamics of the full system with large dimensional wave functions [1,2,3]. Contrary to the propagation of reduced density matrices with generalized Master equations, there are no approximations, like the weak coupling limit or the Markov approximation, involved. In this talk we present comparisons between reduced and exact dynamics, for different coupling strengths and dissipative functionals. The advantages and shortcomings of the method are discussed.

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TWO WEAKLY-COUPLED CONDENSATES

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The recent realization of a single weak link for an atomic Bose-Einstein condensate in an optical double-well potential allows for the first time observation of coherent Josephson oscillations directly on the level of populations on either side of the junction. Furthermore it opens up the way to fully characterize the tunneling dynamics since not only the dynamics of the population difference can be measured but even the time evolution of the relative phase is detectable. How the residual interaction of the atoms can lead to a new dynamical regime, which is characterized by an inhibition of tunneling, will be discussed in detail.

The good experimental control of the atomic system also allows for a quantitative study of thermally induced fluctuations of the relative phase between the weakly linked condensates. The connection of the phase fluctuation to the coherence between the two condensates will be discussed. Since the thermal fluctuations exist for any non-zero temperature their measurement can be employed as a new type of primary thermometer for atomic Bose-Einstein condensates. Our recent results on the heat capacity of a quantum gas at ultra low temperatures using this new noise-thermometer will be presented.

DYNAMICAL DECOUPLING TECHNIQUES FOR COHERENT QUANTUM CONTROL: RECENT DEVELOPMENTS

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The design of schemes for coherently manipulating quantum dynamics is central to quantum control theory as well as to a variety of applications in quantum information science, including decoherence suppression strategies and quantum simulation protocols. After reviewing the basic principles underlying dynamical decoupling techniques, I will illustrate how the latter provide a useful control-theoretic framework for the manipulation of both closed- and open-system evolutions, and highlight current developments in the field. In particular, I will compare recently developed randomized decoupling methods [1,2] with conventional deterministic schemes, and discuss the application of dynamical decoupling to controlling electron spin coherence in quantum dots [3].

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BREATHING IN A CLASS OF SWITCHED LINEAR SYSTEMS WITH COMPLEX EIGENVALUES

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The phenomenon of breathing or intermittent operation in a class of piece-wise continuous systems is studied as well as its relation with system parameters. The class of systems under study comprises a continuous time subsystem and a switching rule that induces an oscillatory path by switching alternately between stable and unstable conditions. It is shown that although regular and chaotic phases evolves irregularly for a given system, their average behavior is surprisingly regular with respect to a bifurcation parameter. It is found that the phenomenon of breathing share some structural characteristics with intermittency; *i.e.* existence of a critical exponent. However, for switched systems, many critical exponents may be required. Bifurcation maps and other analysis tools allow us to gain insight into the origin of breathing. An electronic circuit is proposed to observe experimentally the phenomenon under study. In this way, the piece-wise continuous system is implemented by switching alternately between two RC linear circuits. The electronic implementation of the system has the feature of being very simple and easy to reproduce.

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TOWARDS AN ENCRYPTION SCHEME BASED ON HYBRID SYSTEMS

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On this contribution, a hybrid time system that evolves switching between two continuous-time vector fields, one stable and the other unstable, is used to construct a secure communication scheme. The proposed cypher encrypts information on the trajectories of a hybrid time system with a switching rule chosen such that the system presents complex behavior. The main difference between conventional encryption schemes and those based on dynamical systems is that conventional encryption is based on discrete-value elements that evolve on discrete-time, while encryption based on dynamical systems utilize entire sections of the trajectories of the system as elements for encryption; that is, continuous-valued elements that evolve on either continuous or discrete-time. Therefore, in the latter, the security characteristics are derived from the structure of the dynamical system used for encryption and its security characteristics can't be analyzed with the same tools as for conventional encryption systems. Ultimately, the security characteristics of an encryption scheme based on dynamical systems can be best analyzed statistically, in terms of how well the information gets hidden by the cypher. A motivation for this study is to investigate the effects of the switched nature of the hybrid-time system on the implementation, realization and performance of an encryption system. One significant characteristic of hybrid-time systems is their simplicity of construction, which may represent an advantage in practical implementations. As an initial investigation, a hybrid time system is used to construct a symmetric block cipher, where the encryption-decryption process is defined in terms of a stroboscopic map of the system trajectories. In this way, the information signal is transformed into a signal that can be transmitted over a public channel and requires from an authorized receiver the use of the transmitter's hybrid time system trajectories to recover the original message. In order to illustrate the proposed encryption scheme, numerical simulations have been performed.

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On the Controlled Synchronization of Dynamical Networks with Non Identical Nodes

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On this contribution, the problem of chaos synchronization on networks of structurally different dynamical systems is investigated. Synchronization on dynamical networks is usually defined in terms of identical dynamical evolution of the state variables at every node in the network. Thus is usually called complete or identical synchronization. For a network with non identical nodes this type of synchronization can't be expected. An alternative form of synchronization is considered, in which the relation between the nodes is defined in terms of a mapping between the state variables of the nodes in the network. In this way, generalized synchronization can be achieved. Different types of generalized synchronization can be defined, depending on how the state space of one node is mapped to the others. The simplest form of generalized synchronization is define the relation between nodes by way of a coordinate transformation, for example a change of coordinates defined by a feedback linealization. Synchronization is a phenomenon that can occur spontaneously. But, in certain circumstances it may be necessary to add interconnections or controllers to the system in order to achieve or improve the characteristics of the synchronization. In this contribution, the latter case is considered. The proposed approach consists on designing a robust controller such that generalized synchronization is achieved. This type of network synchronization is call controlled synchronization In this study, the case of systems that can be expressed in canonical form by an appropriately chosen coordinate transformation. In order to achieve generalized synchronization on a network of strictly different nodes, local robust controllers are designed which force the network to synchronize in terms of their transformed coordinates. The main results of this study are illustrated by numerical simulations of a network of well-known chaotic benchmark systems.

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Application of Gray code to the cryptanalysis of chatic cryptosystems

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Gray code (or reflected binary code) has been extensively used in engineering, telecommunications, genetics, and even mathematical puzzles. In short, the Gray code is a binary numeral system where two successive values differ in only one digit. In [1], the kneading theory on symbolic sequences, which manipulates symbols, was translated to number theory by a transformation into Gray codes. It was showed how the symbolic sequences of a 1-D quadratic map are ordered according to the Gray code for a given parameter value and different initial points as well as for a given initial point and different parameter values. The Gray code was then generalised to introduce the Gray Ordering Number (GON) -in the interval (0, 1) - allowing the simultaneous ordering of different size symbolic sequences. The introduction of Gray codes and Gray numbers in 1D quadratic maps is highly beneficial from the computing viewpoint, since the handling of symbolic sequences is substituted by the use of numbers.

From other viewpoint, in [2] the Gray codes were applied to the cryptanalysis of the Baptista cipher [3]. It was shown that given a symbolic sequence and the initial condition, the map's parameter value can be obtained. Likewise, given a symbolic sequence and the map's parameter value the initial condition can also be obtained. This result has a great importance in cryptanalysis, since many cryptosystems use as secret key these two values: initial condition and parameter.

In this presentation and starting from the preliminary work by [4], we explain how these results can be taken further and provide different ways to get the secret key from just the symbolic sequence. We show the limitations inherent to this method and in which cases it is best applied. These results show that in the design of a cryptosystem based on 1D-quadratic maps, it is all important to conceal the underlying symbolic sequence. We also show the quality of initial condition and parameter estimates when only partial information about the symbolic sequence is available.

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On the security of a chaos-based encryption method for color image

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Recently, a new chaos-based encryption method for color image was proposed in [X. He, Q. Zhu, P. Gu, Lecture Notes in Artificial Intelligence, 4062 (2006) 671-678]. The method is composed of two basic parts: position permutation and diffusion of pixel value. The operations included in the two parts are both determined by a random number sequence generated by iterating a chaotic dynamic system. According to the security requirement, the two basic parts are performed alternatively for some rounds. Although the original authors claimed that the method is very secure, we find there exist a serious flaw of the diffusion function. In addition, the encryption method can be broken with two chosen images when the iteration number is one. Furthermore, the flaw of the diffusion function is remained in the final encryption function no matter what is the iteration number. Essentially, the encryption method under study can be attributed to the same type with the schemes proposed in [G. Chen, Y. Mao, C. K. Chui, Chaos, Solitons & Fractals, 21 (2004) 749-761], [Y. Mao, G. Chen, and S. Lian, International Journal of Bifurcation and Chaos, 14 (2004) 3613-3624], [J. Shen, X. Jin, and C. Zhou, Lecture Notes in Computer Science, vol. 3768 (2005) 270-280], where only the bitwise OR and addition operation are involved in the multi-round encryption function. In [C. Li, S. Li, J. Nunez, G. Alvarez, G. Chen, IACR's Cryptology ePrint Archive: Report 2007/108], we have proved that some intermediate variables of any scheme of the type can be recovered under differential attack. So, we also discussed the probability for recovering the secret key from the intermediate variables.

AN EFFICIENT DIFFUSION APPROACH FOR CHAOS-BASED IMAGE ENCRYPTION

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With the advancement of mobile communication technologies, the utilization of audio-visual information in addition to textual information becomes more prevalent. Cryptographic approaches are therefore necessary for secure multimedia content storage and distribution over open networks such as the Internet. A traditional way to resist statistical and differential cryptanalyses is to employ permutation and diffusion alternatively. Recently, research in the area of image encryption using chaos theory has been emerged. Some existing chaotic image encryption schemes use a multi-dimensional chaotic map for pixel permutation in the spatial domain while taking another one-dimensional (1-D) chaotic map as the diffusion function. The multi-dimensional chaotic map for permutation is the discretized standard, cat or baker map since the number of pixels at each side of an image is an integer. However, for satisfactory security and diffusion performance, the 1-D chaotic map employed for diffusion is usually a real-valued function whose high computational complexity lowers the overall encryption speed. In this paper, we propose a more efficient diffusion function using simple table lookup and swapping techniques as a light-weight replacement to the 1-D chaotic map. Simulation results show that at a similar security level, the proposed method requires a shorter encryption time than the cryptosystems using real-valued 1-D chaotic map. This is because the table lookup and swapping operations are much faster than the floating-point computations.

EMERGING COLLECTIVE BEHAVIORS OF ANIMAL GROUPS

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Many animal groups routinely make consensus decisions jointly with all group members. For example, a swarm of honeybees searching a new nest site, a flock of birds deciding when to leave a foraging patch, or a group of ungulates, primates, and fishes selecting where to travel after a rest period. Here we build a novel model merging the locally neighboring reciprocal action and alignment together to investigate the mechanisms of consensus decision-making and its robustness. Our model reveals that the shapes of the coherent flocks are limited in a common narrow interval for different group sizes and information structures, that is, the average elongation of a coherent flock is approximately varying from; the larger the proportion of informed individuals the easier to reach a consensus decision for a group with a little conflict of interest between informed individuals, however, the larger the proportion of informed individuals the more difficult to reach a consensus decision for a group with a significant conflict; the larger the group the easier to reach a consensus decision for a group with a little conflict of interest between informed individuals, on the contrary, the larger the group the more difficult to reach a consensus decision for a group with a significant conflict; the larger the difference between the numbers of the informed individuals the easier to reach a consensus decision for a group with a fixed total number of informed individuals; the alignment ratio and weights of preferred goals of informed individuals of the group are trade-offs between accuracy and split ratio for consensus decision-making. Moreover, the coherent groups keep a fixed shape and their average maximum move distances are linearly increasing as the distance between two information sources increases. In particular, when the information source is suddenly changed, a coherent group will collectively select the exact direction of the changed information sources in a short response time providing that there are enough informed individuals. The smaller the group the higher the average accuracy to collect the exact direction of the changed informed sources for a given proportion of informed individuals. Furthermore, the coherent groups display a surprising degree of tolerance against errors, however, they simultaneously show an extremely fragile to attacks. Our model and approach discover some novel phenomena and also reveal some underlying mechanisms of the consensus decision-making and its robustness in biological systems.

Chaotification of CMLs

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The coupled map lattice (CML) as a spatiotemporal chaotic system was proposed in 1983. Since it is a simple model with most essential features of spatiotemporal chaos, the CML has been extensively studied in the fields of bifurcation and chaos, pattern formation, physical biology and engineering. Recently, the CML has been applied in cryptography, where spatiotemporal chaos in the CML is very desirable and plays a key role. There is a method proposed, by shifting the binary representation of the CML output the first several bits, to chaotify the CML, where the investigation of chaotification of the CML is numerical. Nevertheless, a mathematically rigorous and effective chaotification method for CML is desirable, which can make an originally non-chaotic dynamical system chaotic, or can enhance the existing chaos of a chaotic system. It is fortunate that mathematically rigorous chaotification methods have been developed and some references therein) since the first mathematical chaotification method proposed by Chen and Lai.

Similar to the Chen-Lai method, a chaotification algorithm is proposed in this paper to chaotify a CML. In the controlled CML, a state feedback in each dimension is applied to guarantee the system trajectory expanding in all directions, and then a mod-operaion is used to “fold” the trajectories back into a compact region whenver the expansion takes them to move out of it. Moreover, sufficient conditions for the feedback gain parameter are derived, under which the controlled CML is proved to have a snap-back repeller. According to the Marotto theorem, it is, thus, chaotic in the sense of Li-Yorke. In terms of a theorem about chaotifying an n-dimensional system defined in a general metric space in the sense of Devaney, the controlled CML with certain control parameter values is also proved rigorously chaotic in the sense of Devaney. Moreover, the above chaotification method with certain feedback parameter values is suitable for chaotifying other coupled logistic-map lattices with different coupling topologies. Finally, the chaotification method is applied to control some typical CMLs by choosing suitable control parameters. Simulation results show that the chaotification method makes an originally non-chaotic CML chaotic and enhances the chaos of an originally chaotic CML, and that the method is applicable to CMLs with different coupling structures.

ANALOG CHAOS-BASED SECURE COMMUNICATIONS AND CRYPTANALYSIS: A BRIEF SURVEY

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Since late 1980s, chaos-based cryptography has attracted more and more attention from researchers in many different areas. It has been found that chaotic systems and cryptosystems have many similar properties. For example, each chaotic system is sensitive to the initial condition, which corresponds to the diffusion property of a good cryptosystem. Most analog chaos-based secure communication systems are designed based on chaos synchronization technique, which was firstly developed in late 1980s. Given two chaotic systems with different initial conditions, chaos synchronization denotes such a phenomena that one chaotic system (called the *slave* system or *response* system) can asymptotically follow the dynamics of another chaotic system (called the *master* system or *driving* system), under the driving of a signal transmitted from the master system to the slave system. Here, one or more driving signals have to be sent from the master system to the slave system. The establishment of chaos synchronization between two remote chaotic systems actually means that some information has been successfully transmitted from one side to another. This naturally leads to the foundation of a chaos-based communication system. Then, by keeping some part of the master and slave systems secret, the chaos-based secure communication can be used to further transmit secret information. That is, a chaos-based secure communication system is created. This paper gives a brief survey to analog chaos-based secure communications and related cryptanalysis work. Firstly we introduce three basic types of chaos-based secure communication systems, and then discuss related cryptanalytic results. Finally some newly-proposed countermeasures against known attacks are outlined.

Collective behaviors in Multi-agent Systems

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Collective behaviors of biological system in nature have been studied by scientists from kinds of fields including biological, physics, animal behavior, social science, computer science and control engineering. A large number of animals, such as fish, birds, ants, bees, will emerge amazing and beautiful complex phenomenon only with local interactions. Many decades ago, biological scientists have developed a number of models for studying these interesting emerging phenomena, which motivates research developments in this field. In 1986, Reynolds [1] developed a model with three rules for mimicking flocks of birds that led to creation of the first computer animation of flocking. Moreover, physicists Vicsek *et al.* [2] proposed a simple 2 dimensional model for studying emergence of alignment of a group of particles in 1995, some interesting results have been derived, especial for that the group of particles would converge to a same direction under some conditions. There are some other important works done by physicists including Toner and Tu, Shimoyama *et al.*, and Levine *et al.*. In recent years, there has been a surge of interest among control scientists in cooperative/coordinated control due to broad application of multi-agent system. Some engineering applications include mobile sensor networks, unmanned aerial vehicles (UAVs) and mobile robotics can be developed with research results from biological systems. Control scientists have done some distinguished work in stability analysis of multi-agent system including Reza Olfati-Saber [3], H. G. Tanner [4] for flocking study, A. Jadbabaie [5] for Vicsek model, Passino *et al.*[6] for swarming stability, and so on. All of these works highlights the development in these fields.

In conclusion, we propose a model for studying collective behavior of multi-agent system. Some interesting results have been derived by simulations. Furthermore, the stable flocking can be reached by PI control laws, and stability analysis results have been derived under some assumptions. The simulation results show some parameters' influence to the system. We expect our work can highlight the researches in this field.

EARLY DETECTION OF LOCUST SWARMING—BEHAVIORAL INDICES FOR PHASE TRANSFORMATION*

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Oriental migratory locust (*Locusta migratoria manilensis)* change phase in response to behavior change and morphological change. This individual-level process is the basis for swarm formation. In the present study, we have developed an individual-based model of locust behavior in which the increase in jumping and turning frequency leads to a phase change. The simulation results are consistent with earlier field and lab observations, and demonstrate that there is significant behavior difference between solitarious- and gregarious phase. The individual based model is implemented in Java using RePast. The computer simulation used a continuous two-dimensional arena. To distinguish between solitarious- and gregarious-type behavior in locusts, ten behavioral variables which discriminated between the solitary- and crowd-reared groups were entered in the construction of a model: 1) number of jumping per unit time, 2) number of turns per unit time, 3) mean length of jumping, 4) time of still, 5) walking speed, 6) walking time, 7) walking length, 8) number of walking. The first two variables described above were retained by the model as significant predictors of phase state. The model combined an individual's values for these two variables to predict the probability that that insect belonged to the solitary-reared group. Model locusts are then characterized by (*i*) a behavioral-phase state, which ranges from 0 (solitarious) to 1 (gregarious), (*ii*) a sex state, and (*iii*) a Cartesian coordinate. Simulations were run with 10 and 20 initially solitarious locusts, placed at random within the arena. The results obtained using the RePast based simulation showed a similar trend to the experimental results; when the individual locust jumps at a frequency greater than 1. 6 times per minute and turns at a frequency greater than 1. 6 times per minute, it belongs to gregarious-type group. Both jumping and turning behaviors were significantly greater ($P < 0.\ 05$) for gregaria locusts than for solitairia locusts. These behavioral parameters of the frequency of locust jumping and turning can be used as "the behavioral indices for phase transformation".

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Stability Analysis of Swarms with a General Topology

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In recent years, multi-agent autonomous systems that imitate natural swarms have attracted a lot of interests. Herds of animals, flocks of birds, schools of fish and even crowds of people are all swarm examples. Swarming behaviors have many advantages, for example, to avoid predators and to increase chances of finding food. Scientific researchers also try to borrow swarm intelligence of cooperative behaviors to develop artificial autonomous systems such as formation control of multi-robot system, unmanned air vehicles (UAVs).

Gazi and Passino analyzed the stability of a class of continuous-time swarm models under the assumption that the network is globally coupled with even weight. In this work, the stability of swarms of homogeneous agents with general coupling topology is investigated. We show that, when the topology of the underlying swarm is strongly connected, the swarm is proved to be stable in a hyper-ellipsoid in n-dimensional Euclidean space, both in open space and in profiles, whether the center of this hyper-ellipsoid is on moving or not. The swarm boundary is characterized by the eigen-structure (eigenvalues and eigenvectors) of coupling matrix; and all the swarm agents will exponentially form a cohesive swarm in a finite time. Swarm consideration on some time-varied profile is also given. Furthermore, as a generalization of the commonly used second smallest (or largest) eigenvalue of the symmetric weighted Graph Laplacian, a generalized critical parameter is proposed to describe dynamic property of the system. Thus this work extends the present results on stability analysis of continuous-time swarms, and gives the relationship between swarming behaviors and the coupling topology.

NETWORK-BASED CORDINATED PREDICTIVE CONTROL OF FLOCKS*

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It is well-known that a ring-shaped network structure is not a good one for efficient mutual communications and global control within a flock of agents, while the so-called small-world networking structure is much better in these respects and is very desirable for fast communication and information transmission, efficient synchronization, and effective global control over the entire network. Thus, in a flock of neighboring-connected agents with a leader, for communication and control purposes it is advantageous to build a small-world-type network structure by random addition of long-range connections from the leader to a few distant agents, so that the leader can affect all the other agents through them via fast communication and rapid control commands.

In this study, the familiar NARMAX model is applied to those agents with direct connections with the leader to predict its motion attitude several steps ahead. Meanwhile, the current attitude measurement error is fed back to rectify the prediction. Then, the attraction-repulsion function is combined with the model predictive control strategy to yield a novel predictive control law. Moreover, at each step, a moving horizon optimization index function minimizing the flock attitude error is optimized to update the control law. In this way, the few agents having direct connections with the leader become 'pseudo-leader*s*', which can tighten the communications from the leader to all other agents. It is shown by statistical simulations that with no more than 20% 'pseudo-leaders', the flock attitude error index will be decreased sharply by about 60% comparing with a conventional approach with one leader in flocking. Consequently, global synchronization is achieved much more effectively at a fairly low cost, with enhanced global stability due to the emergence of these few 'pseudo-leaders' in the flock.

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Structure-Function Relationship in Complex Brain Networks Expressed by Hierarchical Synchronization

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The brain is one of the most complex systems in nature, with a structured complex connectivity. Recently, large-scale corticocortical connectivities, both structural and functional, have received a great deal of research attention, especially using the approach of complex network analysis. Understanding the relationship between structural and functional connectivity is of crucial importance in neuroscience. Here we try to illuminate this relationship by studying synchronization dynamics in a realistic anatomical network of cat cortical connectivity. We model the nodes (cortical areas) by a neural mass model (population model) or by a subnetwork of interacting excitable neurons (multilevel model). We show that if the dynamics is characterized by well-defined oscillations (neural mass model and subnetworks with strong couplings), the synchronization patterns are mainly determined by the node intensity (total input strengths of a node) and the detailed network topology is rather irrelevant. On the other hand, the multilevel model with weak couplings displays more irregular, biologically plausible dynamics, and the synchronization patterns reveal a hierarchical cluster organization in the network structure. The relationship between structural connectivity and functional connectivity at different levels of synchronization is explored. Thus, the study of synchronization in a mutilevel complex network model of cortex can provide insights into the relationship between network topology and functional organization of complex brain networks

CONTROLLING CHEMICAL TURBULENCE IN SURFACE REACTIONS

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Spatiotemporally disordered states in catalytic CO oxidation on Pt(110) are characterized by the emergence of topological defects. We analyze the statistical properties of defects in this reaction and derive a probabilistic description based on the gain and loss rates of defects. Deviations from the theoretically predicted rate laws can be explained by short-range correlations between defects of opposite topological charge. A global time-delay feedback scheme is implemented experimentally to control chemical turbulence in this reaction. We present results showing that turbulence can be efficiently suppressed and a variety of novel patterns can be stabilized by applying global delayed feedback. We furthermore consider the corresponding complex Ginzburg–Landau equation in the Benjamin–Feir unstable regime and analytically investigate the stability of uniform oscillations depending on the feedback parameters. We show that, in agreement with the experimental results, a noninvasive stabilization of uniform oscillations is not possible in this type of system.

FEEDBACK-MEDIATED CONTROL OF SPIRAL WAVES

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Spiral waves of excitation are fascinating examples for the spontaneous formation of spatio-temporal patterns in macroscopic systems far from thermodynamic equilibrium.

I will review several methods of feedback-mediated resonant drift of spiral waves to guide a spiral wave core along an arbitrary given trajectory through an excitable medium. The control of core movement is very precise and allows us, for example, to avoid existing heterogeneities within the medium, where the spiral wave could be captured.

In our theoretical approach the reaction-diffusion equations of the active medium extended by appropriate feedback terms are mapped onto an autonomous dynamical system for the feedback-induced drift of the spiral core. We have studied bifurcations of the drift velocity field varying the feedback strength, the time delay in the feedback loop, and the geometrical shape of the domain from which the feedback signal is detected. Our experimental results obtained within an open gel reactor for the light-sensitive Belousov-Zhabotinsky system are in very good agreement with theoretical predictions from the corresponding drift velocity fields and confirmed by numerical simulations of the underlying Oregonator equations.

Finally, I briefly discuss a novel approach where the parameters of the Archimedean approximation of a spiral wave are calculated from the passage times of the wave fronts through a small number of point detectors. Using the information about the actual phase of spiral rotation, the spiral core can be moved in a well-controlled manner along a chosen trajectory to any desired position in the medium.

Our results might be interesting for cardiology because certain cardiac arrhythmias as ventricular fibrillation are believed to be related to spiral wave dynamics and spiral instabilities.

Boundary Control of Reaction-Diffusion Systems

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Control of Reaction-Diffusion systems through feedback applied at a boundary represents an experimentally convenient (and often the only practically feasible) way to influence their stability and dynamics. The good news is that such feedback can be computed analytically for a broad class of such systems in the linear approximation. The bad news is that, as the size of the system grows, the feedback starts to lag the growing disturbances in the bulk, leading to transient dynamics. Disturbances exhibit strong transient growth, followed by an asymptotic decay once the feedback catches up. We show how transient growth can lead to nonlinear instabilities in the presence of feedback and environmental noise. In particular, we show how the basin of attraction of the target state in the presence of feedback can be computed analytically and used to determine the magnitude and spatial structure of the "optimal" (or most dangerous) disturbances leading to control breakdown. This picture leads to a natural size limit for noisy systems controlled at the boundary.

SUPPRESSION OF COMPLEX REENTRANT ACTIVITY IN A REALISTIC MODEL OF CARDIAC TISSUE BY A WEAK EXTERNAL PACING

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Cardiovascular diseases (CVDs) are responsible for more than 4 million deaths each year in Europe and account for about 30% of life-span loss in Europe. A major group of CVDs involves cardiac arrhythmias. The extreme form of such arrhythmias and the prevalent mode of the sudden death among patients with CVDs is ventricular fibrillation (VF), which is a fast developing disturbance of spatially organized contraction of ventricles that is a consequence of abnormalities of electrical conduction in the heart muscle. Since VF, sustained for only a few minutes, leads to death, an immediate intervention is required. In emergency care medicine the application of high-energy electrical stimulation to the patient's chest is commonly used to suppress the fibrillation and restore the normal heartbeat. The application of electrical pulses for the termination of fibrillations is also used in implantable cardioverter defibrillators (ICDs) initiating low-power electrical pulses automatically when they detect dangerous activity.

The recent investigations of active media offer new opportunities for the electrical defibrillation: The amplitude of the external stimulation can be *essentially* decreased and the turbulent regime in excitable systems can be suppressed by a sufficiently weak non-feedback periodic external forcing applied globally [1] or locally [2-4] (see also refs. therein). By these manners, it is possible to stabilize the turbulent dynamics and reestablish the initial cardiac rhythm, because such a strategy leads to the relaxation of the medium to the rest state.

On the basis of a quite realistic Fenton-Karma model of cardiac tissue we resolve the problem of suppressing the fibrillative activity by a low-voltage local non-feedback electrical forcing of monophasic and biphasic shapes. In contrast to well-known systems of a FitzHugh-Nagumo type, the used model accurately reproduces such mesoscopic characteristics as the action potential duration and conduction velocity restitutions found in cardiac tissue. Such a low-energy defibrillation has a great advantage in comparison with other widespread methods since it, in particular, does not require the knowledge of the frequency of re-entrant waves.

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STABILITY OF SPATIALLY LOCALIZED STRUCTURES IN SUBCRITICALLY UNSTABLE PATTERN-FORMING SYSTEMS UNDER GLOBAL CONTROL

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We consider the influence of a global feedback control on a nonlinear system governed by a subcritical Ginzburg-Landau equation. It is shown that the feedback control can stabilize spatially localized structures in a definite region of parameters. Out of the stability range, these structures are subject to two basic modes of instability: (i) instability with respect to the appearance of new localized structures; (ii) internal oscillatory instability of the localized structure. The latter type of instability appears in the case of a delayed control. A generalized variational approach is used for the development of a low-dimansional dynamical model of interacting localized structures. The basic types of nonlinear dynamics are described.

Controlling spatio-temporal systems using multiple delayed feedback

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A control method for manipulating spatio-temporal chaos is presented using homogeneously, inhomogeneously or locally applied feedback signals based on several different delay times. As illustrated with the two dimensional Ginzburg-Landau and the Fitzhugh-Nagumo equation this method can, for example, be used to suppress turbulent fluctuations, to convert chaotic spiral waves into guided plane waves and for trapping spiral waves.

CONTROLLING COLLECTIVE DYNAMICS IN OSCILLATOR ENSEMBLES

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We suggest a method for suppression of synchrony in a globally coupled oscillator network, based on the time-delayed feedback via the mean field. Having in mind possible applications for suppression of pathological rhythms in neural ensembles, we present numerical results for different models of coupled bursting neurons. A theory of the method is based on the consideration of the synchronization transition as a Hopf bifurcation. Next, we consider an alternative approach, without using delay in the feedback loop. In this case, the suppression is achieved by organizing an interaction between the ensemble and a passive oscillator. Technically, this can be easily implemented by a simple feedback scheme. The important feature of our approach is that the feedback signal vanishes as soon as the control is successful. The technique is illustrated by the simulation of a model of an isolated population of neurons. We discuss the possible application of the technique in neuroscience.

TRAPPING OF WAVES AND TWISTED SPIRALS IN FORCED OSCILLATORY MEDIA: RESULTS FOR THE CATALYTIC CO OXIDATION ON PT(110) AND THE OREGONATOR MODEL

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A new kind of nonlinear nonequilibrium patterns – twisted spiral waves – is predicted for periodically forced oscillatory reaction-diffusion media. We show furthermore that, in such media, spatial regions with modified local properties may act as traps where propagating waves can be stored and released in a controlled way. Underlying both phenomena is the effect of the wavelength-dependent propagation reversal of traveling phase fronts, always possible when homogeneous oscillations are modulationally stable without forcing. The analysis is performed using as a model the complex Ginzburg-Landau equation, applicable for reaction-diffusion systems in the vicinity of a supercritical Hopf bifurcation.[1]

We consider two examples of realistic models describing reaction-diffusion systems with local oscillatory dynamics under the conditions of periodic forcing. Using the Krischer-Eiswirth-Ertl model for the catalytic CO oxidation on Pt(110) we demonstrate that phase front reversal can be expected under periodic variation of the CO partial pressure. Temperature heterogeneities on the Pt surface can be used to trap phase fronts. Another example for a more realistic model is the Oregonator which describes the light-sensitive BZ reaction. Our simulations of the Oregonator show that wavelength-dependent front propagation reversal is possible when the light intensity is varied periodically. It can be expected as well in the regime beyond the canard explosion, where the nature of the oscillations is relaxational rather than harmonic. Phase front traps can be realized by spatial variation of the forcing intensity.

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DOUBLE TURING STRUCTURES IN THE REVERSIBLE GRAY-SCOTT SYSTEM

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Pattern formations have been studied as typical phenomena in dissipative systems.

In most cases, a system that can be described by the function of free energy is filled with one kind of pattern element such as a spot or a line. This nature is shown by Nonomura and Ohta in a block co-polymer system[1]. They showed mathematically and numerically that the final state of the system is filled with one of two pattern elements even if the system has two at the beginning. So far as we know, there is only one exception that the generalized Swift-Hohenberg system shows a static pattern with two stable pattern elements[2].

Similarly, most of dissipative reaction-diffusion systems are filled with only one kind of pattern element. Even when a system has two kinds of pattern elements initially, one of them shall be dominant and the other appears as defects in the final pattern. Therefore it is unlikely that a reaction-diffusion system supports more than two domains composed of different pattern elements at the same time.

We will present that spots and lines coexist in a dissipative reaction-diffusion system that is supported by the reversible Gray-Scott model[3], where the value of each parameter is spatially homogeneous. Such pattern formation occurs when both a single spot and a single line are solutions of the system. This phenomenon is associated with such a novel characteristics of the system that the distance between the pattern elements is widened spontaneously by local perturbation. We will discuss the interaction between two pattern elements and conclude that their repulsive nature is responsible for the self-rearrangement of patterns in the present system.

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GEOMETRIC CONSTRAINTS IN ELECTROCHEMICAL PATTERN FORMATION

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Due to the long-range nature of coupling mediated by ion migration in an electric field, the pattern selection in reaction-migration systems (such as electrode surfaces, nerve cells) crucially depends on the system geometry. Consequently the dynamical behavior can be quite different by choosing different arrangements of the electrodes, in particular the distance between the electrodes and the location of conductor/insulator interfaces can significantly alter the patterns observed. The effects are presented with experiments using the formic acid oxidation on platinum electrodes. The corresponding reaction-migration equations are derived and their solutions compared to the experimental findings.

MANIPULATING EXCITABLE DYNAMICS IN GENE-REGULATORY NETWORKS

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We study the dynamical mechanism underlying the transient state of competence in the stressed bacterium Bacillus subtilis. Experimental analysis via time-lapse fluorescence microscopy, together with mathematical modeling, allowed us to identify a genetic circuit module that behaves in an excitable way. Competence for DNA uptake arises in this circuit as a noise-driven excitable state, while the corresponding quiescent state represents vegetative growth. Identification of this excitable module allowed us to devise ways to control the excitable dynamics, that could shed light on the evolutionary origin of this phenotypic behavior.

SCROLL WAVE INSTABILITIES IN A CHEMICAL EXCITABLE MEDIUM

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One of the most prominent dynamical structures observed in two-dimensional excitable media (such as neural or cardiac tissues, or the Belousov-Zhabotinsky reaction). Their three-dimensional analogues are scroll waves or rings. While the 2-dimensional systems have been extensively investigated and subject to many forms of perturbation or control, only scant reports on the experimental studies of 3-dimensional scroll waves and their stability have been presented. This is mostly due to the difficulties encountered in the observation of such 3-dimensional dynamic patterns.

Here we present experimental studies on the scroll waves and their stability using the Belousov-Zhabotinsky reaction as a chemical excitable medium. Three independent types of instabilities have been detected. First, we show that scroll waves with a linear filament (the line connecting the spiral tips, and hence acting as organizing centre of the scroll wave) are instable upon a gradient-induced twist. The other two instabilities arise in a system where the scroll wave is allowed to meander: the so-called 3-D-meandering instability and the negative line tension instability: The initially straight filament becomes zig-zag shaped and its length oscillated showing a three-dimensional meandering instability, while, in the long time limit, the filament snakes and its length expands substantially due to the line tension which becomes negative. Numerical simulations that take into account the aging-induced decrease in excitability of the reaction medium. The simulations corroborate the experimental findings and their interpretation.

Finally, we present the concepts how to experimentally manipulate these scroll waves.

Exploiting Chaos to Design Reconfigurable Hardware

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Here I will review work in chaos-based computing, done in collaboration with W. L. Ditto and K. Murali. First it will be shown how the rich variety of threshold-controlled responses from a chaotic element may be exploited to constitute a reconfigurable computing medium. Then schemes using synchronization to design dynamic logic cells will be discussed. Finally, the implementation of various different theoretical ideas in proof-of-principle experiments will be presented.

REALIZATION THEORY METHODS FOR THE CONSTRUCTION OF POSITIVELY-INVARIANT SETS

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Suppose that a non-stationary system is given by some measurements of input-output signals. Assume that there exist some parameter-dependent function spaces and a general parameter-dependent input-output operator generating these signals. Certain parameters of the function spaces and of the integral kernel are unknown. Using some elements of realization theory, we construct an abstract non-stationary system in some weighted function space and describe positively-invariant sets of this system.

GLOBAL STABILITY OF PHASE-LOCKED LOOPS

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Phase-locked loops (PLLs) are frequently encountered in radio engineering and communication. Phase-locked loops (PLLs) are frequently encountered in radio engineering and communication. Once they had been invented in the 1930s-1940s (De Bellescize, 1932; Wendt, Fredentall, 1943), intensive studies of the theory and practice of PLLs were carried out (Viterbi, 1966; Gardner, 1966; Lindsey, 1972; Leonov, Reitmann and Smirnova, 1992; Leonov, Ponomarenko and Smirnova, 1996; Kroupa, 1973; Kroupa, 2003; Best, 2003, Razavi, 2003; Razavi, 2001; Egan, 2000; Egan, 1998; Abramovitch, 2002). The main requirement to PLLs for array processors or distributed clocks system is that they must be floating in phase. This means that the system must eliminate the clock skew completely. The elimination of the clock skew is one of the most important problems in parallel computing and information processing (as well as in the design of array processors (Kung, 1988). Several approaches to solving the problem of eliminating the clock skew have been devised for the last thirty years. In developing the design of multiprocessor systems, a way was suggested (Kung, 1988) for joining the processors in the form of an H-tree, the lengths of the paths from the clock to every processor (or to local region of processor) are the same. However, in this case the clock skew is not eliminated completely because of heterogeneity of the wires (Kung, 1988). Moreover, for a great number of processors (or local clocks region), the configuration of communication wires is very complicated. This leads to difficult technological problems. In this paper new type of floating PLL for processors working in parallel is designed. It is proved that in the classical case when the multiplier is applied as a phase detector, for a complete eliminating of misphasing we need to involve a nonlinear electron element with the characteristic of the relay type into a block-scheme. Global stability analysis for new of PLL is given. For the floating phase locked loops new stability conditions are obtained.

SHUKOVSKY STABILITY IN DYNAMICAL SYSTEMS. GENERALIZATION OF ANDRONOV-WITT THEOREM

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Andronov-Witt theorem is brilliant achievement of Andronov scientific school [1]. Generalization of this theorem for regular linearization was obtained by Demidovich [2]. Here for investigation of Zhukovskii stability a new research tool - a moving Poincare section - is introduced. With the help of this tool, generalization of theorems of Andronov-Witt and Demidovich for irregular linearization are carried out.

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ESTIMATION OF DYNAMIC BUCKLING LOADS IN APPROXIMATE SHELL MODELS VIA FREQUENCY-DOMAIN METHODS

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In mechanical systems with thin elastic-plastic parts dynamic buckling may occur. In practice the estimation of buckling loads is very often done for the static buckling problem based on Hill's bifurcation functional. In the contribution we investigate the time-dependent analog of this functional, which goes back to L. H. N. Lee. We give an interpretation of this functional as a quadratic constraint for the displacements and nonlinear parts of the equation of motion. This allows the use of frequency-domain methods from absolute stability theory. An elastic-plastic bifurcation as loss of stability on a finite time interval occurs, if the nonlinearities at a certain time moment do not satisfy the quadratic constraints.

SPECIFICATION OF CONTROL PROBLEMS UNDER UNCERTAINTY IN FINANCES

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The attempts to apply classical methods of optimization based on the theory of optimal and adaptive control to realize the management of an investment portfolio very often tumble over serious problems. For instance the application of control theory as the stochastic version of dynamic programming approach implies the detailed information about the structure of factors in stochastic differential equations describing the dynamics of assets constituting portfolio. The latter information in contemporary financial markets seems hardly to be available. The methods of adaptive control theory are also not very often applicable because of the strongly nonstationary behavior of parameters of these or those modeling equations describing the dynamics of portfolio value. Because of the aforesaid it is not surprising that the problem to create special control methods adapted to the investment portfolio management has long drawn the attention of researchers. Usually such methods imply the creation of control providing in a particular sense the positive dynamics of profit along with the minimization of quantitative and qualitative information about the structure of modeling equations. Moreover one of the most common models for assets pricing is the model of geometrical Brownian motion. Nevertheless when following this way to create the control of investment portfolio there arise a number of difficulties which may be formulated as follows. The heart of the matter is that the designing of control up till now has been based as a rule on the principles of self-financing strategy. The latter means that the purchase or sale of any assets automatically implies sale or purchase of a volume in the equivalent money terms of other assets constituting portfolio. It is essential to note that realization of any circuit of management based on self-financing strategy implies the required number of assets in the portfolio significantly depends not only on the prices of struck bargains but also on the volatilities of corresponding assets. The point is that the tracking of the assets volatilities with arbitrary precision in real time is hardly possible. In this connection it is clear that the occurrence of essential mistakes is possible while defining the amount of assets included in a portfolio. How significantly such errors can affect the ultimate goal of management to provide the profitableness of portfolio remains not clear. The aforesaid makes reasonable to pose the problem of creating the management of portfolio with a feed-back control based only on the prices of struck bargains to provide in some sense portfolio profitableness on a certain time interval and within the framework of the pricing

AN AUTOMATIC FEEDBACK ADJUSTMENT CONTROL IN CHAOTIC SYSTEMS

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First, we present the method that enables chaotic systems to change its dynamics to stable periodic dynamics by an automatic feedback adjustment of an additional parameter of a dynamical system with an extreme value approach. This approach uses only feedback of the largest value obtained from observations of a fixed interval of time series of the system variable and therefore does not require any a priori detailed information of the system. We apply this method to several discrete-time chaotic systems and confirm numerically that chaotic states can be stabilized to stable periodic ones. The stabilized states in the system are formed in periodic windows with respect to the additional parameter.

Next, based on the automatic feedback adjustment of an additional parameter, we propose a strategy for controlling periodic orbits of desired periods in chaotic dynamics and tracking them toward the set of unstable periodic orbits embedded within the original chaotic attractor. The improved method does not require information on any reference states for the targets. Assessments on the method's effectiveness and robustness are given by means of the application of the technique for the stabilization of unstable periodic orbits in both discrete- and continuous-time systems.

The advantages of the proposed method over the existing chaos control techniques are as follows. The method overcomes some difficulties encountered by the existing methods, e.g. the proposed method does not require a reconstruction of the parametrical variations in the UPOs' stable and unstable manifolds as in OGY-based methods, nor pre-tuning of the principal parameters such as the delay time and the gain as in DFC-based methods, and therefore it constitutes as an appropriate strategy to control fast dynamical processes in real time toward any desirable periodic dynamics.

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A NEW MECHANISM FOR CHAOS SUPPRESSION

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Most nonlinear dynamical systems may possess chaotic behavior for a certain choice of parameters. Since there are situations for which this behavior might be undesirable, different methods have been developed in the past years to suppress or control chaos. The idea that chaos may be suppressed goes back to the publications where it has been proposed to perturb periodically the system parameters with the final effect of suppression of chaos.

The main idea of our investigations is to apply a general perturbation to a certain dynamical system in such a way that the final behavior is not chaotic. In other words, given a certain dynamical system for which chaos exist for a given choice of parameters, the challenge is to find an appropriate perturbation, that we call the function of stabilization, which would convert the dynamical system into non-chaotic. This is done analytically for a general two-dimensional system, and then the results are applied to the nonlinear pendulum and Duffing oscillator for a choice of parameters for which these systems show chaotic behavior. Afterwards, we show by using numerical computations that there is a complete agreement with the analytical results. The physical meaning of the stabilizing perturbation in the case of the pendulum and Duffing oscillator corresponds to a series of hits acting on the system. Nevertheless, what we show here is that we can find this stabilizing perturbation, which eventually will depend on each dynamical system. The idea can be useful for a

CONTROL OF CHAOS IN A SPINNING KELVIN TYPE GYROSTATE SATELLITE UNDER THE INFLUENCE OF GRAVITATIONAL FORCE FIELD

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A kelvin type satellite consists of two rigid parts, an axi-symmetric rotor and a bigger platform. The rotor angular velocity is usually very high and the platform can rotate slowly in comparison to rotor's velocity. Singularities of this kind of gyrostate in zero gravitational field were classified in [1]. Chaotic motion of this system in a circular orbit was first studied in [2].

In this article we use fuzzy control of Poincar map method to stabilize periodic orbits of chaotic regimes in a Kelvin type satellite.

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PULSIVE FEEDBACK CONTROL FOR STABILIZING UNSTABLE PERIODIC ORBITS IN A NONLINEAR OSCILLATOR

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We examine a strange chaotic attractor and its unstable periodic orbits in case of a single degree of freedom nonlinear oscillator with non symmetric potential with single well. We propose an efficient method [1,2] of chaos control stabilizing these orbits by a pulsating feedback technique. Discrete set of pulses enable us to transfer the system from one periodic state to another. In this paper we consider the effects of different number of pulsations per cycle and different pulsation time lengths.

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SEPARATION OF PARTICLES IN VELOCITIES IN BREATHING BILLIARDS

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Models of classical statistical mechanics with chaotic properties – billiards with oscillating boundaries, which hold much favour last time – are considered. Billiards are very convenient models of several physical systems. For example, particle trajectories in billiards of specific configuration can be used in modelling a lot of dynamical systems. Moreover, most approaches to the problems of mixing in many-body systems go back to billiard-like questions. A natural physical generalization of a billiard system is a billiard whose boundary is not fixed, but varies by a certain law. Such a type of billiards is often said to be breathing billiards. This is quite a new field which opens up new prospects in studies of problems that have been known for a long time.

We showed that for billiards with developed chaotic properties the consequence of the boundary perturbations is a phenomenon of Fermi acceleration [1]. However, for nearly integrable billiard systems perturbations of their boundaries lead to a new phenomenon [2]: There is a separation of particles in velocities. If the initial particle velocity exceeds some critical value which is specific for the given geometry of the billiard, then particles are accelerated in average. Otherwise, their moderation takes place. This gives us a possibility to control the billiard particles in their velocities by a weak periodic perturbation of the billiard boundary.

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CONTROLLING CHAOTIC TRANSIENT AND THE IMPROVMENT OF SYSTEM FLEXIBILITY

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In this work, we address the problem of how to exploit the dynamics behind a chaotic transient behavior to improve system performance and adaptability to many operational conditions requests. The phenomenon of chaotic transient is explained as due to the presence of a chaotic saddle in the phase space. Different systems operation points can be associated to the set of unstable periodic orbits that exists embedded in the chaotic saddle. A classical control procedure associated with a control of chaos strategy is proposed as a methodology to quickly guide system trajectories among different operation points and to keep the system on a particular operation point. The methodology is applied on an electronic circuit system

PHASE CONTROL METHOD FOR NONLINEAR SYSTEMS.

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Control of nonlinear systems has attracted a great interest in last years. Here we present a nonfeedback method to enhance or tame crisis-induced intermittency in nonlinear dynamical systems. By adding a small harmonic perturbation to a system parameter, the intermittent behavior can be enhanced or suppressed depending on the value of the phase difference between the main driving and the small perturbation. The key role of the phase in selecting the final dynamical state is very useful from a control point of view, since there is a large variety of situations in which the modulation of the accessible parameters might be limited, and the phase is an additional degree of freedom that may be useful.

PHASE CONTROL OF CHAOS

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Chaos in a forced nonlinear oscillator can be suppressed by a nonfeedback method, just by adding a harmonic perturbation to one of the system's parameters. In this work we focus on the role of the phase difference ϕ between this perturbation and the main driving from a chaos control point of view. Using the Duffing oscillator as a paradigm of periodically driven chaotic system, we show numerically and experimentally that chaos can be collapsed to different periodic orbits and the required perturbation amplitude can be minimized by an adequate selection of ϕ. Thus, a critical dependence on ϕ to suppress chaos is observed. The method is applied in a real laboratory system reproducing the Duffing oscillator with a slight asymmetry in the potential . We show the robustness of the method even in this non ideal case, thus showing that this type of control can be applied in many real situations.

ESTIMATING THE STATE OF LARGE SPATIO-TEMPORALLY CHAOTIC SYSTEMS

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State estimation is a general prerequisite for controlling a system or for predicting its future evolution. In this talk we will address the problem of estimating the state of a large spatio-temporally chaotic system from limited noisy data and a knowledge of a system model. For large systems, state estimation can be particularly challenging because straightforward application of the conventional technique may become infeasible due to computer limitations. This problem has very general interest, for example, in weather forecasting. This talk will present background material, a proposed solution for treating large systems, and results from application of our method to weather and to a laboratory experiment.

CONTROL OF BIFURCATIONS IN POWER ELECTRONIC DC-DC CONVERTERS THROUGH MANIPULATION OF THE SALTATION MATRIX

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Power electronic Dc-DC converters widely used in industry are known to exhibit undesirable subharmonic and chaotic behaviour beyond certain parameter ranges, and very often the first onset of instability is caused by a period-doubling bifurcation. In this paper we propose methods of controlling the bifurcation to extend the range of desirable period-1 operation, by taking advantage of the switching nature of such circuits. At the switching events, the evolution of perturbation is given by the so-called "saltation matrix," and hence it is possible to influence the Floquet exponents by manipulating this matrix. In physical terms this implies controlling the triangular wave used in the pulse-width modulator, or using a control logic that uses voltage as well as current feedback. We demonstrate the resulting control of the bifurcation both by simulation and by experiment.

MODIFICATION OF CHAOTIC SYSTEMS LIMIT SETS BY MULTIPARAMETRICAL OPTIMAL CORRECTION

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In the paper we investigate the problem when the aim of control is the modification of the system limit set (chaotic attractor) into the stable invariant set. This problem is on a joint of chaos control and bifurcation control methods, and the complete understanding of stabilization peculiarities requires the development of means of multiparametrical analysis. Hence the dynamic correction technique of parametric space of chaotic systems is offered. Thus the demand of small parametric changes naturally allows formulating the problem of optimal correction. Based on Pontryagin's maximum principle the corrective functions and necessary conditions of achievement of the invariant stable set are found. The efficiency of correction for chaos suppression is demonstrated on Lorenz system.

SAFE SETS FOR HORSESHOE MAPS

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Horseshoe maps are ubiquitous in nonlinear dynamical systems. Their stretching and folding action implies the existence of a chaotic saddle, but it also makes all the trajectories escape from the region where they are defined. Thus, there is a large variety of situations in which it might be desirable to avoid such escapes. Here we propose an advantageous method to achieve this goal. We show that the particular geometrical action of the horseshoe maps implies the existence of a set, the safe set, where the trajectories can be stabilized even if the control applied is smaller than the noise amplitude. We illustrate our technique with the aid of the well known Hénon map, and we show how it can be applied to avoid divergences in a noisy open billiard.

ON THE STABILITY AND STABILIZATION OF MECHANICAL SYSTEMS OF GENERAL TYPE

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In this paper two problems of stability are considered. In the first problem the stability of mechanical systems with dissipative, gyroscopic, potential and positional non-conservative forces is investigated. The stability is analyzed in the case when the potential energy has maximum at the origin. The condition for asymptotic stability in terms of system coefficients is obtained by using Lyapunov function.

The presence of positional non-conservative forces considerably complicates the stability problem and excludes direct application of classical Kelvin-Chetaev theorems.

In the second problem stabilization of the gyroscopic system by means of non-linear dissipative and positional non-conservative forces is solved.

Stability of gyroscopic system with two degrees of freedom is attained with the help of gyroscopic stabilization (instability degree is equal to two). In terms of system coefficients the asymptotic stability conditions are obtained. The cases when the gyroscopic stabilization is being destroyed are pointed out as well.

SHAPE CONTROL OF SMART STRUCTURES USING FLUIDIC ACTUATORS

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Shape control means control of position or alignment of a certain number of points of the structure so as to track a desired value, which is an important task of smart structures. Shape control is mostly extended by smart materials such as piezoelectric actuators or shape memory alloys.

In this paper a new approach for static shape control of beams without the draw back of the smart materials-based scheme is developed. A system of eccentric reversing channels embedded into a structure which acts as a continuous actuator. Shape control of elastic structures is then developed utilizing this fluidic actuator. In this system, by adjusting parameters such as fluid's velocity, fluid's density, and the eccentricity path's equation of the channel, shape and deflection curve of the beam can be controlled. Several analytical examples are at last demonstrated considering different eccentricity paths for the channel with and without external load. Distinct characteristics are observed in the deflection curve associated with this kind of fluidic actuators, such that the tip deflection for a cantilever beam embedded with fluidic actuators does not necessarily occurs at the tip.

This method can be applied in aircraft wings for getting higher lift or drag at the time of take off or landing.

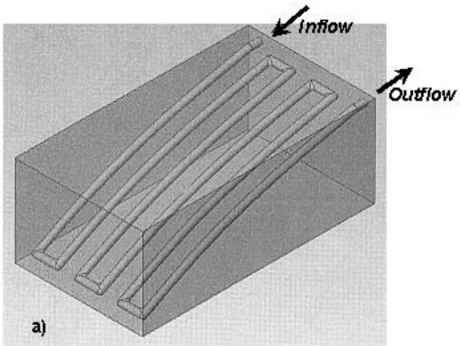

Figure 1- Configuration of a fluidic actuator embedded in an elastic structure

DYNAMICS OF A SWING

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Dynamic behavior of weightless rod with a point mass sliding along the rod according to periodic law is studied. This is the simplest model of children's swing. Asymptotic boundaries of stability domains are derived near resonance frequencies. Regular and chaotic motions of the swing under change of problem parameters are found and investigated numerically.

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On D-stability of mechanical systems

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The concept of D-stability of matrices appeared rather long ago, for the first time,– in the publications related to mathematical economics, and further it found application in mathematical methods of ecology. Let $\sigma(A)$ be the spectrum of matrix $A \in M_n(R)$; $D_n \subset M_n(R)$ be a class of diagonal matrices with positive elements on the main diagonal. Matrix $A \in M_n(R)$ is called D-stable when $Re(\lambda) < 0$ for all $\lambda \in \sigma(DA)$ for any $D \in D_n$. Only some necessary and some sufficient conditions of D-stability are known for general form $n \times n-$matrices. Necessary and sufficient conditions of D-stability are known for 2nd and 3rd order matrices. Matrix $Q \in M_n(R)$ belongs to class P_0 when all the main minors of matrix Q are nonnegative, and for each $k \leq n$ there exists a strongly positive minor of matrix Q of order k. It is known that the requirement $A \in (-P_0)$ is the necessary condition of D-stability of matrix $A \in M_n(R)$.

Let matrix A be the matrix of the differential equation of a linear mechanical system

$$\frac{dx}{dt} = Ax, \;\; x \in R^{2m}, \; A = \begin{pmatrix} B & C \\ E & 0 \end{pmatrix},$$

where B is an $m \times m-$matrix of dissipative and gyroscopic forces, C is an $m \times m-$matrix of positional forces, E is a unit matrix.

If matrices C and B are diagonal and definite negative then the system is D-stable. This is an obvious corollary of the Thomson-Tait-Chetayev's theorem. As far as arbitrary matrices $C, B \in M_m(R)$ are concerned, the known theorems on stabilization of mechanical systems fail to give any constructive conditions of D-stability.

The paper suggests a complete analysis of the system having two degrees of freedom, when the matrix $A \in M_4(R)$. Necessary and sufficient conditions of D-stability in terms of matrix elements have been obtained. Furthermore, the problem has been reduced to the verification of positiveness of the Hurwitz determinant for the characteristic equation of matrix DA for any $d_i > 0$ $(i = 1,2,3,4)$ and the conditions $A \in (-P_0)$.

As far as the system having three degrees of freedom is concerned, matrix A has the dimension of 6×6. Complete investigation of positiveness of Hurwitz determinants in symbolic form represents a complicated problem. We have obtained only necessary conditions of D-stability in terms of matrix elements.

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BIFURCATION DIAGRAMS OF FAMILIES OF CONTROLLABLE SINGULAR SYSTEMS UNDER PROPORTIONAL AND DERIVATIVE FEEDBACK

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In this work we consider differentiable families of triples of matrices $\varphi(\xi) = (E(\xi), A(\xi), B(\xi))$ with the parameter vector $\xi \in R^k$, representing families of regularizable singular linear time invariant systems in the form $E(\xi)\dot{x}(t) = A(\xi)x(t) + B(\xi)u(t)$, with $E(\xi), A(\xi) \in M_n(C)$, $B(\xi) \in M_{n\times m}(C)$ for each ξ, under proportional and derivative feedback.

The knowledge of a complete system of invariants for regularizable systems permit us to obtain a canonical reduced form and describe generic families permitting to analyze the neighborhood of a given system showing bifurcation diagrams of a critical points.

SOME SPECTRAL PROBLEMS ON HYDRODYNAMICAL STABILITY OF NON-NEWTONIAN AND PLASTIC FLOWS

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The generalized Orr – Sommerfeld problem (GOSP) [1] simulating a hydrodynamical stability of 1D (x_1, x_3) shear flow with velocity profile $v^\circ(x_3)$ in non-Newtonian, visco-, and rigid-plastic materials is considered. This spectral problem consists of one ordinary differential equation on stability for the perturbation $\varphi(x_3)$ of stream function

$$\begin{aligned}\varphi^{IV} - 2s^2\varphi'' + s^4\varphi - 4\kappa s^2 \left(\frac{\varphi'}{|v^{\circ\prime}|}\right)' &= \\ &= [(\alpha + isv^\circ)(\varphi'' - s^2\varphi) - isv^{\circ\prime\prime}\varphi]\Re\end{aligned} \tag{1}$$

and the certain set of uniform boundary conditions. The latter may be given both on rigid walls and boundaries of rigid zones (layers in 1D case) typical for materials with yield limit stress. In (1) α is spectral parameter, s is wave number along x_1-axis, $\Re$ and κ are Reynolds' and Il'youshin numbers.

The following aspects are analysed in detail in the work:

— hydrodynamical interpretation of the GOSP problem as the problem on stability;

— sufficient estimates of stability;

— classical particular cases and possible limit transitions by $\Re$ and κ.

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BUCKLING OF A COLUMN AS A BENCHMARK NONLINEAR CONTROL DESIGN PROBLEM

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The stability analysis of elastic bodies started with pioneering work of Euler in 1744. Since then researcher tried to enhance the buckling load of elastic systems by various techniques including: increasing the mode of buckling, use of the follower forces, employing piezoelectric actuators, optimizing the shape, use of gyroscopic forces etc.
Enhancing Stability of structures is - of course - a major concern for designers, in particular to ensure that a structure will not undergo poorly damped or even unbounded vibrations. In order to obtain improved stability properties - or to reach nominal specifications with a thinner and lighter design - a control device (whether active, semi-active, or passive) may be used.
The present paper sets out to investigate the feasibility of using modern feedback control techniques to enhance the buckling load of an elastic column model. The control techniques employed include the following: feedback stabilization methods for critical nonlinear systems, linear feedback stabilization, partial stabilization, and a technique for design of deadbeat controllers. These techniques were successfully applied to TORA benchmark problem back in 1995[1], which concerns stabilizing of a translational linear oscillator by an attached eccentric rotational proof mass actuator. Application of modern nonlinear control techniques to this fundamental problem not only helps in understanding basic concepts of nonlinear control design but also is beneficial to design of better structures and machines.

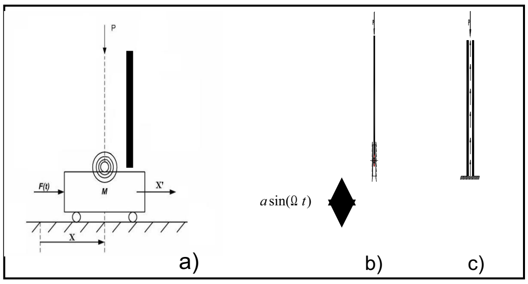

Figure 1 Configuration of Euler column model

ON APPLICATION OF FIRST INTEGRALS IN ANALYSIS OF CONSERVATIVE SYSTEMS

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The paper proposes a new approach to obtaining and qualitative investigation of invariant manifolds for the systems of differential equations, which assume polynomial first integrals. The approach is based on the following Theorem: If a system of differential equations

$$\dot{x}_i = X_i(x,t,), \ \ i = 1,...,n$$

assumes a family of smooth first integrals $V(x,t,\lambda) = c$ (where λ is the family's parameter), and if partial derivatives of this family with respect to the variables $x_i, \ \ i = 1,...,n$ may be represented in the form

$$\frac{\partial V}{\partial x_i} = \sum_{l=1}^{k} a_{i,l}(x,t,\lambda)\varphi_l(x,t,\lambda) + \sum_{l=1}^{k}\sum_{p=1}^{k} a_{i,l,p}(x,t,\lambda)\varphi_l(x,t,\lambda)\varphi_p(x,t,\lambda) + \ldots,$$

and the rank of matrix $||a_{i,l}(x,t,\lambda)||$ is "k" on the family of manifolds

$$\varphi_l(x,t,\lambda) = 0, \ \ l = 1,\ldots,k,$$

then the equations $\varphi_l(x,t,\lambda) = 0, \ \ l = 1,...,k$ define a family of invariant manifolds, whose elements attribute stationary values to the corresponding elements of the family of first integrals $V(x,t,\lambda) = c$. Consequently, this is a family of invariant manifolds of steady motions (IMSMs).

Investigation of the sets in the space of the variables $x_1,...,x_n,\lambda$, on which the rank of the matrix $||a_{il}(x,t,\lambda)||$ becomes lower, allows one to find (identify) invariant submanifolds, which lie on the invariant manifold $\varphi_l(x,t,\lambda) = 0, \ \ l = 1,\ldots,k$.

Several examples related to application of this approach for the purpose of finding IMSMs and their submanifolds in a number of mechanics problems are given, for example, in Euler's equations, which describe motion of a rigid body in perfect fluid, as well as in some other quite integrable systems. In some cases, it appears to be possible not only to find IMSMs and their submanifolds, but also, using Lyapunov's second method, obtain sufficient stability conditions.

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INVARIANT SETS OF DYNAMICAL SYSTEMS WITH SYMETRIES: EXISTENCE, STABILITY AND BIFURCATIONS

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Existence, stability and bifurcations of invariants sets of dynamical systems with first integrals are considered. Modifications of classical Routh-Salvadori, Poincare-Chetaev and Smale results are given. The general results are illustrated with various mechanical examples: rigid body with a fixed point in the Clebsh-Tisserand and Goryachev-Chaplygin cases, a heavy rigid body and a heavy rigid body with liquid on horizontal plane with friction etc.

INDEFINITE DAMPING IN MECHANICAL SYSTEMS AND GYROSCOPIC STABILIZATION

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It is surprising that only few papers are dealing with indefinite damping matrices in linear systems of 2nd order differential equations. Indefinite damping matrices can cause instability. In the meagre literature on the subject we can find remarks that modelling of sliding bearings and cutting of metals can lead to negative damping (dry friction) and therefore to instability (self-excited vibrations).

One of the motivations for the present work is the following industrial problem. There exists an increasing interest in car manufacturing to investigate shrieking of breaks. Models so far developed show negative damping terms in the governing equations induced by a decreasing friction characteristic.

Consider a linear mechanical system of differential equations of the form

$$\boxed{M\ddot{x} + D\dot{x} + Kx = 0} \tag{1}$$

The mass matrix $\boxed{\;}$ and the stiffness matrix $\boxed{\;}$ are both real symmetric and positive definite ($M^T = M > 0,\ K^T = K > 0$), and the symmetric damping matrix $\boxed{D^T = D}$ is assumed to be *indefinite.* The system (1) can be stable or unstable due to the indefinite damping matrix. Let us assume instability, then the question arises how to stabilize the system. If we stick to linearity, the addition of a gyroscopic force $\boxed{\;}$ with a skew-symmetric matrix $\boxed{G, (G^T = -G)}$ on the left hand side of equation (1) might perform a desired *gyroscopic stabilization.*

After investigating some special cases we will find an appropriate solution of the Lyapunov matrix equation for the general case. To this end we rewrite system

$$I\ddot{x} + (D + G)\dot{x} + Kx = 0 \tag{2}$$

as a first order system

$$\dot{z} = Lz, \quad L = \begin{bmatrix} 0 & I \\ -K & -B \end{bmatrix}, \quad B = D + G, \quad z = \begin{bmatrix} x \\ \dot{x} \end{bmatrix}. \tag{3}$$

System (3) is stable, if there exist symmetric matrices $P > 0$ and $Q \geq 0$ which satisfy the Lyapunov matrix equation.

$$L^T P + PL = -Q. \tag{4}$$

We develop a procedure to find such matrices P and Q.

Examples show the deviation of the stability limit found by this direct method of Lyapunov from the exact value.

BIFURCATIONS OF EQUILIBRIA IN POTENTIAL SYSTEMS AT BIMODAL CRITICAL POINTS

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Bifurcations of equilibria at bimodal branching points in general potential systems are investigated. General formulae describing postbuckling paths and conditions for their stability are derived in terms of the original potential energy. Formulae describing unfolding of bimodal branching points due to a change of system parameters are given. A full list of possible cases for postbuckling paths, their stability and unfolding depending on three system coefficients is presented. In order to calculate these coefficients one needs the derivatives of the potential energy and eigenvectors of the linearized problem taken at the bifurcation point. The presented theory is illustrated by a mechanical example on stability and postbuckling behavior of an articulated elastic column having four degrees of freedom and depending on three problem parameters (stiffness coefficients at the hinges). For some of the bimodal critical points numerical results are obtained illustrating influence of parameters on postbuckling paths, their stability and unfolding. A surprising phenomenon that a symmetric bimodal column loaded by an axial force can buckle with a stable asymmetric mode is recognized.

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STABILITY, BIFURCATIONS, CONTROL IN DYNAMICS OF THREE-WHEELS ROBOTS

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The existence, stability and branching of steady motions of three-wheels robots on the rough plane are studied within the assumption on asymmetric mass distribution. The existence and stability of periodic motions is discussed. Common methods of steady motions analysis are used. The results are illustrated with bifurcation diagrams. Special interest is represented with problems of maintenance of stability (a problem of stabilization) of steady-state motions of these robots.

SOLUTION TO THE CHELOMEI PROBLEM

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In 1956 V.N. Chelomei recognized that statically unstable elastic systems can be stabilized by vibrations. He came to the conclusion that the elastic column compressed by an axial force exceeding critical Euler value can be stabilized by high frequency axial vibration applied to the end of the column. In this paper formulae for the higher and lower boundaries of the excitation frequency are derived and analyzed.

It is shown that unlike stabilization of an inverted pendulum by high frequency vibration of the support the column is stabilized by frequencies of the order of the first transverse vibration frequency of the column lying within an interval.

The work was supported by INTAS-SB RAS, grant no. 06-1000013-9019.

ADAPTIVE STABILIZATION OF DYNAMIC SYSTEMS WITH PERIODIC COEFFICIENTS

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Oscillation processes are main processes for a lot of events in nature and technique. One of types of oscillation systems is the type of systems with the periodic coefficients. In particular case the coefficients change on the harmonic law. We can find examples of the systems with parameters oscillations in mechanics, electronics, biology and so on. One of the major problems in oscillation systems is the design of controller for the stabilization of motion. In modern control theory there are many design techniques, which decide the problem of motion stabilization for particular cases of oscillation systems. In this paper the stabilization of the dynamic characteristics of the systems with limited harmonic parametrical and (or) additive disturbances is considered. In the adaptive control theory the special attention is paid adaptive algorithm synthesis methods for realization of required dynamic accuracy in systems with essentially non-stationary characteristics. The decision of this problem for the some plant class can be received on the basis of the localization principle. In this case we organize system motions with different velocities so that uncontrollable disturbances are located in a fast movement contour and slow movements are submitted to desirable dynamic requirements. To achieve such effect it is possible with the help of a feedback on a full vector of first derivatives of state variables. In the paper the question about decrease the scale of SISO adaptive systems is discussed. The order is generally determined by orders of the control plant, the state observer and adaptive regulator. The order reduction of one of devices like a observer or an adaptor brings about the decrease of the system scale. In essentially non-stationary systems in which the uncontrolled disturbance rate is commensurable with the velocity of transient process, the change of the observer dimension relative to dimension of the plant can result a loss of the adaptive system stability. Therefore there is offer the transformation of non-stationary plant model allowing to reduce quantity of parametrical disturbances which are included in the modification model due to introduction of a new combined disturbance. In result the reduction of adjusted contour number is achieved. The required dynamic accuracy of the system is provided with the help of the “fast” adaptor. The synthesis of the full and lowered orders adaptors, and also convergence conditions the output processes to a desired trajectory are considered. This research was supported by the Russian Foundation for Basic Research, project number 06-08-00732-a.

ON THE STABILITY OF THE FAMILIES OF THE LIBRATION POINTS IN GRAVITATIONAL-REPULSIVE FORCE-FIELD OF A BINARY STAR-SYSTEMS

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One of the most interesting and physically adequate applications of the restricted three-body problem is using it for a study of a motion of microparticles or a particles of dust clouds in the gravitational-repulsive force-field of a binary star-systems, when these particles besides gravitational forces from the stars also experience a considerable light-pressure forces (which increase while a sizes of a particles decrease) from each of them. A main interest to this problem which has been firstly formulated almost 50 years ago [1] and is called photogravitational three-body problem is connected first of all with the investigations of a relative equilibrium positions of a particles in a rotating (together with the stars) coordinate system analogous to the well-known libration points of the classical problem. But almost in all works [2] where these equilibriums were studied (including their stability) it was not taken into account the principal difference this problem from the classical one: if in classical case the position of each libration point does not depend from the size and the mass of the particle, then in considered case the positions of the libration points are defined both by the parameters of the gravitational-repulsive force-field and by the size and the mass of the particle, which form «sail capacity» of a particle. This allows to draw a conclusion about a possibility of arising of the families of the libration points and a cloud accumulations of the particles filling them. Besides unlike to the classical problem in this case there are families of libration points, lying in a plane, which is normal to the orbital plane of the stars. By means of transferring from parameter space of the system to its configuration space and introducing some generalized parameter that characterizes the radiation power for a given binary system a very simple geometrical interpretation of stability conditions of all libration points is given. The analysis conducted makes it possible to establish the stable forms of cloud accumulations of the particles both in a plane and in a space case.

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OPTIMIZATION PROCEDURES FOR GENERALIZED EIGENVALUE PROBLEMS AND THEIR APPLICATIONS IN STRUCTURAL DYNAMICS

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Eigenvalues appear as vibration frequencies and buckling loads in structural dynamics applications. We discuss the numerical solution of generalized eigenvalue problems by optimization procedures [3]. The study of symmetric systems (in which the mass and stiffness matrix are real and symmetric) is taken up in the first part. Here, we apply variational principles for symmetric matrices as suggested by Auchmuty and Mongeau [2, 5].

The second part is devoted to systems with non-symmetric stiffness matrices. Such systems arise when follower forces are present. Our major motivation is the stability of non-conservative systems. Variational principles introduced by Auchmuty [1] are used to trace eigencurves of parameter-dependent eigenvalue problems.

Calculations are carried out in SciPy [4].

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SYNCHRONIZATION AND PROPAGATION OF OSCILLATORY ACTIVITY: MULTI-STABILITY AND HYSTERESIS

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Oscillatory activity of cells has been the topic of many studies. Oscillatory activity can be due to action potential firing corresponding to the well-known Hodgkin-Huxley (HH) type dynamics of ion-channels in the cell membrane or due to HH-type IP3-mediated calcium oscillations in the endoplasmic reticulum (ER) causing periodic oscillations of calcium transients in the cytosol. We show analytically that coupling of these two oscillatory mechanisms reveals a complex, rich spectrum of both stable and unstable states of cells with hysteresis. The predicted bi-stability corresponds to experimentally observed cell states. Coupling of these oscillatory systems in the cell provides a robust mechanism for intra- and intercellular signaling by propagation of activity in a network of cells.

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MULTISTABILITY OF CARDIAC EXCITATION: A SIMULATION STUDY OF A MODEL OF VENTRICAL CARDIAC ACTION POTENTIAL

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Many rhythms of physiological processes demonstrate the coexistence of different dynamical regimes at a fixed set of stimulation parameters, i.e. multistability. Several forms of bistability involving two different periodic rhythms have been described in experimental cardiac electrophysiology using isolated cells and small pieces of cardiac tissue. Results of these experiments have been illustrated by computational simulations of biophysical cell-models. However, a detailed analysis of the multistability of steady states of action potential duration as an intrinsic property of single cardiac cell has yet to be performed. The aim of this work is to elucidate the mechanism of multistability of steady states of action potential duration. In this study, the bifurcation analysis, as well as numerical simulations, are performed for a Luo and Rudy (LR1) action potential model. The main focus of investigation is on the sensitivity of steady states of action potential duration to initial conditions. We have found finite size regions of parameters of stimulation where the ventricular cardiac action potential model is very sensible to initial conditions. In this region, the different initial conditions lead to the different stable periodic rhythm. We determine the shaping of attraction basins on the action potential curves. Such basins of attraction contain a set of initial conditions which determinate a steady state of action potential duration. We have found a close association between the attraction basins of the steady states of action potential duration and the cardiac vulnerable windows on ECG record, during which extra stimuli can induce life threatening arrhythmias.

HOW DOES A HETEROGENEOUS LARGE-SCALE CONNECTION TOPOLOGY INFLUENCE THE LOCAL AND GLOBAL DYNAMICS OF NEURAL SYSTEMS?

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Contemporary brain theories pose that the emergence of cognitive function is based on the interplay between small-scale and large-scale architectures. In particular, functional differentiation is mostly restricted to the more peripheral primary cortical areas, whereas the cognitive processes rely more on the higher cortical areas. In neural systems, the local small-scale network connectivity is translationally invariant and referred to as homogeneous; in contrast, all the large-scale connections are spatially variant and called heterogeneous. Many of these large-scale connections develop and undergo myelination (resulting in an increase of signal transmission speeds by an order of magnitude) during the first years of infancy and adolescence in humans. We discuss the effects of such – heterogeneous connection topology and variation of transmission speed of long range fibers – onto the global network dynamics and show that developmental changes generally enhance large-scale synchronizability.

DYNAMICALLY MAITAINED SPIKE TIMING SEQUENCES IN NETWORKS OF PULSE-COUPLED OSCILLATORS WITH DELAYS

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Neuronal spike timing patterns have long been considered insufficiently accurate to enable encoding of information. Recently, however, neurons have been shown to be able, *in vitro* and *in vivo*, to generate spike sequences with millisecond temporal precision. These sequences are used to represent sensory information; they play a role in encoding memory traces and correspond to behavioral patterns. Precisely timed spiking sequences have been produced in theoretical models with various degrees of realism, including recurrent neural network coupling or spiking neurons, but each of them can only generate one or a few fixed sequences. A much larger variety is needed to fulfill realistic information capacity requirements. The problem is, however, what kind of dynamics enables neurons to generate such variability in a robust way. In the present study, we show that pulse-coupled integrate-and-fire oscillators with large delays can generate a novel collective dynamics that enables a solution to our problem. The collective dynamics reveals spontaneous jumps between different quasistable phase-locking states. The behavior is characterized by the fluctuations of their finite-time Lyapunov exponents, which are negative on average but sometimes jump to positive values. Thus, robustness in an average sense is combined with incidental variability. This provides the system with the ability to generate a large diversity of precisely timed sequences, each of which is reproducible after a variable interval. We consider the existence of the dynamically maintained spike timing sequences in parameter space for fixed and randomly distributed time delays. The distributed delays considerably enhance the predominance of the dynamical patterns in parameter space. Adding plausibility to the model, therefore, improves its function. Moreover, possible neural substrates for the existence of large delays are discussed.

ASSOCIATIVE MEMORY AND INFORMATION RETRIEVAL IN A TWO-LAYER OSCILLATORY NETWORK OF SPIKING NEURONS

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We consider two-layer architecture of oscillatory neuron network for associative memory. The first (input) layer keeps the input pattern to be recognized and their units are uni-directionally connected with all units of the second (control) layer. The connection strengths are weighted using the Hebb's learning rule. The terminal state of the control layer is formed due to forced-phase locking effect. We have found the conditions when the phase-locked state reproduces the profile of the one of memorized patterns providing error-free retrieval characteristics in network of Kuramoto's phase oscillators. It is also analyzed how such system can restore or recognize the patterns with a certain level of distortions initially imposed in their profile. Similarly to Hopfield models the dynamical system describing phase evolution remains a gradient one. However the location of the "energy" minima is not fixed and can be controlled by the stimulus pattern in the input layer.

The uni-directional couplings between the oscillators and forced synchronization have been further used to illustrate the information retrieval in biologically relevant network of spiking oscillators. Being stimulated with excitatory/inhibitory uni-directional (synaptic) coupling such unit responds with either in-phase or anti-phase spiking, respectively. We use the spiking phase to represent the information patterns. We have shown that under certain conditions the spiking network is capable to store and recognized the information patterns for associative memory. Note that in contrast with phase model (weak coupling limit) the spiking network reconfigures itself fast between different phase-locked patterns.

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RECONSTRUCTING DYNAMICS OF SPIKING NEURONS FROM INPUT-OUTPUT MEASUREMENTS IN VITRO

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Reconstruction of mathematical models of neural dynamics from input-output measurements is one of the most difficult problems in analysis and understanding of neuronal function. This is particularly true when physical equations of the neuron are uncertain, states are not available and parameters of the model are not known a-priory. In our paper we restrict the class of possible models to the Hindmarsh-Rose neuron. This is a minimal yet efficient model capable of mimicking broad ranges of neural activities -from single spikes to chaotic bursts. We aim at the development of a procedure for fitting parameters of the Hindmarsh-Rose model neurons to input-output data recorded in vitro. We demonstrate that traditional techniques based on design of adaptive observers are not applicable here because the model cannot be transformed into canonic observer form. We show, however, that a combination of control-theoretic tools such as small-gain theorems and the concept of Milnor attractors lead to successful solution of this problem. Using these two concepts we develop a novel identification algorithm, which enables simultaneous reconstruction of state and parameters of the model. We show how this algorithm can be used in the problem of analysis of extra-synaptic signal transmission.

SYNCHRONIZATION OF NONLINEAR NEURAL OSCILLATORS WITH DIFFUSIVE COUPLING: DOES THE LEAKAGE OF NEUROTRANSMITTERS MATTER?

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Synaptic signal transmission is traditionally believed to be the main channel for neural interaction. Recently, however, several research groups in the UK and Japan reported that spillover of neural transmitters from the synaptic clefts can in principle be an extra, yet relatively unexplored, channel for neural interaction. To what extent do these extra channels affect neural interaction? We provide a theoretical analysis of this problem and propose a simple physical model for the spillover, which takes transmitter diffusion into account. We found that transmitter diffusion can be described by time-varying coupling, of which the steady-state solution generally follows the Gaussian law. We implemented this coupling in a Hindmarsh-Rose model neuron and analyzed how it affects the dynamics of single cells and populations. Extrasynaptic diffusion results in a system in which the oscillators are coupled through variables with substantially different time scales. For this new class of systems we derived sufficient conditions for complete synchronization.

PROPAGATION PROPERTIES AND ONSET OF ALTERNANS IN A REALISTIC MODEL OF THE RABBIT HEART[1]

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Instabilities similar to the ones found in physical and chemical systems are also suspected to be responsible for cardiac arryhtmias like ventricular and atrial fibrillation. To get more insight, we have implemented a realistic model of a rabbit heart and compared simulations of wave propagation and the surface electrogram with experimental measurements recorded on the surface of an isolated rabbit heart in Langendorff-perfusion (Dhein lab at Leipzig university) . Detailed comparisons with experimental measurements of rabbit hearts under normal conditions as well as under influence of drugs like ajmalin and palmitoleic acid (PA) reveals a simple connection between reaction-diffusion wave properties and changes in the electrocardiogram: while a change in the local properties (ajmaline) strongly influences the recorded QRS times, the latter quantity is barely influenced by a change in the spatial coupling resp. conductivity (PA). Ajmalin and PA both reduce the propagation velocity by 20%, which can be reproduced within the model. In addition, clear indications of heterogeneous properties of cardiac tissue have been found: the recorded potentials from the left and right ventricles are qualitatively different with respect to the form of the T-wave. This difference occurs also in the simulations if the heterogeneities are incorporated correctly.

For high frequencies of the heart beat conduction block is found in simulations[§]. These phenomena could be related to the alternans instability of the periodic heart beat. The critical frequency for the onset of alternans rabbit heart is 250 msec. Numerical bifurcation analysis allows an accurate determination of the onset of alternans as well as a test for simple hypotheses for the origin of alternans like the restitution criterion. The influence of ionic channel modifications on the onset of alternans has also been studied in detail, yielding a stabilization of alternans for reduced calcium ionic channel conductivity, while a decrease in sodium or potassium conductivity leads to further destabilization of the periodic heart beat.

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DYNAMICS OF THE BLOOD PRESSURE CONTROL SYSTEM DURING HEAD UP TILT TEST

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In physiological conditions, human blood pressure is controlled by the autonomous nervous system. The primary aim of this complex control system is to maintain the blood flow and pressure adjusted to the needs of the body. There are many factors that affect blood pressure, such as body position (hydrostatic pressure), variability of intrathoracic pressure, changing rate of venous return, flow autoregulation or baroreceptor hysteresis, to name just a few. To fulfill the aim of control a complex system of feedback loops is maintained. The main monitoring receptors include blood pressure receptors and chemoreceptors. The control is applied to the heart rate, heart contractility, vascular tonus, breathing rate and depth and, in the long time scale, to the body water balance.

The aim of the current work is to reveal the functional aspects of this control system that manifest themselves as simple linear correlations (including time delay) between various physiological observables. The measurements include correlation between respiratory signal, blood pressure and heart rate. The physiological data include the recordings of 12 patients who underwent the head-up tilt testing (HUTT) using the Westminster protocol. The diagnostic protocol is designed to show the dynamical characteristics of the blood pressure control system subject to various physiological stress factors (pressors) such as application of a postural stress, controlled breathing and hand grip test. Apart from the results concerning correlation, a basic structure of the control system is proposed and a minimalistic model of blood pressure control is built which mimics the correlation properties measured in the physiological data. Also various dynamical phenomena that occur in the rich measurement protocol are discussed.

FRACTAL ANALYSIS OF HEART RATE DYNAMICS IN HYPERTHYROID PATIENTS

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The observation that hyperthyroid patients manifest symptoms and signs similar to those of hyperadrenergic states suggests autonomic dysfunctions in hyperthyroidism. The analysis of heart rate variability (HRV) has been used to understand the modulation of the cardiac autonomic nervous system and the characteristics of the heart rate dynamics. Time and frequency domain HRV parameters, along with correlation dimension (CD) and detrended fluctuation analysis (DFA), were assessed from 30 min electrocardiogram recordings in 25 newly diagnosed hyperthyroid Graves' disease patients and 25 sex-, age-, and body mass index-matched normal controls. Compared to the normal controls, the hyperthyroid patients revealed significant differences in the following HRV parameters: a decrease in the standard deviation of RR intervals, total power, high frequency power (HF) and CD; and an increase in low frequency power (LF) in normalized units, the ratio of LF to HF, and DFA. We conclude that hyperthyroidism is characterized by both increased sympathetic and decreased vagal modulation of the heart rate. In addition, the fractal analysis of HRV indicates reduced complexity and impaired tolerance to cardiovascular stresses in hyperthyroidism.

NON-INVASIVE CARDIAC MAGNETIC FIELD MAPPING DETECTS EARLY ALTERATIONS IN CARDIAC ELECTROPHYSIOLOGY IN RATS WITH SEVERE HYPERTENSION

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Objective: Hypertension induced morphological changes like left ventricular hypertrophy and fibrosis are accompanied or even preceded by alterations in electrophysiologic properties of cardiomyocytes. We investigated whether effects of electrical remodeling can be monitored noninvasively by Cardiac Magnetic Field Mapping (CMFM) in genetically modified rats.

Methods: Transgenic rats harboring both human renin and angiotensinogen genes (dTGR) feature cardiac hypertrophy, fibrosis, increased mortality and ventricular arrhythmias. We performed ECG and CMFM (7-channel SQUID-System) and characterized structural and molecular remodeling (hypertrophy, fibrosis, ion channel expression) in dTGR (week (w) 5 and 7), Sprague Dawley (SD) controls and dTGR treated with AT1 blocker (Losartan (LOS) 30mg/kg/d; w 7).

Results: Systolic blood pressure (BP) and cardiac hypertrophy (CH) increased in dTGR from week 5 to 7 week compared to matched SD and LOS treated animals ($p<0.05$). These findings were accompanied by progressive increase of myocardial fibrosis and changes in ion channel expression.

CMFM of untreated dTGR showed progressive prolongation of de- and repolarization already present at week 5 compared to controls. Inhomogeneity of depolarization and repolarization increased with progression of cardiac damage. Magnetic field maps of dTGR showed most prominent changes in late depolarization. Treatment with LOS improved all CMFM parameters.

Conclusion: CMFM noninvasively characterizes effects of electrical remodeling and impact of pharmacological treatment in hypertension induced cardiac damage in small rodents. The differences are already present at early stages, when cardiac fibrosis and hypertrophy begin to increase.

INTERACTIONS BETWEEN SHORT-TERM AND LONG-TERM CARDIOVASCULAR CONTROL MECHANISMS

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An early diagnosis and treatment of cardiovascular dysfunctions is a challenge due to the complexity of the underlying processes.

The cardiovascular system incorporates several controlling mechanisms acting as feedback loops over different time horizons. Because of their complex interrelationships, information-based methods such as autonomic information flow (AIF) functions promise to be useful in identifying normal and pathological behavior. Optimal adjustment between those controllers is necessary for healthy global behavior of the organism.

We investigated the question, whether there are typical relationships between short-term and long-term AIF by means of a meta-analysis of several of our own clinical studies of the prognosis of patients with multiple organ dysfunction syndrome, chronic heart failure, cardiac arrest, myocardial infarction, idiopathic dilated cardiomyopathy, and after abdominal aorta surgery.

We found a fundamental association of increased short-term randomness (decreased AIF) and decreased long-term randomness (increased AIF) due to pathology and associated with increasing risk.

A systems theoretic validation of this fundamental type of association was done by an appropriate mathematical model using a dissipative system with two feedback loops over different time horizons. The systematic simulation of an increasing collapse of the short feedback loop confirmed the inverse association between short-term and long-term information flow as a fundamental, system inherent type of re-adjustment which occurs under pathological conditions.

Assessing the interplay between mechanisms acting on different time scales by AIF functions presented in this paper may improve the understanding of complex cardiovascular control and developing therapeutic implications.

EFFECT OF MATERNAL RESPIRATORY RATES ON FETAL-MATERNAL HEART RATE COORDINATION

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There is evidence that during pregnancy fetal and maternal cardiac activity may coordinate over short periods of time. However, there is also a high probability of phases with spurious fetal-maternal heart rate coupling resulting simply from the naturally changing frequencies of two independent cardiac oscillators. We postulated that conditions conducive to physiological cardiac interaction between mother and fetus might be achieved by controlling maternal heart rate. Aim of this work was to assess the occurrence of fetal-maternal heart rate synchronization epochs under conditions of controlled breathing of the mother. We examined three healthy pregnant women between the 36th and 40th week of gestation. In each pregnancy we obtained simultaneous 5 min. fetal and maternal magnetocardiograms (MCG) with varying rates of maternal respiration: spontaneous, 15 cpm, 10 cpm, 20 cpm, 12 cpm and spontaneous. In each of the resulting 18 MCG data sets, fetal and maternal R peaks were determined and RR interval time series were constructed. From each pair of fetal and maternal RR interval series synchrograms were constructed using the stroboscopic technique and all epochs of synchronization >10s were identified. In order to distinguish epochs resulting from physiological interaction and those due to transient combinations of heart rates, so-called "twin surrogate data sets" of the maternal MCG were constructed, combined with the fetal MCG data and also examined as described above. In the original data, most epochs (35%) were found at a breathing rate of 20 cpm, the least (6%) at a rate of 10 cpm. Under spontaneous breathing as well as at 12 and 15 cpm, the number of epochs found was similar (14-17%). In the surrogate data, the relative occurrence of epochs was similar to that of the original data for spontaneous breathing and 12 cpm (14-18%) as well as for 10 cpm (7%). However, the number of epochs for 20 cpm was lower than that for the original data (20%) and higher for 15 cpm (26%). The results suggest that under conditions of relative rapid breathing the probability of fetal maternal cardiac interaction is greater. Furthermore, the chance of such synchronization seems to decrease at 15 and 20 cpm. In conclusion, higher maternal breathing rates may provide conditions under which fetal maternal cardiac interaction may be studied.

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ANALYSIS OF CARDIOVASCULAR OSCILLATIONS: NEW APPROACH TO THE EARLY PREDICTION OF PRE-ECLAMPSIA

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Pre-eclampsia (PE) is a serious disorder with high morbidity and mortality occurring during pregnancy; 3%–5% of all pregnant women are affected. Early prediction is still insufficient in clinical practice. Although most pre-eclamptic patients show pathological uterine perfusion in the second trimester, this parameter has a positive predictive accuracy of only 30%, which makes it unsuitable for early, reliable prediction. The study is based on the hypothesis that alterations in cardiovascular regulatory behavior can be used to predict PE. Ninety-six pregnant women in whom Doppler investigation detected perfusion disorders of the uterine arteries were included in the study. Twenty four of these pregnant women developed PE after the 30th week of gestation. During pregnancy, additional several noninvasive continuous blood pressure recordings were made over 30 min under resting conditions by means of a finger cuff. The time series extracted of systolic as well as diastolic beat-to-beat pressures and the heart rate were studied by variability and coupling analysis to find predictive factors preceding genesis of the disease. In the period between the 18th and 26th weeks of pregnancy, three special variability and baroreflex parameters were able to predict PE several weeks before clinical manifestation. Discriminant function analysis of these parameters was able to predict PE with a sensitivity and specificity of 87.5% and a positive predictive value of 70%. The combined clinical assessment of uterine perfusion and cardiovascular variability demonstrates the best current prediction several weeks before clinical manifestation of PE.

RECURRENCE PLOTS IN THE ANALYSIS OF ICD HEART RATE RECORDINGS

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The implantable cardioverter defibrillator (ICD) can successfully terminate ventricular tachyarrhythmias, which are the most common mechanism of sudden cardiac death. However, sometimes they are oversensitive – which leads to a spurious intervention of the device. Every such intervention may be the cause of a change in the tissue of the heart and it can be also painful. Together with psychological problems that the occurrence of an ICD intervention creates, spurious interventions decrease the quality of life of the patient. Modern ICDs are able to store RR intervals preceding the onset of arrythmia as well as control sequences – such that do not end with a lethal arrhythmia. In this work, we examined 70 recordings of 20 patients. The aim of this study was to determine if, using recurrence plots, it is possible to distinguish between the control recordings, the recordings ending with an ICD intervention and those ending with a spurious intervention.

Each recording was about 2000 RR intervals long. If an intervention had occurred, the part containing the beginning of the arrhythmia before the intervention was deleted from the recording. The recordings were analyzed using a moving widow of 200 RR intervals. The RP was computed for each window separately and the position of the window was incremented by a single RR interval. For each RP, statistics of the Recurrence Quantification Analysis were calculated. These statistics were plotted as a function of the index of the sliding window. To detect differences between recordings ending with an intervention and the controls, several different statistical methods were used.

We obtained an 80 percent success rate for the whole study group. Instead of looking for ways to distinguish between groups of recordings (e.g. between the group of control recordings of all patients and the group of ICD intervention recordings) we decided to look for criteria enabling to distinguish the control, the spurious intervention and the correct ICD intervention recordings for the given patient. We found that different RQA statistics were statistically significant for different patients.

Rather surprisingly, our method allows also to treat recordings with a significant content of atrial fibrillation. One of the reasons for spurious interventions of the standard ICD algorithms is the misinterpretation of this condition. Thus, our result may have practical applications.

ENTROPY-BASED COMPLEXITY OF SHORT-TERM HEART PERIOD VARIABILITY IS LINKED TO CARDIAC AUTONOMIC MODULATION

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In the context of short-term heart period variability analysis entropy-based complexity is usually evaluated based on the estimation of the conditional entropy quantifying the amount of information that is carried by a sample of the series when past samples are known (the smaller the information, the more regular and predictable the series). Changes of entropy-based complexity of heart period variability series have been related to aging and disease. More recently it has been suggested that entropy-based complexity of short-term heart period variability might be closely related to cardiovascular regulation but changes of complexity have been never reliably linked to a progressive variation of the cardiac autonomic modulation. In short-term heart period variability studies conditional entropy is more frequently estimated according to: i) approximate entropy (ApEn; Pincus SM, Chaos, 5:110-117, 1995); ii) sample entropy (SampEn; Richman JS and Moorman JR, Am J Physiol, 278:H2039-H2049, 2000); iii) corrected conditional entropy (CCE; Porta A et al, Biol Cybern, 78:71-78, 1998).

The first aim of this study is to verify whether complexity indexes based on entropy rates and applied to short heart period variability series can track the gradual increase of sympathetic modulation (and the concomitant decrease of vagal one) produced by graded head-up tilt test. The second aim is to compare well-established entropy rate estimates (i.e. ApEn, SampEn and CCE) over the same experimental protocol. Entropy-based indexes were computed over short heart period variability series (about 250 cardiac beats) derived from ECG recordings during head-up tilt with table inclination randomly chosen inside the set {0, 15, 30, 45, 60, 75, 90} in 17 healthy subjects. We found that: 1) ApEn does not change significantly during the protocol; 2) all indexes measuring complexity based on entropy rates including ad-hoc corrections of the bias arising from their evaluation over short data sequences (i.e. SampEn and CCE) evidence a progressive decrease of complexity as a function of the tilt table inclination, thus indicating that complexity is under control of the autonomic nervous system. Therefore, SampEn and CCE provide indexes that can be valid alternatives to linear spectral indexes in monitoring non-invasively sympatho-vagal balance.

COMPARISON BETWEEN BODY SURFACE POTENTIAL MAPPING AND MAGNETIC FIELD MAPPING OF THE REPOLARIZATION SEQUENCE IN PATIENTS WITH ARRHYTHMOGENIC RIGHT VENTRICULAR CARDIOMYOPATHY

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Arrhythmogenic right ventricular cardiomyopathy (ARVC) is a disorder that predominantly affects the right ventricle and causes ventricular tachyarrhythmias (VTA). Body-surface potential mapping (BSPM) has been shown to be a useful tool to investigate the ventricular repolarization properties in ARVC. The aim of the present study was to examine whether magnetic field mapping (MFM) may be an additional diagnostic tool with advantages compared to BSPM . Methods: Sixty-four leads body-surface potential maps and 42 leads magnetic field maps were obtained during sinus rhythm in 12 patients with task force based diagnosis or positive genotype of ARVC and 12 healthy subjects. Seven of 12 ARVC patients had a history of VTA. BSPM- and MFM- maps of the repolarization period were analyzed both visually and mathematically. We performed a field pattern recognition, analyzed number and position of map local extrema and calculated the inhomogeneity index (IHi). Results: in all 12 healthy volunteers a normal dipolar field distribution and IHi was found in BSPM and MFM. The IHi was significantly increased in the ARVC group both in MFM and BSPM. Approximately two third of the ARVC pts had dipolar field pattern in BSPM with abnormally large negative areas over the right thorax, whereas the remaining pts showed short time multipolar field pattern during the T-wave. In contrast, eleven of 12 ARVC pts showed both abnormally magnetic field distribution and MFM-multipolarity. A specific magnetic field pattern with two positive extrema at the beginning of the repolarization period was found in 8/11 pts . Six of 7 pts with a history of VTA and 1/5 pat without VTA demonstrated this pattern in the MFM, not seen in the BSPM. Four pts without VTA events showed different multipolar MFM pattern. Conclusion: The magnetic field mapping gives new information regarding the electrophysiological properties of the right ventricle that are undetectable by BSPM. It seems that MFM is a useful tool for screening of cardiomyopathies and risk assessment of VTA within the ARVC population.

MAGNETOCARDIOGRAPHY OF MICE USING A STANDALONE MULTICHANNEL SQUID DEVICE

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Magnetocardiography (MCG) has been proposed as a tool for drug safety assessment and phenotype characterization in genetically modified small animals. To this end, a multichannel superconducting quantum interference detector (SQUID) system dedicated to mouse MCG in laboratory environment has been developed. Here, we report pilot measurements of murine MCG demonstrating the applicability of the system. As a reference, MCG mesurements of mice using a conventional 93 SQUID system are presented.

The mouse MCG measurement system comprises a liquid helium dewar with a horizontal 27 mm warm bore, an integrated superconducting Nb shield against external magnetic distortions and up to six low-Tc SQUID sensors for MCG detection. Animal studies were approved by the local ethics committee. Mouse MCG measurements have been conducted on anesthetized animals with a sampling rate of 3 kHz and a measurement time of 1 min.

The magnetic shielding at the sensor position was found to be better than six orders of magnitude. The measured SQUID noise is 2.7 fT/Hz^1/2 at 100 Hz, dominated by thermal noise in the superinsulation of the dewar. Detection of the murine MCG was feasible. The QRS peak amplitudes amounted up to 5 pT. Mechanical vibrations of the measurement system caused background noise of similar amplitude.

A wavelet analysis revealed a maximum signal-to-noise ratio in a frequency band of 150+-30 Hz. Using a scalable complex wavelet as a narrow band pass filter, we were able to identify the timing of the heart beats and to construct the RR time series. After averaging the heart beats, a quantitative assessment of ventricular depolarization and repolarization was possible.

Simultaneously, cooling of the superconducting shield in a reduced static magnetic field reduced the influence of mechanical vibrations on the MCG signal.

Conclusion: Our new multichannel MCG system allows contactless MCG studies on mice in a common laboratory environment. Due to the integrated shielding, the system offers a compact alternative to MCG systems operated in a magnetically shielded room. Adaptive signal processing and improvement of operational procedures are necessary to the enable clinical applicability of the system.

HOW AND WHICH NON-LINEAR MEASURES OF CARDIOVASCULAR OSCILLATIONS CONTRIBUTE TO RISK STRATIFICATION?

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Nowadays, there are no generally accepted indications to identify cardiac patients with an increased risk of sudden cardiac death or ventricular arrhythmias for prophylactic defibrillator implantation or cardiac transplantation. Linear methods of heart rate variability and baroreflex sensitivity analysis could not considerably contribute to risk stratification in those patients.

The aim of this study was to analyze the suitability of the non-linear methods short and long term symbolic dynamics (STSD/LTSD), detrended fluctuation (DFA), Poincaré plot analysis (PPA) and compression entropy (CE) in comparison to heart rate and blood pressure variability (HRV, BPV) analysis for a non-invasive risk stratification in patients with different cardiac diseases.

For risk stratification in DCM patients (n=91) based on 30 min ECG and continuous blood pressure recordings four parameters from BPV, STSD and PPA revealed significant differences between low and high risk (maximum sensitivity: 90%, specificity: 90%). These results suggest that STSD and PPA are useful non-linear methods for enhanced risk stratification in DCM patients.

For risk stratification in 509 (ischemic and non-ischemic) heart failure patients based on 24h ECG recordings nine parameters from HRV, LTSD, CE and especially DFA revealed significant differences between low and high risk. These results suggest that especially DFA and LTSD in combination with HRV revealed significant differences between low and high risk (maximum sensitivity: 85%, specificity: 85%). These results suggest that LTSD and DFA are useful non-linear methods for enhanced risk stratification especially in ischemic heart failure patients.

In conclusion, non-linear parameters enhance risk stratification in cardiac patients but their diagnostic precision differs depending on the primary heart disease.

CARDIOVASCULAR DYNAMICS DURING NORMAL AND PATHOLOGICAL SLEEP

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Sleep is an active and regulated process with restorative functions for physical and mental conditions. Based on recordings of brain waves and the analysis of characteristic patterns and waveforms it is possible to distinguish wakefulness and five sleep stages. Sleep and the sleep stages modulate autonomous nervous system functions such as body temperature, respiration, blood pressure, and heart rate. These functions consist of a sympathetic tone usually related to activation and to parasympathetic (or vagal) tone usually related to inhibition. Methods of cardiovascular physics are used to analyze heart rate and respiration to detect changes of the autonomous nervous system during sleep. Data driven modeling analysis and synchronization analysis and their applications to heart rate and respiration during sleep in healthy subjects and patients with sleep disorders are presented. The observed changes can be used to distinguish sleep stages in healthy subjects as well as to differentiate normal and disturbed sleep on the basis of heart rate and respiration recordings without direct recording of brain waves. Of special interest are the cardiovascular consequences of disturbed sleep because they present a risk factor for cardiovascular disorders such as arterial hypertension, cardiac ischemia, sudden cardiac death, and stroke. New derived variables can help to find indicators for these health risks.

PROPERTIES OF A NONLINEAR OSCILLATOR MODEL OF THE CONDUCTION SYSTEM OF THE HEART

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A dedicated nonlinear oscillator model able to reproduce the pulse shape, refraction time and phase sensitivity of the action potential of a natural pacemaker of the heart was developed. The phase space of the oscillator contains a stable node, a hyperbolic saddle and an unstable focus. The first aim of the talk will be to discuss which phenomena obtained clinically in human heart rate variability are due to the nonlinear dynamics of the individual nodes of the conduction system of the heart. The model reproduces the well known saturation and the decrease of heart rate variability due to an increase in sympathetic activity. Sinus arrest (or pause) occurs in the model due to a single, well timed, external pulse just as it occurs due to a single supraventricular ectopy. Several ways by which the oscillations cease in the system are obtained (models of the asystole). The model simulates properly the way vagal and parasympathetic activity modulates the heart rate (i.e. the vagal paradox). Two such oscillators coupled unidirectionally and asymmetrically, reproduce the properties of heart rate variability obtained from patients with different kinds of heart block. It is usually claimed that in living systems approximately 3% of the minimum level noise may be expected. We show that such a level of irregular behaviour is obtained when our oscillator is subject to a regular, periodic drive. We extend the model into a one dimension chain to simulate the properties of the SA and the AV nodes of the conduction system of the heart together with the atrium. The conditions of obtaining a time interval alternance are discussed.

UNRAVELING THE DYNAMICS OF GENE REGULATION IN CELL MIGRATION USING NEURAL NETWORKS AS A TOOL FOR REVERSE ENGINEERING

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Information reflecting cellular behavior is encoded in the kinetic of its functional elements. Thus, understanding these systems ultimately involves the insight into the dynamics of gene regulatory networks (GRN) as a response to external stimuli.

Here, we introduce novel methods to unravel both the topology and dynamics of a GRN, controlling cell migration in keratinocytes. On the experimental side, we use multiple temporally-resovled microarray experiments, each of which causes a different cell fate, from which one can extract a small list of candidate genes exclusively responding to cell migration. On the modeling side, we combine a reverse engineering with a statistical approach in the search for a robust network topology and dynamics of the underlying GRN. We employ a Continuous Time Recurrent Neural Network (CTRNN) as a phenomenological model for gene expression and interaction in combination with a genetic algorithm for parameter estimation. Owing to the fact that biological systems are usually robust to parameter variability, we independently fit the CTRNN to the experimental data >10,000 times, thus identifying those interactions as edges in the networks that significantly often reappear in all fits. As a result, we have unraveled both the networks topology and dynamics, showing that the network converts a transient input into a permanent cellular decision through the establishment of various positive feedback loops between the candidate genes. Most important, the model predictions have all been in agreement with current biological knowledge. Moreover, several of the predicted gene interactions have been verified in independent control experiments. Consequently, we have established a novel reverse engineering method that generally (i) allows dynamic modeling of GRNs, (ii) is directly applicable to the analysis of microarray data and (iii) is capable generating readily testable hypotheses.

1

ANTIGEN PRESENTATION VIA MHC CLASS II: STUDY OF THE ASSOCIATION BETWEEN HLA DR AND THE INVARIANT CHAIN CD74 ISOFORM EXPRESSED AT THE CELL SURFACE

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We have been interested in developing methods for studying the physical interaction of the molecules of the immune system; in particular those involved an antigen presentation. Earlier we reported a novel single molecule method for investigating and quantifying co-localization of cell surface receptors. Here we show the association of CD74 with MHC class II molecules. CD74 is the surface isoform of the invariant chain. In the cytoplasm the invariant chain plays a key intracellular role in the assembly and targeting of newly synthesized MHC class II molecules; however the role of cell surface isoform, CD74 is not well understood. We find that 25 ± 1.3 % of CD74 and 17 ± 0.3 % of HLA-DR are co-localized on M1DR1/Ii/DM cells. The association of CD74 with HLA-DR and the internalization of HLA-DR are both inhibited by $HA_{307-319}$, a peptide that binds strongly and specifically to the peptide-binding groove of all HLA-DR alleles. A similar inhibition of HLA-DR internalization by $HA_{307-319}$ was also observed in monocytes-derived dendritic cells. We conclude that CD74 interacts with HLA DR and facilitates internalization of empty HLA-DR into the cytoplasm. This would enable HLA DR molecules to bind exogenous peptides in early endosomes prior to recycling and thus optimizing the repertoire of histocompatibility molecules available at the cell surface of an antigen presenting cell. This study offers a model for investigating protein-protein interactions on single living cells and thus can be a powerful tool in immunology and computational bioinformatics.

THE VARIETY OF GENOMIC OUTPUT IN HOMO SAPIENS

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The human genome contains ~25,000 regions that code for proteins yet these regions produce ~100,000 different proteins. This is because many of our genes can produce more than one protein, through the mechanism of alternative splicing. Alternative splicing is one of the key evolutionary drivers in mammalian history, but we presently have little knowledge about how groups of genes make coordinated splicing decisions. Moreover, although only about 1.5% of our DNA codes for protein, it is likely that >50% of our DNA codes for RNA. Much of this non-coding RNA is likely to be functional, but we presently have little knowledge of how networks of non-coding RNA are regulated.

COMPUTATIONAL STUDIES ON THE ROLE OF PROTEASOMES IN ANTIGEN PRESENTATION

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The proteasome is a central cellular protease involved in the degradation of most intracellular proteins. In particular, the proteasome is considered to function as the main supplier of peptides presented by the major histo-compatibility complex 1 (MHC-1) on the cell surface with the aim to signal T-lymphocytes of the adaptive immune system the metabolic status of the cell (self-recognition). In the past, we have undertaken several modelling studies to unravel the mechanism by which the proteasome cleaves a given protein into a characteristic set of shorter fragments. This way we were able to establish scoring matrices that may help to predict the probability with which an arbitrary peptide bond will be cleaved by the proteasome. More recently, we have focused on the sequence specificity of some other important molecular players involved in the MHC-1 mediated antigen presentation: the transporter for antigen presentation (TAP) shuttling peptides from the cytosol into the endoplasmic reticulum (ER) and so called trimming proteases resident in the cytosol and the ER and attacking peptides from their N-terminal end. The talk will provide an overview of these computational studies as well as of our current attempts to develop a kinetic model of the whole MHC-1 presentation pathway taking into account the kinetic and specificity features of its main steps.

VARIETY OF DYNAMICAL REGIMES IN COUPLED SYNTHETIC GENETIC OSCILLATORS

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We study an interplay of coupling, stochasticity and population size in a population of coupled synthetic oscillators with relaxator dynamics. We show that control of the coupling strength and noise can effecticely change the dynamics of the system leading to behaviours such as clustering, synchronous and asynchronous oscillations, and suppression. Moreover, under certain conditions an optimal amount of noise can lead to increased order in the system. We show also that reliable timing of decision-making processes can be accomplished for large enough population sizes, as long as cells are globally coupled by chemical means. In the light of these results, we conjecture that cell proliferation, in the presence of cell-cell communication, could provide a mechanism for reliable decision making in the presence of noise, by triggering cellular transitions only when the whole cell population reaches a certain size.

Next, in contract to previous studies focused on the synchronization of communicating genetic units, we address the question: what mechanisms can be responsible for multirhythmicity in globally coupled genetic units? Here we show that an autoinducer intercell communication system that provides coupling between synthetic genetic oscillators will inherently lead to multirhythmicity and the appearance of several coexisting dynamical regimes. Furthermore, we propose a new mechanism for quantized time production in network of coupled relaxators, based on the interplay of cell--cell communication and stochasticity. We discuss how inhomogeneity can be used to enhance such quantizing effects, while the degree of variability obtained can be controlled using the noise intensity or adequate system parameters.

PROTEAMALG: A NEW TOOL FOR PREDICTION OF THE SUBSTRATE DEGRADATION AND FRAGMENT PRODUCTION BY THE 20S PROTEASOME AND PA28

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Proteasomes are multicatalytic enzyme complexes responsible for degradation of the majority of the proteins and production of epitopes for MHC class I antigenic pathway. We have developed a kinetic model of proteasome degradation and entire proteins, which considers some of the major variables present in the in vitro proteasome digestion experiments. The new algorithm Proteamalg enables the prediction of the substrate degradation and fragment production versus time. This algorithm uses the solution of kinetic differential equations to describe the dynamics of the fragment concentration. The model covers all possible fragments which can be produced from the original substrate. The model analyzes the effect of several variable conditions, such as substrate concentration, length and sequence of the polypeptide, presence of regulatory complexes, on the degradation of the substrate and on the production of digestion fragments. The algorithm successfully describes the dynamics of concentrations, the deceleration of short peptide degradation, and an effect of the regulation particle PA28 on the production of double and single cleavage products.

SELF ORGANIZATION IN PROTEIN FOLDING

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The closed loop hypothesis of Berezovsky and Trifonov implicates the closure of loops of length 25-35 through hydrophobic interactions at the ‘locks’ as a key event in protein folding. The hypothesis is supported by published analyses of 9 major superfolds. Here we have generated multiple sequence alignments for the 9 superfolds with PDB codes 1thb, 1ilb, 256b, 2rhe, 1aps, 2stv, 4fxn (2fox), 1ubq and 7tim and have analysed the degree of conservation at the loop ends. Seventy percent of these loop ends are found to be well conserved and the peak in the distribution of distances between these well conserved regions lies at around 25 residues; both observations are consistent with the Berezovsky and Trifonov’s hypothesis. This initial work has been published: BK Yew et al., J Mol Graph, ’07); here we present developments of this work.

COMPUTATIONAL TOOLS FOR THE OPTIMIZATION OF ANTIRETROVIRAL DRUG THERAPIES

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Despite the approval of 18 antiretroviral drugs and the use of combination therapy, successful treatment of HIV-infections is hampered by the emergence of drug-resistant genetic variants in response to therapy. Finding a new potent drug combination after treatment failure is considered challenging, because most accumulated mutations confer resistance to multiple drugs.

We present computational methods for the integration and analysis of host genetic data, viral sequence data, phenotypic resistance data, and clinical data from infected patients. We design and implement a relational database schema that serves as the logical and physical basis for this task. We introduce a mixture model of trees to describe probabilistically the evolution of drug resistance. Machine learning techniques are applied to predict phenotypic drug resistance and coreceptor usage from genotypes. To support therapy optimization, we develop a scoring function for drug combinations that involves estimating the genetic barrier of the combination therapy relative to the viral strain. The scoring scheme is shown to be predictive of virological response in patients.

NOISE-INDUCED RHYTHMICITY IN AN ENSEMBLE OF CIRCADIAN OSCILLATORS

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The circadian rhythm pervades the whole organism from the level of the proteins to the activity of the whole body and its interaction with the environment. In natural conditions, the circadian clock is controlled by a periodic and very reliable external light-dark cycle and is phase-locked to it. In mammals the circadian pacemaker is located in the suprachiasmatic nucleus of the hypothalamus and consists of two paired nuclei, each containing ≈10,000 neurons. The neurons are controlled by protein concentrations of a genetic clock circuit. Interestingly, the circadian clock is able to produce precise self-sustained oscillations under constant light conditions. By high and constant light the circadian clock undergoes a transition from the rhythmic regime to an arrhythmic behaviour without any clear rhythm in the activity.

We model the circadian pacemaker on the genetic level and investigate an large ensemble of non-identical Goodwin oscillators globally coupled by neurotransmitters [1]. The Goodwin oscillator describes the interplay amongst the clock mRNA, the clock protein, and the transcriptional inhibitor. The collective activity of all oscillators generates an overt rhythm that can be e.g. the motor activity or the body temperature. The dynamics of a single cell is affected by light and intercellular coupling. According to ref. [2] we assume an influence of the light intensity on the coupling strength in such a way that increasing light reduces the coupling. The different eigen-frequencies of the individual Goodwin oscillators cause a de-synchronisation, hence the overt-rhythm undergoes a transition from self-oscillations to a steady state for increasing light whereas the individual non-identical genetic oscillators preserve their self-oscillations for all light conditions but de-synchronise amongst them for large light levels.

We are interested in constructive effects of noise in the environmental light on the circadian overt rhythm. We found a noise induced overt rhythm generation for constant light intensities that evoke an arrhythmic response in the noise-free case. The noise has a resonance-like influence on the overt rhythm with a clear maximum at an optimal noise intensity. Due to the absence of any external pacemaker or periodic signal, because we are working under constant light conditions, the resonance found in the overt rhythm versus the noise intensity is a kind of Coherence Resonance. The resonance can be observed only in the overt rhythm and not at the level of the individual oscillators, hence we found a joint effect of noise, coupling and the synchronisation amongst the oscillators. Noteworthy, the noise-induced rhythm generation only needs a very small synchronisation level.

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THE 20S PROTEASOME: TOWARDS UNDERSTANDING SUBSTRATE UPTAKE

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The 20S proteasome is a 700kDa, ubiquitous, multi-subunit protease that consists of four heptameric rings arranged in an $\alpha_7\beta_7\beta_7\alpha_7$ fashion. The barrel-shaped complex is traversed by a central channel, which widens into two antechambers and the central chamber. Entrance to the antechambers is restricted by an orifice in the α-subunit rings. The active sites are formed by the N-terminal threonine of the active β-subunits residues located in the central chamber. Such architecture prevents the destruction of proteins not destined for degradation.

For the elucidation of the mechanism underlying the translocation of polypeptide chains into the central cavity of the 20S proteasome and the precise role of the two antechambers we use archaeal 20S proteasomes as model systems.

We used quasi-stable “host-guest” complexes to characterize the state of the proteasome and of substrates “en route” to the central cavity. The complexes were formed by incubation of inhibited proteasomes with a variety of substrates and subsequent trapping of “guests” within the internal cavities of the proteasome. Analysis of the location of the guests within the complexes and of the stoichiometry of the complex by imaging techniques (electron microscopy and confocal microscopy) and mass spectrometry, revealed the function of the antechambers as storage places during the translocation process. Moreover, crystal structure analysis in combination with an extensive mutational analysis disclosed the amino acids crucially involved in the mechanism of this translocation process.

ELECTRON SPIN-CONTROL AND MANIPULATION IN MICRO- AND NANOSTRUCTURES

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As an alternative to electronic charge, the storage and transport of electronic spin in semiconductor devices - "spintronics", may revolutionize the electronic device industry, with spin based transistors, opto-electronic devices, and memory. Moreover, the semiconductors and quantum dots may eventually enable quantum computing in the solid state. Although efficient room temperature electrical spin injection in metals has been commercially employed into today's magnetic read heads through giant magnetoresistance, electrical spin injection into semiconductors has been quite challenging. One of the promising candidate for effective spin-injection is so-called half-metallic ferromagnets (HMF).

Potential applications of systems based on HMFs in magneto- and spinelectronics including spin injectors, magnetic field sensors, and magnetic memory devices stimulated the investigation of the electronic properties of HMFs by a multitude of experimental and theoretical approaches. The main question remains however if the 100% spin polarization at the Fermi level theoretically predicted for HMFs can be confirmed experimentally.

In the talk we will consider theoretical predictions which were made for a huge number of materials as well as the experimental methods that allow to control the spin-state of electron in the solid. As an examples we will present the recent experimental results on the investigation of materials with high spin polarization by different experimental methods: spin-resolved photoemission, point contact Andreev reflection, magnetoresistance of tunneling barriers, etc.

Method of measurements with random perturbation

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Here we report on application of simultaneous perturbation for stochastic approximation (SPSA) algorithm [1] for filtering systematic noise in photoelectron spectra of solid state (oxygen-terminated W(110) surface was taken as an object) [2]. In many experiments physicists have to deal with the observation noise of unknown nature. Traditionally, the observed noise is assumed to be a mutual independent and zero-mean. These assumptions are often hard to justify in practice and without them, the validity of many algorithms is questionable in physics applications. For example, it is known that the standard "least-squares method" or the "maximum likelihood method" give wrong estimates if the observed noise has an "unknown-but-bounded" deterministic nature or it is a probabilistic "dependent" sequence.

Photoelectron spectra were measured in normal emission geometry from the oxygen-terminated (for better stability in long-time experiment) preliminary cleaned W(110) surface. As light sources we have used He IIα and Al Kα lines with photon energies of 40.8 and 1486.6 eV. The first line was used in order to obtain the photoelectron spectra of the valence band and the second one as source of a systematic noise. The studied spectra were recorded with He IIα line in the range of 30-42 eV of kinetic energy and respective noise was introduced in the range between 33 and 40.2 eV via switching-on and -off of the Al Kα photon source, respectively. In this case the secondary electrons excited in the W(110) were produced as a perturbation.

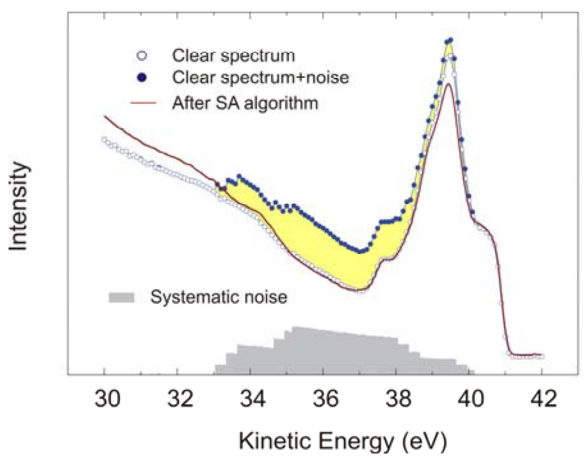

Fig. 1. Experimental photoelectron spectra of the valence band of W(110) obtained with He IIα radiation with (open circles) and without (closed circles) systematic noise. Spectrum obtained after application of SPSA algorithm to the series of 50 experimental spectra is shown by straight line. The gray area in the low part of the plot is a systematic noise.

In our analysis of the experimental data by means of SPSA algorithm we have used 50 photoelectron spectra where systematic noise was introduced. Figure 1 shows the valence band spectra of original oxygen-terminated W(110) surface (with and without noise) and spectra obtained on the basis of SPSA algorithm (systematic noise is shown in the low part of the plot as a grey area). We have found that the resulted SPSA-spectrum is in good agreement with the spectrum measured without systematic noise. On the basis of these results we conclude that application of SPSA algorithm can be useful for analysis of different experimental data (for example, photoelectron spectra). We can expect a wide application of this method for filtering out of systematic noises that can appear in different kind of measurement/experiments.

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RECENT EXPERIMENTAL DEVELOPMENTS OF HARDWARE FOR SOLID-STATE HYBRID COMPUTERS

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Various advanced experimental approaches to development of hardware for solid-state quantum and hybrid computers will be reviewed. Underlying physical aspects of realization and operation of quantum elements will be thoroughly discussed. Particular attention will be paid to recent developments in the field of ordered magnetic quantum-dot arrays coupled to biological objects like proteins and DNA molecules.

NEW BREED STOCHASTIC HYBRID COMPUTERS

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In this paper model of new breed stochastic hybrid computer is proposed. The new way of possible element base creation and computation process organization are described. Recommendations for architecture and language development are given. Some process oriented computing models are discovered.

In a few years the size of the computer unit cell will reduce to 100-200 angstrom (0.01-0.02 microns). Such devices will not be able to work with ordinary bits {0, 1} and the information nature itself will change. New devices will operate with the "wave functions" instead of "digits" and the new breed of mediums will require new mathematical fundamentals. On one hand this will lead to the change of the main classical algorithms and on the other hand it will allow to come closer to the solution of the artificial intelligence problems.

It is very likely that the basic principle of the future computing devices operation will be asynchronous work of a number of parallel processes. One of the processes can be a quantum bit or a register of a classical computer. At specific moments of time stepwise changes will take place in the evolution of the essential processes. Usually such changes are caused by restrictions imposed on resources and the necessity to redistribute resources between the processes. When describing the mathematical model of such new devices we cannot use the rough digitalized approximation, because the majority of real physical processes have fundamentally non-linear nature. That is why small inaccuracy in the initial conditions even for the short periods of time may lead to significant dispersion of the trajectory. This makes for the necessity to study the new type of computers as stochastic hybrid systems.

States and memory of the hybrid stochastic computing device change both stepwise (discretely) and evolutionally (continuously). At the same time it is implied that all data is defined nonstrictly and has stochastic nature.

The set of processes lying at basis of the new device will be called a set of basis primitives. For example for the elementary operations the classical bit, quantum bit, or quantum bit cluster (f-bit) can be used as basis primitives. In this situation it is possible to use the f-bit for function convolution operation performed at one cycle.

OPTIMAL CONTROL OF A MECHANICAL TWO-MASS-SPRING SYSTEM USING INVARIANT ELLIPSOIDS TECHNIQUE

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In description and control of real-life physical systems, *exogenous disturbances* and *uncertainties* in the system coefficients should unavoidably be accounted. There exist various models for both; in this paper we adopt the *unknown-but-bounded* model due to its adequacy to many systems encountered in practice and minimum a priory requirements imposed. Namely, no statistical properties, rates of variation, etc., are involved; the uncertainties and disturbances are assumed to be arbitrary, and only bounds for their admissible values are known. This viewpoint leads to the guaranteed set-membership approach to control and system theory and to the invariant sets ideology. In particular, this ideology has got diverse applications in estimation, filtering, minimax control in the presence of uncertainty, etc., because it often provides simple yet somewhat accurate outer approximations of reachable sets of dynamic systems.

In many cases, of the most adequate models of exogenous disturbances are the so-called persistent disturbances. However, the presently known techniques such as l_1-optimization theory, lead to high-dimensional controllers and are very hard to implement. Also, precise description of reachable sets for systems subjected to persistent disturbances is extremely cumbersome.

A natural way to overcome these difficulties is to appeal to the invariant sets ideology in order to reduce complexity and attain the control objectives. Among possible shapes of invariant sets, *ellipsoids* should be distinguished because of their simple structure and direct connection to the quadratic Lyapunov functions approach. On top of that, a powerful apparatus of *linear matrix inequalities* and *semidefinite programming* can be used as a technical solution tool.

With a well-known benchmark control problem for a mechanical two-mass-spring system as a motivation, in this paper we provide a robust formulation for the problem of optimal rejection of persistent exogenous disturbances in systems subjected to matrix uncertainties and develop the solution technique based on the invariant ellipsoids concept.

STOCHASTIC APPROACH TO A CLASS OF CONVEX OPTIMIZATION PROBLEMS

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Prospective computers based on quantum logic can be efficiently modelled as dynamic systems subjected to uncertainty, and the architecture ideology of these quantum computers (QC) suggests use of stochastic tools to control and describe their functioning. On the other hand, such new devices are expected to be especially powerful when implementing various randomized algorithms of data processing and structuring, image recognition, clustering, etc. Also, peculiar to these new tasks are massive arrays of information corrupted by exogenous perturbations and subjected to uncertainty in the model description. In other words, in the new line of research related to quantum computations, the development of new *stochastic* optimization methods and *robust* approaches are of great current importance both in optimizing the functioning of a QC and solving typical applied problems for which use of QCs is supposed to be highly advantageous.

We consider a broad class of optimization problems of this type and propose a new approach to dealing with them. The problems under consideration are formulated in terms of linear matrix inequalities (LMI) and reduce to optimizing a linear function subjected to these constraints, referred to as semidefinite programming (SDP). Many problems in various areas such as optimization, control, estimation of reachability domains of dynamic systems, optimal control, to name just a few, are reducible to such setup.

Our approach is based on estimating the center of gravity x^c of convex bodies by means of *random walk* using the new notion of *boundary oracle*. This estimate of x^c is then used in a new modification of the *cutting hyperplane* method aimed at reducing the value of the objective function at a guaranteed rate. Of most practical importance is a generalization of the method to robust statements of the problem where the coefficient matrices contain additive norm-bounded uncertainties. In this case, the *robust boundary oracle* is devised and the method appropriately modifies. Preliminary numerical examples show the validity and good performance of the method.

It should be also noted that the random walk algorithm for estimating the center of gravity is expected to have an independent interest in the QC-related problems.

ARCHITECTURE FOR ARTIFICIAL INTELLIGENCE HYBRID COMPUTING

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System is called hybrid when it uses some alternative computations, based on another architecture than von Neumann. Hybrid systems are often used to solve difficult problems in many applications more effectively, than pure classical computations. Contemporary technologies provide a way to integrate into one system many different devices by wrapping them into web-services or using other network technologies. This allows to build distributed non-trivial systems of devices running certain algorithms together with objects observed.

The whole task for such a system can be formulated in terms of sub-tasks and algorithms solving them and streams of data going through the system. Several algorithms can be used to solve common task, communicating through the common informational space of facts. In these terms it is easier to describe systems of artificial intelligence, using different techniques of adaptation and optimization.

Practically, typified tasks, data streams and parameterized algorithms, described in certain way, can be run in container which instanciates entities. So, user of such a systems gets possibility to switch between algorithm solving one task, adjust algorithm parameters, construct complicated blackboard systems from simpler sub-systems.

Several projects evolving in the Department of Mathematics and Mechanics of SPbU, including software for biological identification, load balancing, and other projects stimulate the authors to create a comon framework for sufficient lexical description of hybrid systems and running them.

CHARACTERIZATION OF ELECTRONIC STRUCTURE OF DNA MOLECULES IMMOBILIZED ON GOLD SURFACE

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The main biological function of DNA is to retain genetic information in all living species. However, the recent painstaking research of physical and chemical properties of DNA suggests, that humanity could try to use the "building block of life" for completely different things that nature did not originally intend for such kind of molecules. For instance, DNA molecule could be used as a molecular wire for design of novel circuits of nanoelectronics, which probably could help to overcome the limit of modern silicon-based technology. For this purpose reliable information about electronic structure, as well as morphology of assembled of DNA molecules are highly important.

In the present work we present spectroscopic research with application of synchrotron radiation of careful studying of mentioned above properties of DNA molecules immobilized on gold surface. We demonstrate that X-ray photoemission can be successfully applied for characterization of chemical environments of DNA molecules. In the same time, the results of X-ray absorption experiment shows spacing orientation of assembled DNA and demonstrates the ability to control manipulation with this molecules at nanometer scale.

How dynamic instabilities can help to increase the performance of low-temperature fuel cells

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Fuel cells are promising energy conversion devices and much effort is focused on their improvement. One problem is that the fuel gas (H_2) is contaminated with CO when produced from methane, the main H_2 source. CO acts as a poison since it adsorbs on the Pt catalyst, blocks H_2 oxidation and reduces the efficiency. The coadsorption of CO also introduces feedback loops in the reaction kinetics which render homogeneous, stationary operation conditions unstable and promote dynamic instabilities.

We present theoretical and experimental results on instabilities and pattern formation in the H_2-CO|Pt-system and discuss strategies how the dynamic instabilities can be exploited to maximize the fuel cell performance in the presence of CO contaminations.

Underetching from simple stochastic etching kinetics

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The morphological richness of electrochemical semiconductor etching is not sufficiently counterparted yet by theoretical modeling. This paper investigates a minimal version of the Current-Burst model with Aging of Föll and Carstensen and demonstrates for a restricted geometry that the Aging concept is essential for underetching, or cavity generation. If the influence of Aging is neglected, the dynamics reduces to a Random Etching Model similar to the Random Deposition model. This computer *gedanken experiment* demonstrates that the stochastic dynamics with ageing-dependent kinetic reaction probabilities accounts for the different etching morphologies compared to those obtained in surface roughening and related systems.

Electrochemical pore formation in semiconductors: Oscillations, Structure Formation and Control

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The electrochemical semiconductor-liquid interface is an inherently instable system, capable of complex spatiotemporal dynamics resulting in a rich variety of pore geometries and diameters. The Current-Burst model with Aging is a stochastic model of electrochemical etching which can explain the morphological structures. I will discuss the main current and voltage oscillation scenarios and possibilities to control the structure formation.

Stochastic analysis of nonlinear electrochemical systems

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Electrochemical reactions may generate oscillations when driven far from thermodynamic equilibrium. In macroscopic systems, such oscillations are described by nonlinear differential equations which rule the time evolution of the chemical concentrations and the double layer potential according to the laws of electrochemical kinetics. Such a macroscopic description does not take into account the molecular fluctuations which become important in systems with a low number of molecules and/or small (nanometer-sized) electrodes. To quantify the effect of fluctuations we have extended Gillespie's algorithm to electrochemical systems (in which rate constants depend on time through the double layer potential). Simulations using this algorithm allow the evolution of the time autocorrelation function for each of the dynamical variables to be calculated and its behavior as a function of system size and of the distance to a Hopf bifurcation to be studied. We have performed a detailed stochastic analysis of electrochemical oscillations that have been recently observed for H_2O_2 reduction on a Pt electrode in an acidic solution when a small amount of halide ions is added to the solution.

Photoactive Device by Electrochemical Processing of Silicon

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We present first data on the photoactivity of a silicon-based device that was prepared by low-temperature, scalable (photo)electrochemical processing. The structure comprises electrochemically metallized silicon oxide nanopores which serve as emitters in the solar cell, an insulating oxide inbetween the pores and the crystalline Si substrate. Nanopores are created in a self-organized oscillatory process on n- and p-type Si. Results with Pt nano-islands show meanwhile above 7% efficiency in a photovoltaic photoelectrochemical solar cell, H2 evolution using illuminated p-Si and yet poor efficiency in solid state photovoltaic devices. Strategies for further improvements are outlined.

Electrochemical conditioning of fractal topographies at the silicon oxide/silicon interface

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On n-type silicon photoelectrodes, immersed in concentrated ammonium fluoride, fractal etch patterns are observable at anodic potentials near 6V. The formation of these patterns was investigated in dependence upon light intensity. For low photon flux, and correspondingly low density of electron-hole pairs, the etch structures exhibit random dendritic branching. For medium photon flux, regular patterns are achieved preserving, e.g., the four-fold symmetry of Si(100) surfaces. At increased light intensities, a transition to chaotic corrosion was found. Model considerations relate the rate of oxide formation to the strength and homogeneity of local strain forces exerted onto silicon bonds. Numerical simulations of strain-induced crack propagation, carried out in dependence upon light intensity and oxidation rate respectively, are reproducing the structures in good agreement with experimental data.

Sudden Onset of Corrosion on Stainless Steel as a Cooperative Critical Phenomenon

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Stainless steels are corrosion-resistant because they are protected by natural self-repairing oxide layers covering their surface. Nonetheless, they can undergo pitting corrosion, rapidly leading to their failure. Resistance to pitting corrosion is a key factor in the safety of nuclear reactors and in the selection of materials for nuclear waste storage. One third of all chemical plants failures is furthermore due to this kind of corrosion. The pitting corrosion is preceded by the appearance of metastable pits on the metal surface, typically initiated at surface defects and inclusions. A transition from metastable pitting to irreversible corrosion occurs abruptly, under only a small change in the corrodant concentrations or temperature. The onset of pitting corrosion has been traditionally attributed to pit stabilization at a single defect site. In contrast to this, we have proposed a theory where the transition is explained as a cooperative effect, resulting from interactions between many metastable pits which lead to an autocatalytic chain reaction of their reproduction. Thus, the corrosion onset corresponds to an effective explosion, with the number of metastable pits undergoing an exponential increase. Near the transition, spreading of corrosion activation waves, similar to infection fronts, should take place on the metal surface. Special experiments in the Fritz Haber Institute and in the Virginia University (USA) have fully confirmed these theoretical predictions. The theory can be applied to design better corrosion-resistant alloys and to develop new methods of corrosion prevention and control.

Noise invoked order in electrochemical systems

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We study, experimentally, the interaction of noise and nonlinear electrochemical dynamics. Both external and internal noise sources are considered. For appropriate noise and system parameters, a variety of interesting and counterintuitive phenomena are observed. It includes the inception of numerous well known resonance effects such as Coherence Resonance, Periodic Stochastic Resonance and Aperiodic Stochastic Resonance. Moreover we detect, a new resonance phenomena that involves the coexistence of Periodic Stochastic Resonance and Coherence Resonance. The above resonances indicate that noise if used judiciously can provoke regularity in electrochemical systems.

Recurrences of long-term correlated

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The analysis of first recurrence time between events is a powerful tool to quantify temporal properties of dynamical systems or sequences of data. If the temporal correlation decays fast enough (e.g., as in strong mixing systems or uncorrelated data) the distribution of recurrence times follows a Poisson law (exponential decay). In this talk we concentrate on the opposite case of systems showing long-term correlations (power-law with exponent $0 < \gamma_c < 1$). We analyze two examples that show that in this case the distribution of recurrence times is non-universal: it decays as a power-law in different intermittent dynamical systems and as a stretched exponential in Gaussian time series.

Recurrence plots and Shannon entropy for a dynamical analysis of asynchronisms in noninvasive mechanical ventilation

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Recurrence plots were introduced to quantify the recurrence properties of chaotic dynamics. Hereafter, the recurrence quantification analysis was introduced to transform graphical interpretations into statistical analysis. In this spirit, a new definition for the Shannon entropy was recently introduced in order to have a measure correlated with the largest Lyapunov exponent. It will be shown that this Shannon entropy, as any geomtric estimation, is dependent on the time series used, a dependence which can be removed when the recurrence plots are computed in a Poincar section. Recurrence plots and this Shannon entropy are thus used for the analysis of the dynamics underlying patient assisted with a mechanical non invasive ventilation. The quality of the assistance strongly depends on the quality of the interactions between the patient and his ventilator which are crucial for tolerance and acceptability. Recurrence plots provide a global view of these interactions and the Shannon entropy is shown to be a measure of the rate of asynchronisms as well as the breathing rhythm.

Using Recurrence Plots to detect Pomeau-Manneville Intermittencies and the related bifurcations

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One of the common routes to chaos is intermittency. The identification of the intermittency type is usually made on the basis of the probability distribution of the laminar phases and the average length of the laminar phases. Both properties have a statistical character, thus to obtain them a long time series has to be examined. We present a Recurrence Plots method, with which a short time series can be analyzed and the identification of the type of intermittency be made. The three types of intermittency introduced by Pomeau and Manneville were examined. The identification of the type of intermittency is equivalent to the identification of the bifurcation associated with it. Our method allows the analysis of short time series.

DETECTION OF CLIMATE TRANSITIONS IN ASIA DERIVED FROM SPELEOTHEMS

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Speleothems offer archives of climatic variability in the past. We analyse isotope records of stalagmites from several caves at different locations in Asia: Oman, NW and NE India and China. These records are proxies for the monsoon rainfall variability at these locations and cover a time range between today and about 12 kyr. At these locations, the influences of the summer and winter monsoon are rather different.

Recurrence is a fundamental property of dynamical systems. A statistical analysis of recurrence plots can uncover hidden transitions in data series, which are not obvious using linear statistical methods.

The analyses of the recurrence structure of the different isotope records of the stalagmites reveals simultaneous transitions at same times, although the data series itself do not correlate. These transitions are also not obvious considering the data by eye. This result suggests that at certain times the entire monsoon system underwent changes which are visible in the isotope records despite the different reaction of the local rainfall on the summer and winter monsoon. Therefore, these changes were probably of global nature.

Estimation of the direction of the coupling by conditional probabilities of recurrence

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We introduce a new method to detect and quantify the asymmetry of the coupling between two interacting systems based on their recurrence properties. This method can detect the direction of the coupling in weakly as well as strongly coupled systems. It even allows detecting the asymmetry of the coupling in the more challenging case of structurally different systems and it is very robust against noise. We also address the problem of detecting the asymmetry of the coupling in passive experiments, i.e., when the strength of the coupling cannot be systematically changed, which is of great relevance for the analysis of experimental time series.

On Recurrence Matrices - Solved and Open Problems

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Recurrence Matrices (RMs) of dynamical systems exhibit an intricate structure that helps to analyse and understand systems based on time series. RMs and the derived Recurrence Plots have been used successfully to study time series from many different fields, e.g. ecology, biology, geopphysics and astrophysics. A successful interpretation of Recurrence Plots is fostered by a deep understanding of the mathematics behind recurrences. Much effort has been made to understand first return times and their statistics. However, much less is known about RMs. In this presentation I will summarise some of the open and solved problems concerning RMs.

Distinction between quasiperiodic and sticky orbits from a recurrence perspective

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It is important to recognize that non-integrable Hamiltonian systems exhibit chaos with some particular features, e.g. the full space is a complicate mixture of periodic, quasiperiodic, and chaotic orbits. Viewed on shorter time scales, chaotic orbits can be divided into two relatively distinct types, namely, filling chaotic orbits which travel unimpededly throughout the chaotic regions and confined, or sticky, chaotic orbits which are trapped near islands of regularity and only escape on much longer time scales. The presence of stickiness yields some substantial difficulties in the use of conventional tools, such as the Lyapunov exponents and spectral analysis. We will present a careful numerical investigation of the recurrence properties of these orbits by using a two dimensional visualization technique, Recurrence Plots. We found that there exist significant distinctions between quasiperiodic, sticky and filling chaotic orbits. Furthermore, RP-based quantification analysis helps to identify the contributions of sticky orbits in the mixed phase space. The most important advantage of our procedure is that the computation time is significantly saved.

INTERDEPENDENCIES OF MENTAL DISORDERS AND AUTONOMOUS DYSFUNCTIONS

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The critical pathology of mental disorders concerns the emotional state of the person but there are also associated disturbances of autonomous functions. These so-called biological markers are disturbances of sleep duration and sleep patterns and disturbances of the hypothalamic-pituitary-adrenal (HPA) axis, the so-called stress axis, with elevated cortisol levels. It can be expected that disturbances of autonomous control systems as well as of mood are caused by neuronal malfunctioning which may concern practically all neuronal levels: systemic interactions, neuronal network connections, single neuron dynamics, synaptic transmitters and/or receptors, ion channels, second messengers and gene expression.

We will describe recent attempts to bring together clinical data and computer simulations of the progression of mental disorders [1] with experimental data and modelling studies of neural dynamics [2]. This new conceptional approach [3] shall also provide interlinks to the associated disturbances of hormone release and sleep-wake cycles on the basis of neuronal dynamics from which we expect a better understanding of the common origin of these multi-level and multiple-system diseases.

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IMPLICATIONS OF POSITIVE AND NEGATIVE FEEDBACK LOOPS FOR THE CONTROL OF THE CORTISOL "STRESS" AXIS: MODELLING AND PARAMETER IDENTIFICATION.

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We like to present a novel model for the hypothalamus-pituitary-adrenal (HPA) system [1]. This physiological system is closely connected to stress in humans. Our model is based on three simple rules which constitute a principle of homeostasis [2]. It include only substantial physiological elements. Its main components include, apart from the conventional negative feedback ingredient, a positive feedback loop. To validate the model, we present a parameter estimation procedure which enables one to adapt the model to clinical observations. We are able to show, that the novel model is capable of simulating clinical trials. Furthermore the stationary of the system is investigated. We show that, under mild conditions, the systems has always a well-defined set-point which reflects the clinical situation to be modeled. Finally, the computed parameter may be interpreted from a physiological point of view and thereby gaining connoting insights in diseases like depression, obesity, or diabetes.

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DYNAMICS OF SLEEP STAGES AND VEGETATIVE PARAMETERS IN NORMALS AND PATIENTS WITH SLEEP APNEA

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Sleep is not just the absence of wakefulness but a regulated process with functions important for the restorative nature of sleep. Based on electroencephalographic recordings and characteristic patterns and waveforms we can distinguish wakefulness and 4 sleep stages with light sleep, deep sleep and rapid-eye-movement (REM) sleep. In order to explore the functions of sleep and sleep stages we investigated the dynamics of sleep stages and vegetative parameters such as heart rate. Heart rate regulation is part of the autonomous nervous system which is strongly influenced by sleep stages [1].

Obstructive sleep apnea is a sleep disorder characterized by repetitive cessations of respiratory flow and cardiovascular changes. We applied detrended fluctuation analysis (DFA) of heart-beat intervals of normal volunteers and sleep apnea patients [2]. The fluctuation analysis was used to calculate inter-beat correlations using different time lags. We found marked differences between light sleep, slow-wave sleep and REM sleep. Whereas we found almost no long-range correlations for slow-wave sleep, there are clear long-range correlations during REM sleep, almost similar to wakefulness. Surprisingly, the result of long-range correlations remained to be the same in healthy volunteers and patients with obstructive sleep apnea.

In order to investigate further the regulation of sleep itself we analyzed the duration of sleep stages and wakefulness in 52 sleep recordings. We found that durations of brief wake episodes during the sleep period exhibit a scale-free power-law behavior with an exponent alpha ~ 2.2. In contrast, sleep episode durations follow exponential distributions with characteristic time scales tau. Our findings suggest a completely different regulation of sleep duration and wakefulness duration. Comparative sleep analysis in cats, rats and mice showed that alpha is similar across species and that tau varies with body mass and metabolic rate. We assume that the common dynamical features of brief awakenings and sleep durations across species provide insights into the dynamics of the neural circuits controlling sleep.

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A NEURON-BASED MODEL OF SLEEP-WAKE CYCLES

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Various brain areas and pathways are involved in the processes of sleep and arousal. Some of them are: thalamus, prefrontal cortex, sensory cortex, hypothalamus and HPA-axis. The existing sleep models mostly consider sleep-wake cycles as an interaction of two processes: homeostatic and circadian [1]. Others are based on the thalamo-cortical interactions [2]. In recent years it became clear that a peptide, orexin/hypocretin, discovered in 1998, plays a crucial role in sleep processes [3]. This peptide is released by the neurons in the lateral hypothalamus which have projections to almost all brain areas. Orexin-releasing neurons are active during wakefulness while they are silent during sleep. It is assumed that these transitions depend on the interconnections of orexin neurons with the prefrontal cortex

We present a neuron-based model of sleep-wake cycles on the basis of reciprocal interactions between orexin-releasing hypothalamic neurons and neurons in the prefrontal cortex and also considers the interactions with thalamocortical circuits, HPA-axis and circadian processes. We use a Hodgkin-Huxley type approach to model individual neurons and synaptic coupling between them.

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UNCERTAIN DESTINATION DYNAMICS: MULTISTABILITY, SYNCHRONIZATION, AND CONTROL

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Many systems in nature are characterized by the coexistence of different attractors for a given set of parameters. Examples for such behavior can be found in different fields of science ranging from mechanical to chemical systems and ecosystem dynamics. The behavior of multistable systems is rather complicated because of the complexly interwoven basins of attraction for the various coexisting attractors. Which of the attractors is realized depends crucially on the initial condition. Multistable systems are very sensitive to noise leading to a hopping process of the trajectory between different states. One of the system classes where this kind of behavior appears are coupled systems where multistability is often related with the loss of complete synchronization leading to the coexistence of synchronized and nonsynchronized attractors. A particularly interesting dynamics appears in two identical coupled systems when a special coupling is applied. This coupling is designed in such a way that the differential equation for the difference of 2 variables, say for example the first one of each system d(x1-y1)/dt=0 in the long-term limit. In that case this difference will be a constant c which is determined by the initial condition. In the long-term limit the system synchronizes but exhibits in principle infinitely many attractors corresponding to the different synchronization manifolds defined by the parameter c. This phenomenon has been called uncertain destination dynamics. We study two coupled Lorenz systems with a parameter set where each of the systems is monostable. This monostability persists when the coupling is turned on and for a particular value of the coupling strength the system becomes multistable and infinitely many attractors emerge all of a sudden. This particular kind of multistability is rather fragile. One can show that a very tiny mismatch in the parameters of the system leads immediately to a disappearance of multistability. If noise is applied to such coupled systems then the trajectory jumps between different attractors as expected. These jumps correspond to a hopping between different synchronization manifolds. We study strategies to control the system in such a way that different attractors can be realized on purpose.

Crisis Resonance in Multistable regime

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Autonomous nonlinear systems commonly exhibit simultaneous coexistence, in the phase space, of chaos and stable steady states, created by subcritical Hopf bifurcation. We show that such chaotic instability can be destroyed by small-amplitude modulation of any system parameters. The chaotic attractor undergoes boundary crisis due to modulation-induced collision with an unstable periodic orbit (UPO). Such boundray crisis exhibits a new resonance that we refer to as 'crisis resonance' in the control parameter space. Crisis resonance implies that crisis occurs at minimal modulation depth due to maximal evolutions of the UPOs and the chaotic attractor. Crisis resonance occurs close to some critical frequency (we refer to as 'crisis resonance frequency') or its multiples. The UPO frequency is a good estimate of the crisis resonance frequency. The small-amplitude parameter modulation destroyes chaos in the presence of noise as well. These features are observed theoretically with the paradigm of autonomous systems, namely Lorenz equations of thermal hydraulics and are in excellent agreement with the experimental results, obtained with an analog circuit of Lorenz equations. These results are to appear in B. K. Goswami, Phys. Rev. 2007.

DELAYED FEEDBACK CONTROL OF CHAOS: BIFURCATIONS IN A LARGE RANGE OF FEEDBACK PARAMETERS

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We consider a deterministically chaotic system subjected to delayed feedback $\mathcal{F}(t)$ in the Pyragas form $\mathcal{F}(t) = K\big(g(\mathbf{x}(t)) - g(\mathbf{x}(t-\tau))\big)$, where g is some scalar function of the current system state $\mathbf{x}(t)$, τ is time delay, $\mathbf{x}(t-\tau)$ is the system state τ time units ago, K is the feedback strength. It is well-known that a skeleton of a chaotic attractor is formed by a countable set of unstable periodic orbits (UPOs). If τ is precisely equal to the period T of some UPO, the orbit may become stable under the appropriate choice of feedback strength K. Note that only the stability properties of the orbit are changed, while the orbit itself and its period remain unaltered. In most real-life applications the periods of UPOs are unknown. However, it might be possible to estimate them approximately in an experiment. Natural questions arise: How a mistake with which the required value of τ is estimated influences our ability to stabilize the UPO? What would be the general effect of the delayed feedback in Pyragas form on the chaotic system at arbitrary values of parameters K and τ?

As an example of chaotic system Rössler system is considered. We reveal the general bifurcation diagram in the parameter plane of time delay τ and feedback strength K which allows one to explain the phenomena that have been discovered in some previous works. Already in 1992 it has been reported by Pyragas that delayed feedback can suppress oscillations and also induce multistability for sufficiently large K. We show that the bifurcation diagram has essentially a multi-leaf structure that constitutes multistability: the larger the τ, the larger the number of attractors that can coexist in the phase space. Feedback induces a large variety of regimes non-existent in the original system. Finally, we extend the analysis of Just et al from 1998 to estimate how the parameters of delayed feedback influence the periods of periodic orbits in the system.

MULTISTABILITY INDUCED BY DELAY AND CONTROLLED BY DELAY

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Feedback loops are relevant for generating persistent memory in neuronal systems, for cellular differentiation in genetic circuits, etc. Time-delays, arising from the fact that signal propagation realistically occurs at a finite velocity, are often a source of multi-stability. Here I discuss the interplay between the intrinsic nonlinearity of an oscillatory neuron and a weak time-delayed feedback loop representing a recurrent synaptic connection. The neuron dynamics is modeled based on a Hodgkin-Huxley type model of thermally sensitive neurons[ab] that presents a variety of firing patterns, including subthreshold oscillations, tonic spikes, spikes with skippings and spike trains. In the regime of subthreshold oscillations, due to the excitable character of the dynamics, it can be expected that even weak feedback can be a strong perturbation of the subthreshold oscillations, and can induce drastic changes. I will show how the feedback amplifies the oscillation amplitude, inducing threshold-crossings and giving rise to a firing activity that is self-regularized by the delay time of the feedback loop. Multistability of firing patters can occur, induced by the feedback loop and controlled by the delay time of the loop. Negative feedback enhances the oscillation amplitude, but if the feedback is weak, it does not induce threshold-crossings and firing activity for all delays: there are feedback-induced spikes only in windows of the delay centered at $\tau \sim (n+1/2)T_0$ with n integer and T_0 the intrinsic oscillation period. Moreover, in these windows the firing pattern is regularized by the delay: for short τ there are tonic spikes; for slightly longer τ there are spikes with skippings. These results will be interpreted in terms of a simple model of an oscillator with a weak delayed feedback loop.

I will also analyze a small ensemble of neurons mutually coupled through their delayed mean field, and show that the ensemble displays different behaviors depending on the delay of their coupling. Either all neurons synchronize their spike or subthreshold activity, or some neurons display subthreshold oscillations while the others fire spikes (i.e., the ensemble divides into clusters). Again, the activity is regularized by the delay of the coupling and the neuronal oscillations can be inphase or out of phase depending τ. There is also multistability of solutions with the coexistence of inphase and out of phase patterns.

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CONTROL OF MULTISTABILITY IN LASERS

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The coexistence of several stable states for a given set of parameters has been observed in many natural and experimental systems as well as in complex theoretical models including lasers. A laser, as a complex nonlinear system, is a very useful instrument for studying many dynamical phenomena. The advantages of the laser proceed from its relative stability under a wide range of operating conditions and its fast response in comparison with, for example, mechanical or fluid systems. Complexity and strong nonlinearity of a laser may result in coexistence of multiple attractors. Such multistability is not convenient for some applications, for example, if one desires to create a stable source of optical radiation with determinate output characteristics. The existence of multiple attractors restricts the development of practical devices for signal or data processing. Several feedback control methods have been developed to stabilize unstable periodic orbits embedded in a chaotic attractor and suppress undesired fluctuations. However, not all instabilities can be suppressed by the feedback control. Small fluctuations in the pump rate can provoke sudden switches between coexisting attractors that impairs the stability of the laser output. The control of multistability in the form of small harmonic modulation of an available laser parameter may help in resolving this problem. The modulation with properly adjusted frequency and amplitude induces boundary crisis to undesirable attractors resulting in their selective annihilation. I will demonstrate with experiments and numerical simulations how the method works in different types of lasers, CO_2, semiconductor, and fiber, as well as the robustness of the control against small noise.

Data-based estimation of generators for Markov processes, using convex optimization

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Construction of stochastic models that describe the dynamics of observables of interest is a useful instrument in various fields of application, such as physics, climate science, and finance. We will discuss a new approach to extract models that describe the effective stochastic dynamics of variables for which data in the form of timeseries are available. The variables are modeled as Markov processes (diffusion processes, or Markov jump processes / continuous-time Markov chains). The problem is one of system identification, in which the generator of the process needs to be estimated from data. This is done by minimizing an object function that measures the difference between the eigenspectrum of the generator and an eigenspectrum obtained from the data. Numerically, it amounts to solving a convex quadratic program with a unique minimum, for which well-established solution methods are available. Several numerical examples will be shown.

Automated generation of stochastic weather prediction models from time series exhibiting metastability

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We present a method for simultaneous dimension reduction, model fitting and metastability analysis of high dimensional time series. The approach is based on the combination of hidden Markov models (HMMs) with localized principal component analysis (PCA) and fitting of multidimensional stochastic differential equations (SDE). We construct a functional combining the part which minimizes the distance from the observed time series to a sequence of low-dimensional linear manifolds (dimension reduction) and a part connected to the probability of the observed projected SDE dynamics in respective manifolds to be coming from the locally linear SDEs (model reduction). We derive the explicit estimators for PCA-SDE model parameters in the case of the fixed sequence of HMM states and employ the Expectation Maximization algorithm for numerical optimization of HMM-PCA-SDE parameters. We demonstrate the performance of the method by application of the algorithm for analysis of historical temperature data in Europe during 1976-2002. We compare the performance of the method with the existing multidimensional SARMA (seasonal autoregressive moving average model) and interpret the results wrt. errors of one–day temperature predictions generated by the models.

A Hidden Markov Model perspective on regimes and metastability in atmospheric flows

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In this study we analyze data from three atmospheric models in order to investigate the existence of atmospheric flow regimes despite nearly Gaussian statistics of the planetary waves in these models. We use a hierarchy of models which describe the atmospheric circulation with increasing complexity. To systematically identify atmospheric regimes we search for the presence of metastable states in the data, and we do so by fitting so-called Hidden Markov Models (HMMs) to the timeseries.

A Hidden Markov Model is designed to describe the situation in which part of the information of the system is unknown or hidden and another part is observed. Within the context of this study, some representative variable of planetary scale flow (for example, mean zonal flow, or leading Principal Component) is known (”observed”), but its dynamics may depend crucially on the overall flow configuration, which is unknown. The behavior of this latter, ”hidden” variable is described by a Markov chain. If the Markov chain possesses metastable (or quasi-persistent) states, we identify these as regimes. In this perspective, regimes can be present even though the observed data has a nearly Gaussian probability distribution.

We fit the parameters of the HMMs to the timeseries using a maximum-likelihood approach; well-established and robust numerical methods are available to do this. Possible metastability of the Markov chain is assessed by inspecting the eigenspectrum of the associated transition probability matrix.

We first apply the HMM procedure to data from a simplified model of barotropic flow over topography with a large scale mean flow. This model exhibits regime behavior of its large-scale mean flow for sufficiently high topography. In the case of high topography we find three regimes; two of those correspond to zonal flow and the third to blocking.

Next a three-layer quasi-geostrophic model is used as a prototype atmospheric General Circulation Model (GCM). Its first Empirical Orthogonal Function (EOF) is similar to the Arctic Oscillation (AO) and exhibits metastability. For this model we find two regime states: one corresponding to the positive phase of the AO with large amplitude and decreased variability of the streamfunction field, and another regime corresponding to the negative AO phase with small amplitude and increased variability. Finally, we investigate a comprehensive GCM. The leading 4 EOFs of this model show no signs of metastability.

Parameter distribution of maximum-likelihood estimators for time series with hidden states

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Recently I. Horenko *et al.* introduced several novel data-driven approaches to analyze high-dimensional time series with hidden regime switching, e.g., time series obtained from metastable molecular dynamics. Based on maximum-likelihood estimators, one can identify regime-switches in the time series, but also parametrize different models for different regimes of the time series. For example, one can assume a Markov jump process corresponding to the regime switching, while the dynamics within each of regime is governed by a Langevin equation. In this talk we give a short overview of these approaches, paying special attention to the reliability of the obtained parameter estimators and their variance.

Generator estimation of Markov jump processes based on incomplete observations non-equidistant in time

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Markov jump processes can be used to model the effective dynamics of observables in applications ranging from molecular dynamics to finance. In this talk we present a method which allows the inverse modeling of Markov jump processes on the basis of incomplete observations in time. For a given time series we estimate an infinitesimal generator which optimally fits the data by maximizing its likelihood. Furthermore, the method allows to handle non-equidistant observations in time as is illustrated on a toy problem as well as on data arising from simulations of chemical kinetics of a gene toggle switch.

Stochastic modelling of fast Hamiltonian chaos

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The study of the long time behavior of systems with time scale separation is considerably facilitated if the fast degrees of freedom can be eliminated without affecting the slow dynamics. By applying projection operator techniques we show that in chaotic Hamiltonian systems the fast subsystem can be replaced by a suitable stochastic process so that the slow motion is effectively described by a Fokker-Planck equation where the interplay of viscous damping and diffusion conserves the total energy and ensures the correct long time behavior. The accuracy and efficiency of this approach is verified by a numerical investigation of suitable model systems.

STRUCTURAL ROBUSTNESS OF METABOLIC NETWORKS ON THE BASIS OF ELEMENTARY FLUX MODES

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Within a certain range, living organisms are remarkably robust against external perturbations (e.g. changes in nutrient supply or temperature) or internal perturbations (e.g. spontaneous mutations). On the cellular level, dynamic robustness in view of the regulation of metabolic fluxes and concentrations can be distinguished from structural robustness implying redundant pathways to compensate, for instance, enzyme deficiencies in metabolism. The simple approach just to take the number of elementary flux modes (EFMs) of a given metabolic network as a measure of its structural robustness (Stelling et al., 2002) does not completely reflect the change in its topology after the knockout of enzymes. Therefore we developed a more elaborate way of quantifying the structural robustness of metabolic networks. The robustness measures are based on the ratio of the number of EFMs in the unperturbed situation vs. the number of remaining EFMs after knockout of one enzyme (Wilhelm et al., 2004) or several enzymes, averaged over all possible knockouts. We applied the robustness measures to biochemical networks describing the amino acid synthesis in Escherichia coli and human liver cells, and the central metabolism in human red blood cells. With the help of the calculated robustnesses we compare the different networks and discuss the results from an evolutionary perspective. We find that E. coli has the most robust metabolism among the cell types we considered. As for the anabolism of non-essential amino acids, E. coli and the hepatocyte show nearly the same robustness.

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INTRODUCTION TO ROBUSTNESS OF BIOLOGICAL SYSTEMS

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We instinctively refer to objects as robust that have proven long-term success and resisted mechanical stress or mishandling, for example a high quality backpack or a well-designed software. This is in particular true for biological systems the existence of which over billions of years has proven long-term success. The perturbations that biological systems have to face may be external ones such as a lack of the favorite substrate or internal ones such as mutations. Their variety makes it difficult to formulate a universal and quantitative framework for biological robustness. However, there are some qualitative properties commonly present in complex robust systems, such as a modular structure or a hierachical organization. Furthermore, the robust behavior with respect to distinct perturbations may be studied. Compared with any engineered or produced object, for biological systems robustness is not the only design principle. Evolvability and adaptability are other properties that are also essential requirements. A nice example for this biological trade-off are mutations that on one hand may result in dramatic internal failure while the same mechanisms may pave the way for adaptation, for example increasing thermostability of a specific enzyme. Obviously, biological systems find the right balance between these conflicting objectives. Analyzing biological strategies therefore may guide the design processes of non-biological systems especially in engineering applications.

This introductory talk will elucidate different aspects of robustness with respect to biological systems: What is meant by robustness in various contexts compared to biological systems? What are the organizational principles that characterize highly robust systems and what are the costs of their realization? How is the robustness of a system related to evolvability, adaptability and the systems degree of fitness?

THE EVOLUTIONARY DESIGN OF SIGNALLING NETWORKS IN THE LIGHT OF SIGNAL-OFF ROBUSTNESS

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The presented study is an analysis of the structural design of intracellular signal transduction networks. Given a simple differential equations model of the dynamics of signalling species existing in active or inactive form, it is shown how the circuitry determines the region in the parameter space for which dynamic stability of the so-called signal-off state can be assumed. The extent of this region is defined as a measure for signal-off robustness of the signalling network. The analysis is based on the hypothesis that signalling networks have evolved towards a design which confers signal-off robustness. A stable signal-off state is important because spurious activations between signalling compounds should be dampened rather than amplified to prevent self-sustaining states. This type of robustness turns out to be closely related to positive feedback cycles, or, more generally, to the set of strongly connected components in the network. The analytical results confirm but also rectify some numerical results and conclusions about the relation between cycles and signal-off robustness made previously (Binder et al.). Furthermore, the effect of structural perturbations on signal-off robustness is analysed, i.e. the structural signal-off robustness of signalling networks. As such perturbations may occur in ontogenesis and during evolution, alike, it is assumed that there is selection pressure towards a design which as far as possible maintains a robust off-state. A systematic numerical analysis on small acyclic digraphs suggests, that networks have a high structural robustness if (1) the connectivity is low, (2) the number of sinks/sources is high, and (3) the path density is low. Investigation of a kinase network retrieved from the Transpath database reveals that it displays maximal signal-off robustness as well as a quite high structural signal-off robustness. Thus, the hypothesis about signal-off robustness as a selective force during evolution may provide a rationale for the design of signalling networks or can at least highlight some design constraints.

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DESIGN PRINCIPLES OF NOISE SUPPRESSION IN BIOLOGICAL NETWORKS

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Information processing networks in cellular systems suffer from strong variations in the amount of their components. As shown in recent experiments, these variations originate to large extent from the stochastic nature of gene expression. Although the underlying mechanisms of gene expression is quite different in eukaryotes and prokaryotes the resulting variations of protein levels show surprisingly the same cause: random bursts of RNA syntheses. Using a combined theoretical and experimental approach we were able to identify the timescales of RNA bursts in E. Coli and their consequences on the variation of protein levels in a clonal population. As a result, highly sensitive signalling networks should not have been evolved on cellular level because of large noise to signal ratio. But as shown for the chemotaxis network in E. coli and the circadian clock in cyanobacteria there exist topological design principles within signalling networks that allow for strong noise suppression on the post transciptional level.

ANALYSING THE ROBUSTNESS OF CELLULAR RHYTHMS

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Autonomous oscillations at the cellular level are important for various timing and signalling functions. The rhythms depend on environmental influences in a specific manner. Here we focus on the question whether sensitivity and robustness are determined by the underlying oscillatory mechanism. In a first step we study the sensitivity of the oscillatory period in models describing oscillations in calcium signalling, glycolysis and the circadian system. By comparing models for the same and different rhythms it is shown that the sensitivity strongly depends on the oscillatory mechanism. In particular, we find models for circadian rhythms to be highly robust, whereas the models describing calcium oscillations show a high sensitivity. The results are discussed with respect to the temperature dependency of these rhythms. In a second step the question of what impact design principles have on the robustness of an oscillator is addressed more explicitly by a direct comparison of systems with positive and negative feedback regulation for various chain length.

MULTISTAGE STOCHASTIC INCLUSIONS OF SPECIAL TYPE AND THEIR MULTIESTIMATES

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The notion of informational set of a controlled system is used for a long time in the theory of guaranteed estimation. For systems with compound uncertainty including as determinate as random disturbances, there are papers where estimates in the form of sets are also considered (I.Ya. Katz and A.B. Kurzhanski). However, these estimates do not reduce to the informational sets when random disturbances are absent. In this connection, in 2000 the author had introduced the notion of random informational set for multistage systems with mixed uncertainty. The introduced sets reduce to the informational ones in determinate case, but they demand further handling because of random unobserved parameters. There is further generalization of the random informational sets called multiestimates for the multistage stochastic inclusions. Under some natural assumptions on the inclusions, the multiestimate $X_t(y,\omega)$ at the instant t represents a compact set depending in anticipating way on the element of probability space and on the measurements $\{y\}^t = \{y_1,...,y_t\}$. In a certain way, we may consider the multiestimate as the random state of the statistically uncertain system. It is convenient to deal with the pair $\{X_t, y_t\}$. The recurrent stochastic inclusions are derived for the elements of this pair. Since these are not equations, but inclusions, we cannot determine exactly the probability distributions of mentioned elements. However, one can determine a family of their admissible probability distributions on the base on P. Huber's technique. Having available the admissible family, it is sufficiently simple to determine the conditional distributions when element $\{y\}^t$ is fixed. So one can obtain the guaranteed estimations from below for the probability of events such as $\{X_t(y,\omega) \subset A\}$ or $\{X_t(y,\omega) \cap A \neq \emptyset\}$, where A is a Borel set. The mentioned approach leads us to very complicated examination of distributions in a metric space of compact sets. Therefore, in this work, relatively simple and special cases of inclusions are considered. In these cases, the situation reduces to the evolution of finite dimensional vectors that form a Markov sequence. Generally, we consider the interval stochastic inclusions and linear systems with the parametric and quadratic uncertainty. For these objects, we define the multiestimates and investigate the recurrent relations for the admissible family of their conditional and unconditional probability distributions. The work is partially supported by the RFBR, grants No. 04-01-00148, 07-01-00341.

SINGULAR LINEAR-QUADRATIC PROBLEM FOR DISTRIBUTED DELAY SYSTEMS[1]

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Singular linear-quadratic optimization problems are of great practical importance. Models of such structure describe physical problems in space flight dynamics, robotics, electrophysics etc. That concerns systems with aftereffect as well.

A singular linear-quadratic optimization problem for a linear system of differential equations with aftereffect is studied. It is shown in [2] that in case without aftereffect such problems have no solutions in a class of ordinary controls and it is necessary to extend the variety of admissible controls allowing impulsive controls for providing the existence of solution. So the characteristic of the studied problem is that the optimal control contains impulsive components concentrated on the boundaries of the control time interval. In contrast to [1], more general type of the system that includes summands with distributed delay and more complicated functional are considered.

The problem is solved as follows. Transforming the problem by a change of variables we obtain an auxiliary regular problem. Having solved the problem obtained by using dynamic programming method and differentiated its optimal control we can find the optimal control for the origin problem.

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STATE ESTIMATION PROBLEMS FOR DIFFERENTIAL INCLUSIONS

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The topics of this paper come from the control theory for systems with unknown but bounded uncertainties related to the case of set-membership description of uncertainty. The motivations for these studies come from applied areas ranged from engineering problems in physics to economics as well as to ecological and biomedical modeling.

The paper presents recent results in the theory of tubes of solutions (trajectory tubes) to differential control systems modeled by differential inclusions with uncertain parameters or functions. Of particular interest is the description of the behavior of these tubes when the system is subjected to state constraints. Such constraints may be induced by given state constraints defined for a plant model or by current state measurements with unknown but bounded noises. The objects under investigation are then known as the viability tubes and their time cross-sections turn to be the attainability domains (or reachable sets) for the original differential system with state constraints. Starting at a specified initial set represented the uncertainty in initial state, the overall system generates a set-valued map (the trajectory tube) that satisfies the semigroup property and therefore, defines a generalized dynamic system. One of the basic problems is the ability to describe either the infinitesimal generator of the respective semigroup or some equivalent notion. This issue is treated here in dual form, namely, either with the aid of evolution equations of the funnel type with set--valued trajectories, or through a generalized Hamilton - Jacobi - Bellman (H-J-B) partial differential equation when cross-sections of trajectory tubes are taken as level sets of the generalized solutions to the H-J-B equation. This paper is devoted therefore to the problems of evolution modeling for nonlinear uncertain dynamic systems with system states being compact subsets. Applying results related to discrete-time versions of the funnel equations of first and second orders we find approximations for such set-valued states of the uncertain dynamical control system.

The applications discussed in this paper are in guaranteed state estimation for systems with unknown but bounded errors and in nonlinear control synthesis. The numerical simulation schemes developed for such problems are also presented.

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ON EXPERIMENTAL DESIGN FOR NONLINEAR GUARANTEED IDENTIFICATION PROBLEMS

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Generally, the differential equations used for modeling of physical and mechanical systems contain unknown parameters, which may be estimated on the basis of information provided by indirect experimental observations. The goal of experimental design is to get maximal information about system parameters from available observations by adjusting the observation conditions. The conventional approach to the experiments design is based on stochastic models for uncertain parameters and measurement errors. An alternative guaranteed approach states from deterministic model of uncertainty with set-membership description of the uncertain items. These items are considered to be unknown but bounded with preassigned bounds. Such model of uncertainty arises in many applied problems of information processing in physics. Within the framework of guaranteed approach the set of parameters, consistent with the system equations, measurements, and a priori constraints called information (feasible) set is considered as the solution of estimation problem. The experimental design in turn comes to optimization of certain functional defined on the class of information sets (e.g. volume, diameter).

In this report we consider the problem of optimal input choice for guaranteed estimation of the parameters of nonlinear dynamic system on the basis of indirect observation. The feasible sets in the problem may be described as the level sets for so-called information function (information state). An information function is defined as a value function for a certain auxiliary optimal control problem. The integral of information function over the set of a priori constraints on parameters is considered as a criterion of optimality. For the case of integral constraints on measurement noise it is shown that considered problem may be reduced to an optimal control problem for the trajectory tubes of considered system. We describe the algorithm of solution based on necessary optimality conditions and provide some examples of numerical simulation. Considered algorithm allows to avoid the immediate construction of information sets under designing the optimal input that results in computational expenditure reduction. The proposed scheme may be extended to the linear systems with disturbances in system equations.

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ON GAME-THEORETICAL MODELING WITH APPLICATIONS TO THE PROBLEMS OF LARGE-SCALE COMPETITIVE PROJECTS

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The paper is devoted to game-theoretical control problems motivated by economic decision making situations arising in realization of large-scale projects, such as designing and putting into operations the new gas or oil pipelines. The approaches and models discussed in the paper seem to be also useful in the fields of physics, biology and other natural sciences. The problem description is the following. Let us assume that there is a market with increasing demand for some goods (say, natural gas or oil). One can supply goods produced (delivered) as a result of realization of a project (for example, to supply gas to this market by constructing the corresponding gas pipelines). Evidently, appearance of the new participants in the market, while saturating it, leads to a decrease in sales for the existing participants. It means that the earlier a participant enters the market the greater profit he or she gets. At the same time, the present value of the cost of project realization is decreasing, and also the demand and prices may be increasing, therefore the later entering the market might be preferable. The above arguments lead to a game-theoretical problem, in which the moments of time when each participant enters the market, play crucial role.

The detailed investigation of the problem for the case of gas pipeline construction included mathematical and computer modeling of Turkey's gas market development. In the paper [1] a rigorous mathematical model was proposed, where the above problem was formalized as a non-cooperative game in which the moments of entering the market (commercialization times) were taken as control variables. Later, a computer realization of this algorithm, which allows to approximate necessary data and forecasts, was developed [2]. In the present paper we propose a mathematical model that takes into account the features of not purely market economy. That leads to the fact that some assumptions of the model are significantly different and sometimes are opposed to those accepted in the in [1]. Criteria functions, which are to be minimized, are defined as combinations of return of investment time and time of entering the market. Analytical and numerical results related to the described game are presented in the paper.

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NECESSARY CONDITIONS OF OPTIMALITY FOR MEASURE DRIVEN DIFFERENTIAL INCLUSIONS[1]

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In this article, we present and discuss first-order necessary conditions of optimality for a very general class of nonlinear impulsive dynamic control systems whose dynamics are given in the form of measure driven differential inclusions and whose trajectories are subject to both state constraints and endpoint constraints.

This control paradigm can be regarded as an idealization of systems with fast and slow dynamics. This is pertinent to important classes of systems with multi-phase missions or reconfigurable dynamics for which the switching between different "productive" activities represented by slow dynamics are modeled by fast dynamics. It is not difficult to see that this paradigm encompasses impulsive optimal control problems where dynamics are specified by controlled differential equations. Moreover, the dependence of the singular dynamics on the "conventional" control constitutes an interesting challenge with practical implications. Other authors have considered impulsive problems for which the singular dynamics depend on the conventional control but their optimality conditions are of different character.

The stated necessary conditions optimality are in the form of both a Hamiltonian inclusion and a maximum condition providing a complete characterization of both absolutely continuous and singular - notably that “during” the jumps - optimal evolutions of the state trajectory. For this, the solution concept plays an important role. Thus, the completion of the graph of a trajectory of bounded variation requires a time reparameterization so that the flow of the new time variable reflects, at each moment, the sum of the contributions of the original time and of the control measure variation. In particular, this yields the emergence of nonzero measure intervals whenever there is a discontinuity in the state trajectory, thus enabling the definition of an “equivalent” trajectory solution to an auxiliary conventional differential inclusion.

The presented necessary conditions of optimality are derived in the context of nonsmooth analysis and remain informative for abnormal processes by considering additional compatibility, regularity and controllability assumptions.

1

OPTIMAL TERMINAL CONTROL PROBLEM FOR DISCRETE-TIME DYNAMICAL SYSTEM

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In this report we consider the dynamical system that consists of one controlled object. The motion of this object is described by linear discrete-time recurrent vector equation. It is assumed that the set constraining control action is known and is convex, closed and bounded polyhedron (with a finite number of vertices) in the corresponding Euclidean vector space. Under these assumptions, we formulate and solve the optimal terminal control problem with a convex functional for such linear discrete-time dynamical system (see [1], [2]). In order to solve of optimal terminal control problem we suggest a recurrent numerical algorithm which reduce the initial multistep problem to solving a sequence of direct and inverse one-step linear and convex programming problems. The results obtained in this report are based on [2]-[4], [6] and can be used for computer simulation of an actual physical and technical processes and for designing of optimal digital controlling and navigation systems for technological and transportation systems. Mathematical models of such systems had considered, for example, in [1]-[5].

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ELLIPSOIDAL TECHNIQUES FOR CLOSED-LOOP CONTROL OF OSCILLATING SYSTEM THAT APPROXIMATES THE TELEGRAPH EQUATION

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This paper describes constructive ellipsoidal algorithms for problems of closed-loop control in oscillating systems which approximate the telegraph equation. The controlled linear ODE system with ellipsoidal constraints is considered. This system describes small oscillations of a chain of springs and weights in a viscous medium and thus approximates the telegraph equation.

The problem is to find the solvability set and the feedback control which ensures that all the trajectories of the system starting from initial set would attain the equilibrium at finite time. The optimal closed loop control can be found from the Dynamic Programming principles using the value function. The value function can be expressed via the solvability set.

The most difficult computational part of such solution is the optimization problem in calculations of the value function. We can simplify the calculations if the solvability set is replaced by an internal ellipsoidal approximation. Thus the closed loop control may be calculated using the relations with ellipsoidal approximations.

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ELLIPSOIDAL TECHNIQUES IN STATE ESTIMATION PROBLEM FOR LINEAR IMPULSIVE CONTROL SYSTEMS

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The present paper is devoted to the problem of impulsive control of trajectory tubes of a dynamical system described by linear differential equations with incomplete information on initial data. This system contains impulsive control terms (or measures) limited not only by usual requirement of finiteness of variation but by special constraint of ellipsoidal type. Particularly, the vectors of jumps of generalized controls under this restriction must lie in the given ellipsoid of an appropriate finite-dimension space. Such problems arise when the possibilities of impulsive control are non-even in different directions. For example, one can consider the movement of flying devices near the earth surface or in narrow gorges.

The aim of the paper is to find the external and internal set-valued estimates of the reachable sets of impulsive control systems with special ellipsoidal constrains on the admissible values of control functions and on the initial state vectors. In this paper we use the well known results of professors A.B. Kurzhanski and F.L. Chernousko about of ellipsoidal estimating the states of dynamical control systems with classical (measurable) controls and develop these results constructing the estimation algorithms that allow to find the upper and inner ellipsoidal bounds (with respect to set inclusion operation) for reachable sets of impulsive control problem with ellipsoidal constraints on impulsive control.

The results of computer simulations in examples of construction of such ellipsoidal external and internal estimates of reachable sets of linear impulsive control systems are given also.

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OPTIMAL IMPULSIVE CONTROL OF STRUCTURE-VARIANT RIGIDBODY MECHANICAL SYSTEMS

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The optimal control of dynamical systems with discontinuous states is a largely non-investigated area. Optimal control of impulsive systems inevitably entails optimal control with discontinuous states. Possible areas of application involve legged locomotion, robotic applications that involve contacts such as grasping. The underlying Lagrangian structure, however, will enable a generalization to more general physical systems.

Contrary to the approach taken in literature so far, instead of taking an interval opening approach, the instant of discontinuity is reduced to an instant with Lebesgue measure zero. The approach requires the different system modes and their order to be specified in advance. The necessary conditions obtained, enable the determination the optimal transition time and location.

Impulsive optimal control requires to search extremizing arcs in the space of bounded variation functions. The considered functional will be a generalized Bolza functional that is evaluated on multiple intervals. By the application of subdifferential calculus techniques to lower semicontinuous functionals, Pontryagin's Maximum Principle (PMP) like conditions are obtained.

The introduced framework will have the ability to model and control of hybrid mechanical systems with discontinuous transitions among different system modes. Some numerical results are presented.

PROBLEMS OF DYNAMIC OPTIMIZATION OF FLOW

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The paper deals with mathematical models of motion of solids and mechanical systems of sequentially joint bodies in a viscous medium. Control laws are found to move the considered systems from the initial state to a given one for optimum energy consumption.

Intelligent autonomous vehicles and robots intended for work in atypical environment has proved to form a great body of knowledge interesting from the viewpoint of challenging applications and being the source of new theoretical research. Particular emphasis is placed on mobile manipulation robots (just this term is preferred in E.P.Popov, A.F.Vereshchagin, S.L.Zenkevich, F.L.Chernous'ko, N.N.Bolotnik, and V.G.Gradetskii) intended for work in a viscous medium. It is caused, for example, by a need in robots to inspect and assimilate water tanks, and to do various technological works in those places.

Design of a special mobile manipulation robot (further we write, in shorthand, MMR) is a complicated problem. Working out control systems matching up the MMR destination is the principal step in solving this problem. The situation when one has to deal with rather limited energy supply of the MMR is natural and, sometimes, inevitable. Then, the following control problem is topical: to find the laws of the control forces and momentums behavior so as to move the MMR from the initial position to a given one for minimum energy consumption. Such a problem is close to the ones of dynamic optimization considered by F.L. Chernous'ko and other researches.

So, the speech goes about a new set of problems being topical from the viewpoint of the theory of singular solutions of dynamic optimization problems.

The totality of the problems solved in the present paper can be used in both the applied theory of singular dynamic optimization problems and design of perspective samples of new machines.

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THE LEAST ABSOLUTE VALUE METHOD UNDER THE LINEAR CONSTRAINTS FOR ESTIMATED PARAMETERS

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Consider a linear measurement model

$$y_i = H_i'\theta + \xi_i, \qquad i = 1, ..., n.$$

Here y_i and ξ_i are scalar measurements and measurement errors; H_i are known m-vectors, θ is an unknown estimated m-vector satisfying the constraints $A\theta \le a$, where a and A are given s-vector and $(s \times m)$-matrix, respectively. In the least absolute value method the full estimate set of the vector θ is defined as

$$\Theta = \operatorname{Arg}\min_{\theta} \left\{ \sum_{i=1}^{n} \left| y_i - H_i'\theta \right| \, : \, A\theta \le a \right\}.$$

In general, the set Θ has more then one element. The purpose of the paper is to investigate fundamental properties of the set Θ and to approximate it by a reasonable method. First of all, we find a certain solution $\hat{\theta}_0$ of the problem. It may be obtained from an auxiliary linear programming problem. Another way consists in the application of a certain iterative algorithm. Secondly, we find a set $\mathcal{L}$ such that $\mathcal{L} \subseteq \Theta$. The set $\mathcal{L}$ is a convex hull of certain extreme points which belong to the boundary of Θ. The calculation of each extreme point reduces to the solution of a large-scale linear programming problem. We show that this problem may be efficiently solved by *the method of column generation*. Assuming that the constraints $A\theta \le a$ have the form $|\theta_i| \le a_i$, $i = 1, ..., m$, we present the calculation for a polynomial measurement model.

ON AN APPLICATION OF THE FILTERING THEORY FOR DELAYED DYNAMIC SYSTEMS TO PLANTS WITHOUT DELAY

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In various dynamic systems, the future state of a process depends not only on a current state but also on the past states of the process. Delayed equations describe a wide class of automatic systems; they are used for modeling mechanical processes which contain pneumatic and hydraulic circuits, the motion of a solid in liquid media, etc. The optimal filtering problem for linear delayed dynamic systems was solved by Kolmanovskii and Maisenberg under the assumption that the initial state of the system is zero almost everywhere. However, this assumption does not always hold. In the present work, this result is extended to the case of *nonzero* initial conditions. The generalization obtained in this work renders the classical result by Kolmanovskii and Maisenberg more final.

Consider a classical filtering problem for a continuous systems without delay but with arbitrarily correlated plant noise (with a given correlation function) and continuous measurements. We construct an auxiliary delayed system where the delay is equal to the length of the observation time and the term with delay is equal to the term with correlated plant noise. Then it turns out that the filtering problem with correlated plant noise is a special case of the corresponding estimation problem for delayed systems. It can be shown that the solution of the filtering problem with correlated plant noise is defined by a Kalman-type dynamic filter with an additional integral term. The gains in this filter are calculated via the solution of a system of functional differential equations that generalize the Riccati equation. Since the plant noise may have an arbitrary correlation function, our problem statement allows us to consider the plant noises that are modeled by *nonlinear* transformations of stochastic processes.

SEPARATION PRINCIPLE FOR LINEAR QUADRATIC CONTROL IN STATISTICALLY UNCERTAIN STOCHASTIC HYBRID SYSTEM*

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We consider the minimax control problem for linear stochastic dynamic systems with both continuous and discrete observations. It is assumed that the intensities of the continuous- and discrete-time noises are not known exactly. The only information available is that the noise intensities are constant matrices which belong to some a priori known compact uncertainty sets of positively semidefinite matrices.

To obtain the optimal control process defined by the system with a priori parameter uncertainty the game-theoretic approach is used, i.e. we find a control process that is minimax with respect to classical mean-square criterion.

We use the results previously obtained for the minimax discrete-continuous linear filtering problem and minimax control problem for purely continuous stochastic systems and obtain the analytical representation for minimax control strategy under natural restrictions on non-degeneracy of the observation processes.

It is shown that the separation principle (which holds for the classical linear stochastic control problem with mean-square criterion) is violated for the minimax control problem for the general case of the uncertainty set. In classical settings the optimal estimate used for the optimal control design does not depend on the parameters of the optimization criterion. For the case of parameter uncertainty, it turns out that this key feature does not take place: the estimate depends on the solution to the dual problem, which, in turn, depends on the parameters of the optimization criterion, so any change of the latter one leads to the necessity of re-computation of the estimate. Hence, unlike the case of full a priori information, the problem of control process design and the observation processing problem are not separated in the minimax case. It should be noted that for a particular case of uncertainty set with a maximal element, the separation principle still holds.

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ON MINIMAX ESTIMATION IN UNCERTAIN-STOCHASTIC MODELS WITH PROBABILITY CRITERIA*

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In this work we study the problem of optimal estimation in the multivariate uncertain-stochastic observation model by minimax criterion with generalized probabilistic risk functions. The most general results in this area are obtained using the mean-square error as loss. Nevertheless, the statistical references based on the mean-square error could lead to non-adequate decisions if the exact joint distribution of random parameters differs from the Gaussian law. At the same time, given a'priori statistical information in terms of restrictions on the moment characteristics, one can find the tight bounds of various non-mean-square risk functions at linear decision rules. This makes possible to suggest efficient optimization procedures for designing linear estimation algorithms, which are optimal in a minimax sense. The practical and theoretical interests motivate the following question: whether linear estimators are minimax-optimal over the class of all measurable decision rules given fixed second-order moments of random parameters? For various linear uncertain-stochastic systems this problem has been investigated in detail using the mean-square risk. In this work we are going to show that there exists a linear operator that is minimax over the family of all unbiased estimators for the broad class of risk functions monotonous with respect to the Euclidean norm of the estimation error. In addition, we treat three kinds of estimation criteria based on expectation, probability, and quantile risk functions.

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VIRTUAL SENSORS FOR LINEAR SYSTEMS: STRUCTURE AND IDENTIFICATION

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Let us consider a discrete-time, linear, time-invariant system S, described as:

$$
\begin{aligned}
x^{t+1} &= Fx^t + G_1u^t + G_2d^t \\
y^t &= H_1x^t + \upsilon^t \\
l^t &= H_2x^t
\end{aligned}
$$

where, for a given time instant t, x^t is the system state, u^t is a known deterministic input, d^t is a (possibly vectorial) unknown disturbance input, y^t is a known (measured) scalar output, l^t is a partially unknown scalar output, υ^t is the measurement noise and F, G_1, G_2, H_1, H_2 are constant matrices of suitable dimensions.

Assume that the pair $[F, H_1]$ is observable and the system matrices F, G_1, G_2, H_1, H_2 are unknown. The filtering objective is to obtain a (possibly optimal in some sense) estimate $\hat{l}^t$ of l^t for $t > \tau$ given that a finite set of noise-corrupted measurements of u^t, y^t and l^t are available for $t = 1, 2, \ldots, \tau$. At any time instant $t > \tau$, only the measurements of u^k and y^k for $k = 1, 2, \ldots, t$ are available.

A huge literature exists on the minimum variance filter design, assuming that the system S is known and the disturbances and measurement noises are stochastic white sequences. In the present context, on the contrary, the system model is not known and the filter should be obtained from a noise-corrupted set of data generated by S in an initial experiment.

The usual solution to the presented problem is a two-step procedure, where an approximate system model is first identified and then a minimum variance filter is constructed on its base. The authors here investigate a possible alternative approach, performing the direct identification of a filter, named Direct Virtual Sensor (DVS), which gives an estimate $\hat{l}^t_V$ of l^t using u^t and y^t as inputs. In general, the DVS offers better performances than the two-step approach. In this work, a new methodology is proposed for the direct identification of virtual sensors for linear dynamic systems.

An example related to the vertical dynamics of a road vehicle shows the effectiveness of the proposed approach.

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PROPERTIES OF CONFIDENCE ESTIMATES FOR STATISTICALLY UNCERTAIN SYSTEMS*

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The state estimation problem for statistically uncertain systems with observation is investigated. A system is called statistically uncertain one if it contains random perturbations with incompletely known distributions, or it contains both random and nonrandom uncertain perturbations. In this paper different approaches to the confidence estimation for statistically uncertain problem with observation are analyzed. It is shown that linear estimates are not optimal even for linear systems depended on Gaussian random perturbations with uncertain mean values. The nonlinear confidence estimates for the system state are constructed using a notion of a random information set. The properties of the estimates are studied.

Let consider an ordinary statistically uncertain problem

$$x = x_0 + Q_1\xi_1, \qquad y = Gx + v + Q_2\xi_2 . \tag{1}$$

Here x is unknown n -vector, y is known observation. Perturbation $\xi = \{\xi_1, \xi_2\}$ is random vector with the standard normal distribution and independent components. The nonrandom vectors x_0, v are known by memberships: $x_0 \in X_0$, $v \in V$.

Definition 1. The set $X(\xi)$ of all states x of system (1) consistent with the observation y for a given value of the random perturbation ξ is called **random information set.**

Definition 2. The measurable set X_α is called **a confidence region** of a level α for the system (1), if the conditional probability $P\{X(\xi) \subset X_\alpha \mid X(\xi) \neq \varnothing\} = \alpha$.

The conditional probability cannot be substituted by unconditional one. The calculation algorithm for the confidence estimates is more complicated than the linear procedure. But it allows us to improve significantly the confidence estimate in the case of small dispersions of the random perturbations. The confidence regions approach to the information set for a system without random perturbation in this case in contrast to the linear estimates.

Theorem. Let the matrices of the coefficients in (1) tend to 0: $Q_i = \varepsilon Q_i^0$, $\varepsilon \to 0$. If the sets X_0, V have interior points and for a given observation y the information set $X^{\det} = X_0 \bigcap G^{+}(y - V)$ is not empty, then for any probability $\alpha \in (0.5;\, 1)$ there are confidence sets X_α^ε such that $X_\alpha^\varepsilon \to X^{\det}$ if $\varepsilon \to 0$.

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CONTROLLED MARKOV CHAINS FOR CONTROLLED N-LEVEL QUANTUM SYSTEMS[1]

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Consider an n-level quantum system, namely a system where states are represented by unit vectors in a complex, n-dimensional Hilbert space **H**. The pure states evolution is then given by the Schroedinger equation. In the Nelson-Guerra *stochastic mechanics* [1]-[3], to each quantum evolution $\{\psi(t)\}$, it is associated a jump Markov process (a continuous-time Markov chain) {q(t)} taking values in X={1,2,…,n}. The probability of occupying the site j at time t is given by $\rho_j(t)=|\psi_j(t)|^2$. In [4], stochastic mechanics, together with the theory of Schroedinger bridges and stochastic control, has been exploited as a *tool* to attack a steering problem for the infinite-dimensional Schroedinger equation. There exists, of course, a large body of literature dealing with control of jump Markov processes. In this paper, we seek to use the latter to derive corresponding results for n-level quantum systems.

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Indirect control of the asymptotic states of a dynamical semigroup

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The largest obstacle to the implementation of quantum technologies is the unavoidable interaction of quantum systems with the surrounding environment. Because of this interaction, the system dynamics is subject to loss of coherence, irreversibility and dissipation, and the appealing properties of quantum systems are lost or compromised [1].

In many situations the environmental action can be accounted for by describing the dynamics of a system s by a quantum dynamical semigroup, that is a Markovian reduced dynamics whose generator L, defined by $\dot{\rho}_s = L[\rho_s]$, has the standard form

$$L[\rho_s] = -i[H_s, \rho_s] + \sum_{i,j} c_{ij} \Big(F_i \rho_s F_j^\dagger - \frac{1}{2} \{ F_j^\dagger F_i, \rho_s \} \Big), \tag{1}$$

where ρ_s is the statistical operator associated to the system s, H_s is an Hermitian operator and the set $\{F_i; i\}$ satisfies $\mathrm{Tr} F_i = 0$, $\mathrm{Tr}(F_i F_j^\dagger) = \delta_{ij}$. The Kossakowski matrix $C = [c_{ij}]$ must satisfy $C^\dagger = C \geqslant 0$ in order to guarantee a consistent physical interpretation of the formalism [2].

The second contribution in the right hand side of (1) is a non-coherent term responsible of the irreversible behavior of the system s. The introduction of this term leads to the appearance of attractors in the state space of s, producing relaxation to equilibrium of the states of the system, not realizable in the absence of the environment. A stationary state for the dynamics, ρ_s^∞, is defined by the condition $L[\rho_s^\infty] = 0$. Necessary conditions for the existence of stationary states and for the convergence of $\rho_s(t)$ to them have been derived in terms of the operators $\{V_i; i\}$ appearing the diagonal form of (1),

$$L[\rho_s] = -i[H_s, \rho_s] + \sum_i \Big(V_i \rho_s V_i^\dagger - \frac{1}{2} \{ V_i^\dagger V_i, \rho_s \} \Big), \tag{2}$$

The conditions that are relevant to our purposes are summarized by the following theorem.

Theorem 1 *Given the quantum dynamical semigroup (2), assume that it admits a stationary state ρ_0 of maximal rank. Defining $\mathcal{M} = \{H_s, V_i, V_i^\dagger; i\}$ the commutant of the Hamiltonian plus the dissipative generators, the following conditions hold true:*

1. If $\mathcal{M} = span(\mathbb{I})$, then ρ_0 is the unique stationary state. Moreover, if $\{V_i; i\}$ is a self-adjoint set with $\{V_i; i\}^{'} = span(\mathbb{I})$, then for all $\rho_s(0)$

$$\lim_{t \to +\infty} \rho_s(t) = \rho_0.$$

2. If $\mathcal{M} \neq span(\mathbb{I})$, then there exist a complete family $\{P_n; n\}$ of pairwise orthogonal projectors such that $\mathcal{Z} = \mathcal{M} \cap \mathcal{M}^{'} = \{P_n; n\}^{''}$. If $\{V_i; i\}^{'} = \mathcal{M}$, two extreme cases together with their linear superpositions may occur. If $\mathcal{Z} = \mathcal{M}$, then for all $\rho_s(0)$

$$\lim_{t \to +\infty} \rho_s(t) = \sum_n Tr(P_n \rho_s(0) P_n) \frac{P_n \rho_0 P_n}{Tr(P_n \rho_0 P_n)}.$$

If $\mathcal{Z} = \mathcal{M}^{'}$, then for all $\rho_s(0)$

$$\lim_{t \to +\infty} \rho_s(t) = \sum_n P_n \rho_s(0) P_n.$$

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COMPARATIVE ANALYSIS OF CONTROL STRATEGIES

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Motivated in part by the rapid growth of nanofabrication and nanotechnology, as well as a surge of interest in novel applications of quantum effects such as quantum information processing (QIP), many control strategies for quantum systems have been proposed. Despite the obvious practical importance of selecting the best strategy for a particular implementation, very little work has been done in comparing different strategies in terms of their effectiveness, efficiency and robustness.

In this paper we compare open-loop control strategies, with focus on geometric, Lyapunov and iterative optimal control techniques. We give a comparative discussion of the several possible formulations of a quantum control problems and an overview of these three control strategies. These strategies are then numerically compared using two typical problems of practical significance in QIP: simultaneous, selective control of several qubits using global pulses and controlled entanglement of coupled qubits in a well-established NMR model.

We find that frequency-selective geometric control tend to produce unwanted off-resonant excitation and low gate fidelities. Lyapunov-derived pulses tend to be spectrally complex with guaranteed but slow convergence, showing that asymptotic convergence is theoretically attractive, but appears less useful in practice, where gate operation and state preparation times are critical. Non-converging antipodal points are also discussed. The iterative optimal control algorithm allows more realistic models including implementational restrictions to be used, and thus generally gives more suitable pulses. Convergence to a global optimum is not guaranteed, however.

Further, although optimisation problems in state, process or observable control are often theoretically equivalent, we find that different formulations can lead to different solutions for the optimal control field. Various parameters which can affect the final solution are discussed. More work is necessary to understand how model choice, problem formulation, numerical solution and algorithmic parameters can be optimised for practical scenarios.

FINDING QUANTUM NOISELESS SUBSYSTEMS: A LINEAR-ALGEBRAIC APPROACH

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The development of technologies that could exploit the potential of quantuminformation processing is nowadays mainly limited by the capabilities of engineering scalable physical devices that act as protected realization of quantum information. This means we need a physical system that admits a controllable and monitorable quantum subsystem for which the action of noise is either negligible or correctable on the time-scale needed in order to complete the desired information-processing task. .Noiseless Subsystems (NS) have been introduced and studied as passive way to protect quantum information from noise. A subsystem of a quantum system Q with associated Hilbert space H_Q is defined by specifying a factor HS (in the the tensor-product sense) of a subspace of H_Q, i.e. $H_Q = H_S \otimes H_F \oplus H_R$.. The main problem one is led to face in many practical cases is that of determining the maximum dimensional NS of a given dynamical model for an open quantum system. Relying on the same ideas that led to the proposal of NSs as error-protected realizations of quantum information, a C*-algebraic approach is employed to provide a procedure that finds a maximum-dimensional NS for a given quantum operation has been recently proposed. The strategy employs advanced results and algorithms from operator-algebras theory, and it is effective only in the case of quantum operation. In the present paper we try to follow another, simpler approach. A linear-algebraic characterization of noiseless structure has been recently developed, and provides a simple tool to verify whether or not a given subsystem corresponds to a noiseless subsystem. The problem of finding protected subsystems in this setting remains non trivial, but we present here some promising results that may lead to linear-algebraic algorithms suitable to both Kraus maps and Markovian generators. After recalling the relevant linear-algebraic characterization for NS dynamics, we start by proposing a simple search procedure for noiseless subspaces, based on the search for simultaneous eigenspaces of the matrices involved. This let us exemplify the differences between the Kraus-map and the Markovian cases. We next provide an algorithm to construct a basis for a given NS in order to make the matrix block-structures explicit. This algorithm also represents a test for the existence of NSs on an invariant subspace directly based on the matrices, and a procedure to find NS in the case of pure tensor factors of the whole system. We also devise a procedure that relies on the previous result and leads to find maximal NS up to some weak hypothesis. Further work is needed in order to turn the algorithm in a tool for finding NS in the general case.

ATTRACTIVE QUANTUM SUBSYSTEMS AND FEEDBACK-STABILIZATION PROBLEMS

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In this paper, we focus on the problem of characterizing and controlling a quantum subsystem of a system undergoing continuous-time, Markovian quantum dynamics. Mathematically, a subsystem S (with corresponding co-subsystem F) of an overall system Q with Hilbert space H_Q is defined by specifying a factor of a subspace in the tensor product sense that is, $H_Q = H_S \otimes H_F \oplus H_R$. From both a conceptual and practical standpoint, the main motivations for introducing and studying dynamical features of quantum subsystems come from Quantum Information Processing (QIP) applications. The notion of a quantum subsystem provides the most general pathway toward protected quantum information: since subsystem-encodings do not demand the state of the whole physical system to be protected, this may allow for enhanced implementation flexibility. As a first step in our work, we both provide a general reformulation of the concept of a quantum subsystem in linear-algebraic terms, as well as a complete characterization of invariant and noiseless subsystems for Markovian quantum dynamics. In order to practically exploit subsystems, initialization of the system in the intended state-space component is required. As in realistic scenarios initialization is unlikely to be achieved perfectly, an intriguing possibility is to explore the existence of invariant subsystems that are both invariant and attractive under the dissipative evolution. We develop a Lyapunov's analysis of the problem from a linear-algebraic perspective and identify sufficient conditions for attractive subsystems to be supported by a Markovian generator. As a main control application, we consider quantum dynamical systems in optical cavities continuously monitored via a homo-dyne detection scheme. Under the assumption that arbitrary open-loop control and feedback operators may be accessible, our linear-algebraic setting provides the starting point for developing synthesis strategies for feedback state-stabilization. In particular, we obtain an explicit characterization of two-dimensional generators able to ensure stabilization of an arbitrary pure state, and extend similar ideas to a feedback-stabilization strategy for n-level systems. The Markovian, output-feedback techniques we employ are also compared, in terms of robustness features, with the Bayesian-feedback approach. More work is needed in order to establish a general Markovian, feedback stabilization scheme for arbitrary n-level systems. Among the most interesting perspectives, further investigation is required, in particular, to establish the full power of Hamiltonian control and Markovian feedback in closed-loop generation of noiseless structures. This may lead to new venues for engineering protected realizations of quantum information in physical systems described by Markovian semi-groups.

Dynamical decoupling schemes for inhibiting decoherence in the propagation of single-photon polarization qubits

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Dynamical decoupling offers a versatile control toolbox for quantum dynamical engineering in both high-resolution spectroscopy and quantum information science. Decoupling schemes operate by subjecting the target system to a series of open-loop control transformations, in such a way that the net evolution is coherently modified to a desired one. This avoids auxiliary memory and measurement resources, while additionally enabling straightforward integration with other passive or active quantum control techniques.

Up to now almost all the experimental demonstration of decoupling techniques have been carried out within nuclear magnetic resonance (NMR) systems. However propagation of photonic qubits along optical fibers could represent an important field of application of dynamical decoupling schemes for combatting decoherence. In such a case "bang-bang" techniques have to be implemented "in space", rather than in time, i.e., along the fiber length. In fact, polarization effects in singlemode fibers are a common source of problems in all optical communication schemes, as well classical as quantum ones. The idea is that, once that the main decoherence sources affecting a single photon polarization qubit have been analyzed and found, one could appropriately engineer the fiber by applying a stress pattern on the fiber implementing a periodical decoupling sequence on the polarization qubit. In order to do that we shall first provide a proof-of-principle demonstration of the efficiency of bang-bang decoupling by modeling the propagation along a fiber as a sequence of birefringent crystals differently oriented with respect to the propagation direction, placed inside an optical ring cavity. Due to birefringence, the polarization and the frequency degree of freedom of a single photon are coupled and the latter degree of freedom induces phase decoherence once is traced over. This scheme has been already considered and experimentally discussed in the simplest case of multiple passes through a single birefringent crystals oriented orthogonally to the wave vector. Here the sequence of differently oriented crystals will provide a more general and complete model of the decoherence affecting the polarization qubit. The sequence of bang-bang operation will be realized by inserting appropriate waveplates between the crystals and we shall see that, by decreasing the length of the crystals, the fidelity of the transmitted qubit increases, approaching unity when the length scale of polarization mode dispersion becomes smaller than the length of the crystal used.

AN ADAPTIVE CHAOTIC SECURE COMMUNICATION SCHEME WITH CHANNEL NOISE AND TIME DELAY

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In this paper, by using synchronization scheme of chaotic neural networks with delay, an adaptive secure communication scheme with channel noise and time delay is proposed. Based on the idea of chaotic masking-modulation, the transmitted message is encrypted by the chaotic signal, and via the adaptive feedback control techniques, the transmitter and the receiver are synchronized with channel noise, so the masked signal can be perfectly recovered by the receiver in the presence of channel noise. In light of the Lyapunov stability theory for stochastic differential equations, several theoretical results are rigorously established. Finally, a numerical example is provided to verify the effectiveness of the proposed scheme, and the time required for recovering the information signal and the performance of the recovered signal very sensitively depending on the time delay and the frequency of the information signal will also be found from the simulation results.

PERFORMANCES AND STABILITY ANALYSIS OF NETWORKED CONTROL SYSTEMS

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The problem of performance and stability analysis of networked control systems with random network delay and data dropout is considered in this paper. The networked control systems with random network delay are described in a state-space form. It presents a new control scheme, which is termed networked predictive control. This scheme mainly consists of the control prediction generator and network delay compensator. The control prediction generator provides a set of future control predictions to make the closed-loop system achieve the desired control performance and the network delay compensator removes the effects of the network transmission delay. The stability criteria of the closed-loop networked predictive control systems are analytically derived for two different control inputs to the observer. In case of stability analysis, a switched system's method has been proposed, which solves the stochastic problem in a deterministic way.

Two different ways to choose control input to the observer are discussed in the paper and the results of performances and stability are presented. Both real-time simulations and practical experiments show the effectiveness of the control scheme.

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LINEAR CONTROL MODELS FOR GUTTA TOKAMAK

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Linear models for the plasma control system of the tight tokamak Gutta are discussed. The characteristics of the different order models are compared. Parameters of the models are calculated using special software that was developed on the base of the PET-code (which is used for the derivations of the linear models for the ITER control system design).

Calculation of a linear model includes 4 parts:

- Description of the tokamak geometry in the appropriate format;
- Calculation of inductances and resistances for all pairs of the circuits including in the models;
- Computation of the plasma equilibrium database;
- Calculation of the linear model matrices.

Before derivation of the models some parameters (e.g. plasma beta, plasma internal inductance and others) are prescribed.

As a result the linear models of the minimal order are chosen to describe the plasma dynamic properly. The linear models derived are necessary for the controller design. The controllers will be used in experiments with plasma control system of Gutta tokamak. Software package for the linear model derivation is used in educational process in accordance with the Applied Mathematics & Physics specialty of the Saint-Petersburg State University.

PLASMA CONTROL PROBLEMS INVESTIGATION ON GUTTA TOKAMAK

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The problems of design of program control and synthesis of feedback controllers in tokamak are considered. The results of the first experiments on the plasma shape control in Gutta tokamak [1] are presented.

A dynamical model that describes the current behavior was built for research of dynamical processes in poloidal conducting circuits. The calculated data obtained on the basis of mathematical model was compared to electromagnetic measurements that were received during the series of test experiments. The problems of program control of discharge with consideration of engineering features of Gutta tokamak are discussed.

In order to design the control system for plasma current, shape and position the structural parametric optimization of transient processes is suggested.

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ROBUST FEATURES OF TOKAMAK PLASMA STABILIZATION SYSTEMS

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The paper describes modern procedures for analysis and synthesis of tokamak plasma vertical position, plasma current and shape controllers on the base of the MAST tokamak example. The linearized plasma model has been obtained with the help of PET code and has been thoroughly analyzed. As a result, a completely controllable system which could be used as a base for controllers synthesis has been extracted. Several controllers for plasma vertical stabilization system have been designed, including some built on a base of LQG-optimal synthesis theory

On the basis of H_∞ control methods the computational technique is presented which allows to estimate robust stability margins and to compare feedback controllers with respect to their robust features.

Some problems related to application of the robust synthesis procedures based on modern μ-theory, such as D-K iterations technique for tokamak's control systems design are described.

PROGRESS IN MUON COLLIDER STORAGE RING LATTICE DESIGN

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A new lattice for a Muon Collider storage ring with a design collision energy of 750 on 750 GeV will be discussed. The important building blocks of the lattice: the Final Focus Section, the Chromatic Correction Section and the Arc Module are described in detail. These components of the collider have been designed keeping in mind that the storage ring must approximately match the footprint of the Tevatron Ring in order to take advantage of existing services and tunnels. The model presented here relies heavily upon a previous, highly optimized 50×50 GeV storage ring lattice design. The current design value for β^* is chosen to be 1 cm, which has the advantage of lower chromaticities and longer bunch lengths (due to the hour-glass effect) as compared to the previous standard lattice with a β^* of 3 mm.

DEVELOPMENT OF ROENTGEN AND NUCLEAR-PHYSICAL CONTRABAND DETECTION SYSTEMS OF THE EFREMOV INSTITUTE

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OPTIMIZATION OF THE BEAM TRANSPORT LINE FOR THE CUSTOMS CYCLOTRON

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Optimization of the beam transport line for the customs cyclotron [2-3], is presented. At first it was solving the beam dynamics inverse problem [1] to match the beam line parameters of the cyclotron. The beam transport line configuration, including two quadrupoles magnetic lenses, was suggested. Magnetic lenses parameters and position was obtained by the CELLY code [4]. The particles trajectory calculations in the space charge dominated beam transport line were performed at the beam intensity of 200 microA by the CBDA code [3]. After optimization the beam Twiss parameters at the entrances and at the exit of the beam line were estimated and found satisfactory.

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ANALYSIS OF TRANSIENT SLOW MOTIONS IN SYSTEMS WITH INERTIALLY EXCITED VIBRATIONS

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A nonlinear system consisting of a rigid platform and mechanical vibroactuator is considered. The platform, connected to an immovable base with elastic and damping elements can move along a fixed direction by means of mechanical vibroactuator (an unbalanced rotor, mounted on the platform and driven with an electric drive). Such a system is a model of many vibrational machines and technological units. During the speed up of the actuator a capture of the current frequency ω near resonance frequency p (Sommerfeld phenomenon) can be observed. Further increase of the supply power of the drive leads to a jump transition from ω≈p to an above resonance frequency ω1>p. A comprehensive study of Sommerfeld effect carried on in numerous publications discovered that "semi-slow" oscillations of rotor frequency may appear with the frequency less than resonance frequency of the system. Analysis of semi-slow oscillations of the rotor is important for a number of methods for control of vibration units allowing to significantly reduced the motor power required for passage through resonance zone.

The main contribution of this paper is analysis of existence and dynamics of "semi-slow" oscillations. The problem is solved by an iterative method combined with direct method of separation of motions. Two autonomous second order equations for slow motions (for rotation frequency) and for semi-slow motions (for oscillations of rotation frequency) are obtained and solved separately. Both equations are valid both in below resonance and in above resonance area. Expression for the frequency and damping of semi-slow oscillations (internal pendulum) in below resonance area are derived. The frequency depends essentially on rotation frequency ω and decreases down to zero when ω approaches the resonance frequency p. The damping of semi-slow oscillations is proportional to the damping in the initial system, i.e. semi-slow motions decay in damped systems. A comparison of the obtained analytical results with numerical results obtained by simulation of initial system equations is given demonstrating a good concordance of the results.

The results of the paper can be used for design and improvement of control methods for vibration units in the start-up mode. Similar analysis is done for the system with two vibroactuators. It is shown that the frequency of semi-slow motions for this system is √2 times greater than for the previous one.

FEEDBACK, CORRELATIONS, AND PROPAGATION OF MEAN ANISOTROPY OF SIGNALS IN FILTER CONNECTIONS

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Performance analysis and optimal design of control systems and signal processing devices substantially rely on the statistical characteristics of the underlying random disturbances. The inevitable uncertainty in the knowledge of these last is a standard motivation for stochastic mini-max settings in Robust Control. The anisotropy-based approach to stochastic robust control occupies a unifying intermediate position between the $\mathcal{H}_2$ and $\mathcal{H}_\infty$-optimal control theories. Initiated about thirteen years ago at the interface of Information Theory and Robust Control, the approach employs the concepts of *mean anisotropy* of signals and *anisotropic norm* of systems.

The mean anisotropy of a multidimensional random signal is defined via its relative entropy, or historically, the Kullback-Leibler informational divergence, with respect to Gaussian white noises with scalar covariance matrices. It therefore quantifies both temporal correlations, that is, "colouredness" or predictability, of the signal and its spatial "non-roundness". The a-anisotropic norm of a system is the worst-case sensitivity of its output measured by the largest root mean square gain of the system with respect to input random disturbances whose mean anisotropy is bounded by a nonnegative parameter a. The anisotropy-based approach to controller design employs the a-anisotropic norm of the closed-loop system as a performance index which is to be minimized, with the magnitude of the parameter a governing the robustness, and hence, conservativeness of the controller.

Since the exogenous perturbations are often caused by superposition of various effects from other interacting systems, the present paper provides a collection of results on the changes in the mean anisotropy of signals propagating through filter connections. In this context, a leading part is played by feedback as a unversal mechanism for creating the temporal correlations in a signal via "recycling" its past history. Furthermore, the role of feedback for the mean anisotropy of signals is closely related to the Kolmogorov-Szegö formula for the Shannon entropy production rate in a stationary Gaussian sequence.

Revisiting the underlying definitions, the paper emphasizes the role of feedback in the construct of mean anisotropy of signals and discusses the propagation of the latter through various types of filter connections. The results of the paper can be used to support physical and engineering intuition for a "rational" choice of the anisotropy level a in the design of anisotropy-based robust controllers.

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Time evolution and pure dephasing of entangled states of two electrons in coupled quantum dots

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We theoretically study the pure dephasing dynamics of two charge qubits in double dot due to the interaction with acoustic and optical phonons. Semiconductor quantum dots (QDs) are often considered as candidate devices for a solid-state implementation of quantum information processing [1,2,3]. The implementation of charge states in quantum dot (QD) systems, recently supported by an experimental demonstration [4], has driven a lot of investigations on coherence properties of these systems. Coherent oscillations in double quantum --dot qubit are observed [5].
We consider the quantum dynamics of two interacting electrons in a vertically coupled quantum dot driven by external electric field, in terms of equations of motion for the density matrix, in which the presence of one electron confined in the double dot representes one qubit. The pure dephasing rates depend on the parameters of the double dot [6]. In order to study the pure dephasing effects on entangled states we adopt three possible measures. We adopt the concurrence C(ρ) in order to quantify the evolution of the degree of entanglement of two qubits in the presence of a bath of acoustic phonons. For second measure, we consider the fidelety F(t) in order to quantify the stability of the quantum system under the action of the phonon-electron interaction. Finally, we explore the linear entropy S(ρ)in order to study the mixed character of a system described by a density matrix ρ ,
Keywords: decoherence, entanglement, double quantum dot

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RESEARCH OF PHYSICAL PHENOMENA OCCURRING IN COMPLICATED DYNAMIC SYSTEMS AT SEISMIC LOADS

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Hydropower constructions, their high dams at seismic loads behave as complicated dynamic systems. During long-term exploitation because of different reasons irreversible processes take place in the body of dam, which can negatively be shown at earthquakes. For behavior forecasting of such constructions at seismic loads the network of complex instrumental and geophysical monitoring should be organized. The material getting in the result of this monitoring can serve as a base for constructions projecting methods perfection, right counting of seismic forces, as well as for conducting of necessary aseismic preventive arrangements.

With this aim the information-measuring system (IMS) of observing and testing is developed, which realizes the continuous tracking, detection and registration of seismic events in digital and graphic forms. The system is set on “Her-Her” dam in Republic of Armenia. IMS allows:

- to conduct continuous monitoring of exploitation object and to forecast the possible development of dangerous seismic deformations;
- to provide the storage of actual data on construction behavior during earthquakes.

IMS consists of hardware part and program control. . In hardware part the seismosensors, computer, printer, power supply unit, commutator of analog signals, 14-digit position module of analog input-output (ADC) of AI16-5A type of Fastwel firm are used.

The system allows to connect up to 128 sensors of seismic oscillations. On seismic event coming the system begins the recording of all sensors data in file, which then can be printed out in form of diagram or saved in diskette in digital form. The results of measurings and analysis of dynamic processes parameters are stated, which are take place in body of dam. The system can be used for monitoring of other hydropower constructions and atomic power plants.

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SYNCHRONIZATION IN A DISTRIBUTED SYSTEM OF MOVING CHAOTIC AGENTS

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In this paper we study the synchronization properties of a distributed system of N random walkers in which each agent is a chaotic system. We consider N moving individuals distributed in a planar space. Each individual moves with velocity $\mathbf{v}_i(t)$ and direction of motion $\theta_i(t)$ [v being the modulus of the agent velocity, which is the same for all individuals]. In our model, the agents are random walkers that update stochastically the direction angle $\theta_i(t)$.

Furthermore, each agent is a dynamical system, and in particular a chaotic one. It is then characterized by a state variable vector $\mathbf{y}_i(t) \in \mathbb{R}^n$ which evolves according to a given chaotic law. In this paper, the case of Rössler oscillators is considered.

Each agent interacts at a given time with only those agents located within a neighborhood of an interaction radius, defined as r. When two agents interact, the state equations of each agent are changed to include diffusive coupling with the other agents.

The interaction network underlying the system is a dynamical one with links evolving in time. In this paper we study the properties of the system and link them with the so-called fast-switching property.

As an example, the case with $N = 2$ is discussed. Both the cases of identical systems and non-identical systems are taken into account. For the analysis of the numerical simulations, we defined the following synchronization error $\delta(t) = \frac{|x_1-x_2|+|y_1-y_2|+|z_1-z_2|}{3}$ and we defined $\langle\delta\rangle = \langle\delta(t)\rangle$ as synchronization index, where the average is performed on the interval $[4/5T, T]$ ($T = 500s$ is the total length of the simulation).

The behavior of the system depends on v. If v is sufficiently high (i.e., under the hypothesis of sufficiently fast switching), we expect that the system behavior with respect to the density ρ has two thresholds, ρ_1 and ρ_2: the two agents synchronize if $\rho_1 < \rho < \rho_2$. Numerical results confirm the theoretical prediction.

Diversity Induced Resonance in Dynamical Systems

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We have recently shown [1, 2] that a system can respond better to an external stimulus if there is some degree of diversity in the constituent units. This shows that, at variance with accepted results, diversity (i.e. variability or heterogeneity) can have a constructive role in the dynamics of an extended system. This result is somewhat reminiscent of that of stochastic resonance by which noise enhances the response of a non-linear system to an external forcing. As in stochastic resonance, the basic mechanisms for diversity-induced resonance are rather generic and require only simple ingredients and we have provided clear evidence in bistable and excitable systems in which the diversity is modelled by quenched noise or, more specifically, by a parameter that adopts a different value for each of the units. These findings show that, under the right conditions, diversity might have a constructive role and suggest that natural systems might profit from their diversity in order to optimize the response to external perturbations. In this communication, we will explain the basic mechanism leading to the resonance effect and show new results concerning a model for opinion formation, in which diversity appears both in the internal preferences of the agents and in the network of contacts amongst them, and in a model of interacting neurons coupled by chemical synapses whose coupling coefficients assume different values according to a certain distribution.

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Predict-Prevent Control Method for Perturbed Excitable Systems

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The control of dynamical systems is a classical problem of engineering, as well as many other sciences, where the most commonly problem is to inhibit the instabilities. Two of the best known methods of control are the OGY method, named from the creators Ott, Grebogi and Yorke [1], and the Delayed Feedback Control method introduced by Pyragas [2]. The aim of this presentation is to introduce an alternative control method, with the particular application to excitable systems, ie., systems that represent the typical spiking dynamics of the heart cells, neurons in the brain as well as many other cells This new control method is based on two steps: prediction and prevention. For prediction we use the anticipated synchronization scheme [3] considering unidirectionally coupled excitable systems in a master-slave configuration. The master is a perturbed system to be controlled, while the slave is an auxiliary system which is used to predict the master's behaviour. We demonstrate that efficient control may be achieved for particular regimes of coupling parameters. Our numerical results are corroborated by using electronic circuits that mimic the Fitzhugh-Nagumo model.

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PHASE-FLIP BIFURCATION: THEORY AND EXPERIMENT

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Coupled oscillators show two types of phase synchronization, namely, *in-phase* and *antiphase* or *out-of-phase,* in both instantaneous coupled and delay coupled systems. A transition to either of the synchronization states can be induced by changing the coupling strength in instantaneous coupled systems or by changing delay time in delay coupled systems. However, the transition from *inphase* to *antiphase* state or vice versa is found intercepted by a desynchrornization regime in instantaneous coupled oscillators. On the contrary, a sharp transition from *inphase* to *antiphase* is observed in delay-coupled oscillators. Obviously, the phase difference of the coupled oscillators jumps from 0 to π for a delay time above a critical value. This phenomenon of sharp transition from *inphase* to *antiphase* with delay is defined as phase-flip bifurcation. Phase-flip bifurcation is accompanied by a large change in oscillator frequency from a lower to higher value. It may be noted that the phase-flip bifurcation is reported in different dynamical regimes like *amplitude death*, *periodic to periodic, quasiperiodic to quaisperiodic and chaotic to chaotic* transition states of many delay coupled nonlinear oscillators, Lorenz system, Rössler systems. Further this phenomenon is found true in many natural systems like ecological models, excitable systems. We report, in this paper, the theoretical background and experimental evidence of phase-flip bifurcation in electronic circuit using Chua oscillators.

OPTIMIZATION OF THE PROPORTIONAL NAVIGATION LAW WITH TIME DELAY

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The terminal phase of plane rendezvous of an active space vehicle and a passive orbital station on the Earth orbit is considered. A rendezvous method used on active spacecraft is an algorithm of proportional navigation which is realized with some minor constant time delay. The coefficient of the guidance law is considered as a control variable, a step time function. The objective is to optimize the guidance law taking time delay into account, namely to determine the coefficient of the law which provides minimization of rendezvous time.

Relative motion of the concerned objects is described by the system of nonlinear differential equations. The problem is studied using Pontryagin maximal principle; results of numerical simulation are presented.

It is shown that time delay essentially effects on the character of optimal guidance. Optimal solution includes regular and singular control values both. In contrast to the case when delay is absent, the coefficient of the guidance law should be chosen variable.

BOUND STATES OF TOPOLOGICAL DEFECTS IN THE SYSTEM OF NON-LINEAR COUPLED GINZBURG-LANDAU EQUATIONS

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Bound states of topological defects arising in a tetragonal lattice formed by two orthogonal standing parametrically excited capillary surface waves are investigated. A system of four coupled Ginzburg-Landau equations is proposed to model the dynamics of waves and formation of the bound states of defects. We choose the boundary conditions for the waves corresponded to zero wave amplitude at side boundaries of square region of integration. The initial conditions were set to correspond to the topological defect belonging to one wave in each standing wave. It was found that it is possible to excite one bound state of topological defects in each standing waves of square pattern. Two topological charges forming a bound state moved as a whole. The defects were spaced apart in the direction of wave propagation. It was revealed that increasing of group velocity resulted in increasing distance between the defects and the bound state will decay, which was verified in numerical experiment. The higher the group velocity, the longer was the distance between defects in the bound state.

Numerical modeling of the system gave solutions corresponding to the bound states observed in experiments with Faraday ripples: formation of bound states in each of perpendicular standing waves, scattering of two bound states belonging to perpendicular standing waves, annihilation of bound states belonging to the same standing wave and having with opposite charges. Numerical simulation showed us that dynamics of topological defects at parametric excitation of waves, formation of bound states of defects, and structure of spatio-temporal chaos depend significantly on boundary conditions. For example, it is not possible to observe a formation of solitary bound state and formation of several bound states with the same topological charges in the system if we use periodic boundary conditions. Only homogeneous boundary conditions allowed us obtained bound states observed in experiments.

PROGRESSIVE MOTIONS OF TWO-MASS SYSTEMS IN RESISTIVE MEDIA

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It is well known that two-mass systems can move progressively in various resistive media, if the masses perform oscillations relative to each other. In the paper, simple mechanical models are considered that demonstrate this phenomenon.

The system under consideration consists of two rigid bodies with masses M and m that can move along a straight line. These bodies are called body M and body m, respectively. The main body M is subjected to the external resistance forces and contains the internal body m that performs specific periodic motions relative to body M. Periodic progressive motions of the two-mass system are obtained and analyzed for certain classes of the relative motions of the internal body m.

Various types of the resistance forces acting upon body M are considered including linear and quadratic resistance depending on the velocity of body M as well as Coulomb's dry friction forces. Both isotropic and anisotropic external resistance forces are examined.

Optimal periodic motions are obtained that correspond to the maximal average speed of the system as a whole.

The maximal average speed is evaluated explicitly for various cases. This speed is zero in the case of the isotropic linear resistance but is positive in the anisotropic linear case. Also, it is positive in the quadratic and dry friction cases, both isotropic and anisotropic.

The principle of motion based on the relative oscillations of internal masses does not require outward devices like wheels, legs, screws, oars, etc. That is why this principle is used for mobile robots and underwater vehicles equipped with moving internal parts. This kind of mobile robots seems especially prospective for robots moving inside tubes and in aggressive media.

In the paper, experimental models employing internal moving masses are presented including carts carrying inverted pendulum and rotating wheels, capsules and two-mass system moving inside tubes. Experiments confirm the realizability of the principle of motion described in the paper.

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Suppressing noise-induced intensity pulsations in semiconductor lasers by means of time-delayed feedback

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We investigate the possibility to suppress noise-induced intensity pulsations (relaxation oscillations) in semiconductor lasers by means of the Pyragas control scheme. In contrast to previous studies, where the control was used to enhance the correlation time and thus the coherence of the oscillations, we focus on the suppression of the oscillations and use the mean oscillation amplitude as a measure. We first consider a generic normal form model which is a paradigm for a system close to a Hopf bifurcation. Here, we find an analytic expression for the mean square amplitude of the oscillations. We then investigate the control scheme analytically and numerically in a laser model of Lang-Kobayashi type.

SUSPENSION ASEISMIC CONSTRUCTION WITH ELASTIC TIE-RODS

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The aseismic system, concerning the proposed suspension construction, has the following characteristics:

1. absence of direct contact of the construction with the soil (suspension construction);
2. transfer of the load to the soil by means of elastic steel tie-rods.

The inertial force in the construction due to an earthquake undulatory shock is directly proportional to the construction displacement variation and inversely proportional to the length of the tie-rods. It has a zero value when the first parameter has zero value or when the second parameter has infinity value. The displacement variation is never equal to zero if the soil displacement and the construction displacement are in phase; vice versa it is equal to zero in phase opposition only with reference to the design seismic frequency equal to $\varphi_p = 1{,}41\ \varphi_{o,n}$, where $\varphi_{o,n}$ is the construction horizontal natural frequency. The design seismic frequency is selected only on the basis of statistical data concerning the design area. In order to safeguard the construction against the resonance danger, which occurs when the seismic frequency equalizes the construction natural frequency, it is necessary to determine an interval of - undulatory and sub-undulatory - seismic frequencies, where the frequencies, including the resonance one, are not compatible with the construction safety. Therefore, with respect to this emergency interval it is essential that suitable devices – that is horizontal dampers and vertical frequency converters – spontaneously start in order to decrease the construction displacemts to values not greater than prearranged admissible displacements of design. In addition, the numerical analysis points out that the inertial force in the suspension construction with tie-rods is on average 4% of the corresponding inertial force in the same construction without tie-rods. This considerable decrease of earthquake energy in the construction gives to the proposed system a remarkable economical competitiveness with respect to other existing aseismic systems.

MOSAIC STRUCTURE OF BIOLOGIC DIVERSITY: A RESULT OF AUTOCONTROL AND SYNCHRONIZATION OF COMPLEX SPATIOTEMPORAL DYNAMICS OF BIOLOGICAL COMMUNITIES

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The principal difficulty involved in describing and studying biologic diversity lies in its more or less pronounced spatial structurization and strong heterogeneity. This is most clearly pronounced in phytocenoses, since the majority of plant species as a rule fill their habitats rather nonuniformly to form accumulations and voids that can far from always be convincingly explained by heterogeneity of the environment in the respective ranges. A successful description and analysis of the mechanisms of this heterogeneity within the framework of classic biological investigation methods are still pending. This communication suggests a mathematical model for spatial-temporal dynamics of plant communities to explain the occurrence of heterogeneous (spotty) spatial distribution by instability of community dynamics by phenomena of dynamic chaos and processes of chaotic self-adjustment. In plotting the given model, we accounted for interaction of plants situated close to each other and affecting both increase of biomass (new shoots, for instance) and restricted biomass growth caused by competition for resources needed for vital activity The basic model version is as follows:

$$\dot{u}_i(x,t) = \int\limits_M \alpha_i(x,y)u_i(y,t)dy - u_i^{\gamma_i}(x,t)\sum_j \int\limits_M \beta_{ij}(x,y)u_j^{\rho_j}(y,t)dy\,,$$

where $u_i\,(x,\,t)$ is the biomass density of the *i-th* species in point x in time t, M the physical space, the community habitat range. Parameter γ_i characterizes the sensitivity of suppressed biomass to competitive impact; parameter ρ_j reflects the non-linearity of dependence of degree of competitive limitation on the density of the overwhelming biomass. Kernels $\alpha_i\,(x,\,y)$ characterize the growth of the biomass of the *i-th* species from point y to point x. Kernels $\beta_{ij}\,(x,\,y)$ characterize competitive impact of the biomass of the *j-th* species in point y for the biomass of the *j-th* species in point x.

An analogous mathematical model of evolution of a biological community with continuous variety of inherited properties was also suggested. The presence of selective densely dependent competition involving high individual adaptability of species was shown to lead to forming of discrete groups (taxons) in distribution of species in accord with inherited variables.

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COHERENT EMISSION OF ELECTROMAGNETIC RADIATION FROM THE SURFACE OF SEMICONDUCTOR PLATE WITH THE SELF-AFFINE RELIEF

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The study of the new principles of the construction of electronic and optics, places the problem of developing of the physical models, which adequately describe their functioning. The promising possibilities present the regular structures, which were formed on the surface of semiconductor material. Regular structures on the surface give to them uncommonly properties. The special surface properties are connected with the disturbance in one of the directions of a strict periodicity of crystal lattice, with the break of the translational symmetry of crystal. Its properties are differed from the properties of crystal in the volume and formation on the surface of some topological special features can reveal the unexpected possibilities for creating fundamentally new type solid-state elements. Behavior of silicon plate, to which by the method of plasma-chemical etching was substituted the figure from a large quantity of grooves of annular form, was investigated. Figure from the ring circuits is basis for fulfilling the affine transformations. The transformations are the multiplication of the points of the figure by the scale factor of $m_1=2^i$ and the turnings to the angle proportional to coefficient of $m_2=2^j$.. Interaction of silicon plate with the described self-affine relief was investigated. The simulation was executed both with two-dimensional and three-dimensional non-stationary models. It was examined the nonlinear and spasmodic jump of the electric charge between the walls of the grooves of surface relief. With this condition was obtained the coherent solution for the emission, generated by semiconductor surface with the self-affine relief. The experiments showed, that the semiconductor plate with the self-affine relief of surface function as the converter of incident to it radiation into the coherent form The motion of electric charges over the surface of plate leads to the formation of the standing soliton-like surface waves, which possess coherent properties The length of these waves is determined by the relief of surface

DESIGN OF CONTROL SYSTEM FOR GROWING CRYSTALS WITH DESIRED PROPERTIES

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The paper describes the problem of development of control system, which is applied to grow high quality crystals by the AHP method. The main feature of this system is that it allows to directly realize the control of a growing crystal properties. In order to solve this problem, a numerical model of thermal processes in growth set-up and temperature distribution control algorithms has been proposed and is now under development. It has been shown and preliminary investigated the nonlinear and unstable behavior of the the control plant.

Stabilization of fixed points by extended time-delayed feedback control

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Time-delayed feedback methods can be used to control unstable periodic orbits as well as unstable steady states. We present an application of extended time delay autosynchronization introduced by Socolar et al. [1] to an unstable focus. This system represents a generic model of an unstable steady state which can be found for instance in a Hopf bifurcation. In addition to the original controller design, we investigate effects of control loop latency and a bandpass filter on the domain of control. Furthermore, we consider coupling of the control force to the system via a rotational coupling matrix parametrized by a variable phase. We present an analysis of the domain of control and support our results by numerical calculations.

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Control of Mechanical Systems under Uncertainty by Small Forces

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We consider a mechanical systems governed by Lagrange's equation

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{q}} - \frac{\partial T}{\partial q} = u + s - \frac{\partial P}{\partial q}. \tag{1}$$

Here $q, \dot{q} \in R^n$ are the vectors of the generalized coordinates and velocities, T is the kinetic energy

$$T(q,\dot{q}) = \frac{1}{2}\dot{q}^\top A(q)\dot{q}$$

The potential energy $P(q) \in C^1$ is a bounded from below function which has a point of global minimum.

Positive definite symmetrical matrix $A(q)$ is represented as follows

$$A(q) = A_0(q) + A_1(q)$$

where $A_0(q)$ is a given symmetrical matrices, whereas $A_1(q)$ is unknown. The potential energy is also presented as a sum of a given function $P_0(q)$ and an unknown function $P_1(q)$

$$P(q) = P_0(q) + P_1(q)$$

The vector of unknown disturbances s and the vector of control forces u are bounded

$$|s| \leq S_0, \quad |U| \leq U_0, \quad S_0, U_0 > 0.$$

The matrix A_1 and the vector-function $\partial P_1/\partial q$ are assumed to be small in comparison with A_0 and the control vector-function u respectively. We assume also that the disturbances are smaller than the control forces which in turn do not exceed the potential forces.

A bounded control is proposed which, under certain conditions, steers the system from an arbitrary initial state to a prescribed terminal state in finite (unfixed) time.

The computer simulation results for the controlled motion of a double pendulum illustrate the efficiency of the proposed algorithm.

STOCHASTIC SENSITIVITY AND CONTROL OF CHAOS

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We suggest a new technique for analysis and control of the forced nonlinear oscillations based on stochastic sensitivity function (SSF). This function describes the dispersion of random trajectories near deterministic attractor. The possibilities of SSF to predict some peculiarities of dynamics for stochastically and periodically forced oscillators are shown. The thin effects observed in Brusselator and stochastic Lorenz model near chaos in a period-doubling bifurcations zone are presented.

The problem of stochastic cycles control based on SSF is considered. The possibilities for formation of stochastic attractor with desired features by feedback regulator are presented. An example of controlling chaos for Brusselator is considered.

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ESTIMATING PHASE EQUATIONS FROM MULTIVARIATE TIME SERIES

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A novel approach is presented for extracting phase equations from multivariate time series data recorded from a network of weakly coupled limit cycle oscillators. Our aim is to estimate important properties of the phase equations including natural frequencies and interaction functions between the oscillators. Our approach requires the measurement of an experimental observable of the oscillators; in contrast to previous methods it does not require measurements in isolated single or two-oscillator setups. This non-invasive technique can be advantageous, for example, in biological systems, where extraction of few oscillators may be a difficult task. We apply this technique to simulated data from prototypical example of coupled limit cycle oscillators. It is shown that our technique enables precise estimation of the natural frequencies and the interaction function from only a single data set. The method is most efficient when data are taken from the non-synchronized regime where the phases of the oscillators are affected by coupling but where no complete phase locking of the oscillators occurs. Applicability to experimental systems is demonstrated by using a network of electrochemical oscillators; the obtained phase model is utilized to predict the synchronization diagram of the system.

STABLE INVARIANT MANIFOLDS OF DYNAMICAL SYSTEMS

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The aim of this work is to establish that, while using the so-called Darboux [1,2] theory of invariant curves (resp. surfaces), algebraic manifolds of dynamical systems provided by a new method [3] of determination based on the use of Differential Geometry properties such as curvature and torsion, are locally (resp. globally) invariant and then, represent local or global first integral of such dynamical systems [4,5]. Conditions for local or global invariant are given. Moreover, it is also established that existence in the phase space of such invariant algebraic manifolds ensures stability of trajectory curves evolving in their vicinity and so, geometrically structure the attractor. Applications to various examplles and particularly to Chua's piece wise linear model and Chua's cubic model exemplify this statement.

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THE COMPLEX NON RESONANT DOUBLE HOPF DEGENERACY: AN ALTERNATIVE APPROACH

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The dynamics close to one complex codimension-two Hopf degeneracy, known as the non resonant double Hopf bifurcation (DH), is analyzed. This singularity appears in several engineering models, especially those concerning with coupled oscillators in electrical and mechanical systems. A frequency domain methodology is applied and then the so-called graphical Hopf theorem is used to detect its nearby dynamic bifurcations. The emerging periodic solutions are approximated using higher order harmonic balance techniques. Thus, the stability change of the limit cycles is checked through the evolution of the eigenvalues of the monodromy matrix under a suitable parameter variation. Particular local cyclic bifurcations are connected with this singularity, mainly originated by a Neimark-Sacker type. This scenario includes naturally the appearance of quasiperiodic solutions (or 2D tori), in what is recognized as the simple case type of the DH. The complex case, which is related with the bifurcations of the mentioned 2D tori, has been considered specially. The frequency approach in conjunction with normal form theory has enabled to recognize certain regions in the parameter plane close to the singularity, in agreement with well known classical results. Moreover, these complementary techniques have allowed to prove the existence of a region of the parameter plane where 3D tori can be found. For completeness, cyclic fold and period-doubling bifurcations, codimension-one Hopf degeneracies and some resonances have been found close to the DH in a doubly LCR coupled electrical circuit. All the outcomes have been contrasted with LOCBIF software.

Nonlinear Observer-based Synchronization of Neuron Models

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Multiple subsystems are required to behave synchronously or cooperatively in many areas. For example, synchronous behaviors are common in networks of (eletro-)mechanical systems, cell biology, coupled neurons, and cooperating robots. This paper presents an observer-based nonlinear feedback scheme for synchronization among Hindmarsh-Rose models which have polynomial vector fields. To this end, first we show that the problem is equivalent to finding an asymptotically stabilizing control for error dynamics which is also a polynomial system. On the basis of the previous result which uses full state information of the other model, we propose a certainty-equivalence control for the error dynamics. In other words, it is shown that the observer error linearization method can be applied to the error dynamics and that the error variable converges to zero due to the stable observer error dynamics and the globally asymptotically stable error dynamics.

VECTORIAL CONTROL OF ASYNCHRONOUS MACHINES PRESENTING THE DEFECTIVE BARS ROTOR

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With progress of the electric genius, the asynchronous motors replace more and more the engines with requiring D.C. current in the electrical drives. The machine is controlled from variable speed with the constraints of operation that supposes. The asynchronous machine, whose only electric entry is on the stator, poses problems for its control. The scalar control is the oldest method used for the asynchronous machine control. The simplicity of implementation of this method makes it prefer in systems not requiring operations at very low speed and strong torque. In the contrary case, it is necessary to call upon the vectorial method to obtain high performances and to improve the dynamic behavior of the machine. . In this article, we present modeling as well as the vectorial control of the machine when a defect occurs in the machine. We will then see the effect of the rupture of the bars on the instructions of control.

We studied also in this article the influence of a rotor defect (rupture of bar) on the current stator. The association of the model multi rollings up and that of Park enabled us to carry out the simulation and the control of the machine in presence (or not) of a defect. In fact, the presence of the defect to the rotor results in undulations of the electromagnetic torque. We approached the influence of the control on the asynchronous machine response which presents rotor defects.

MASTER EQUATION APPROACH TO MODELLING MULTI-STATE MEMORIES AND PROCESSORS

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A master-equation approach is used to study phase-change processes that describe various operating regimes of optical and electronic processors and multi-state memory devices. The model is able to predict the behaviour of phase-change materials in energy accumulation and direct overwrite regimes, thus providing a background for future device design and evaluation. We compare the theoretical results with experimental observations and discuss possible further developments of the model.

ON MINIMAX ESTIMATING HILBERT RANDOM ELEMENTS*

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The problem of designing optimal algorithms for estimating random elements has received earlier considerable attention. Basically, the works devoted to the infinite-dimensional estimation problems deal with linear procedures and do not discuss the efficiency of nonlinear estimates. On the other hand, the nonlinear optimal estimation algorithms are essentially based on using the true distribution of the random elements involved. Nevertheless, these obstacles of optimal methods can be overcome by means of a minimax approach. Actually, even though the class of estimators contains all nonlinear transformations, the minimax estimate turns to be linear under very broad assumptions. In the finite-dimensional case, this result holds whenever the covariances of the model parameters are supposed to belong to a compact set. Furthermore, it turns out that for the uncertainty set under consideration the least favorable distribution is Gaussian. In this paper, the analogous results are proved for the infinite-dimensional model. Using the technique of dual optimization we provide the sufficient conditions for the minimax estimate to be defined analytically via a solution of the dual optimization problem. Thus, if the least favorable covariance (i.e., the solution of the dual problem) is found, the minimax estimate should be designed as the optimal one. For numerical calculation of the minimax estimate we present the recursive algorithm which takes into account only finite-dimensional transformations of the observed random element.

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BOUNDS FOR THE SET CONTAINING ALL COMPACT INVARIANT SETS OF THE LINEARLY COUPLED LASER SYSTEM

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In this work we study the localization problem of all compact invariant sets of the 5-dimensional coupled laser system. By a localization we mean a description of a set containing all compact invariant sets of the system under consideration in terms of equalities and inequalities defined in the state space. Our approach is based on using the first order extremum conditions. Nowadays there have been published a number of papers containing a solution of this problem for different chaotic systems. The principal aim of our paper is to examine the localization problem for the coupled laser system. The interest to studies of coupled lasers is due to needs of constructing high power coherent lasers. Besides, now it is well-known that the coupled laser system can exhibit chaos even if each of individual laser systems is stable. Therefore it justifies the appearance of publications containing a dynamical analysis of the coupled laser system. Our main results consist in finding a number of localization sets formed by frusta, a circular cylinder, two parabolic cylinders and some other quadratic surfaces. Parameters of these localization sets are computed explicitly.

MEAN SQUARE STABILITY AND CONTROL FOR INVARIANT MANIFOLDS OF NONLINEAR STOCHASTIC SYSTEMS

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A mean square stability for the invariant manifolds of nonlinear stochastic systems is considered. The first approximation linear systems for invariant manifolds are introduced and a notion of P-stability (projective) is proposed. A criterion for P-stability is obtained.

Mean square stabilization of periodic and quasiperiodic solutions of stochastically forced nonlinear systems is considered. The necessary and sufficient stabilizability conditions are presented. The methods for design of feedback stabilizing regulator for SDEs are suggested. The examples of constructive solving of stochastic control problem are demonstrated.

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OSCILLATIONS AND MULTISTABILITY IN THE ELECTRODE PROCESSES OF PSEUDOHALOGENIDE COMPLEXES OF NICKEL(II) – EXPERIMENT AND THEORY

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Oscillations and multistability in selected electrochemical systems will be described. The description of such systems has some common points with the characteristics of the ac circuits, in terms of the impedance measurements.

The systems under study were the electrolytic processes in which, at the streaming mercury electrode, the thiocyanate and azide complexes of nickel underwent reduction to the respective products. These systems exhibit one or two regions of the negative differential resistance (NDR) in their current-potential characteristics. Accordingly, under appropriate conditions the former system exhibits sustained current oscillations and bistability, whereas the latter one – bistability and, very rarely reported in chemical systems, tristability.

It will be shown how the mechanisms of these processes give rise to such instabilities, particularly to tristability. The experimental bifurcation diagrams will be compared with the theoretical ones. Furthermore, the experimental (Nyquist) impedance spectra of both systems, indicating the possibilities of the respective bifurcations, will be presented and the theory underlying these spectra will be outlined.

The reported phenomena widen the set of electrochemical systems in which complex dynamic behaviors can be observed. In particular, the conditions for the onset of tristability indicate the ways of searching for other electrochemical systems in which such a rarely reported behavior could be found.

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A STUDY ON GLOBAL STABILIZATION OF A CLASS OF DISCRETE-TIME SYSTEMS BY USING SYMBOLIC DYNAMICS

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Chaos, signifying randomness and irregularity, is ubiquitous in nonlinear dynamical systems. The hallmark of chaos is sensitive dependence of the system's state on initial conditions. That is, a small error in the initial conditions can lead to a large error in the state of the system after a finite time interval. In many practical situations it is desirable if chaos can be avoided. The OGY-method was proposed as the first method controlling chaos in 1990, and since then, much related research has been carried out. The principal purpose of chaos control is stabilization of a periodic orbit embedded in an attractor.

Symbolic dynamics is introduced in order to characterize the orbit structure of a dynamical system via infinite sequences of ”symbols”. The study on symbolic dynamics has a long history, and many dynamical systems that are topologically conjugate to symbolic dynamics are known. One of the advantages of using symbolic dynamics is that it is easier to focus on certain properties of a dynamical system. For example, the existence of a periodic orbit with any period can be easily proven, and it is even possible to show there is a dense orbit in the state space. In chaos engineering, symbolic dynamics is used for chaos communication and the targeting problem.

The purpose of our study is global stabilization of a periodic orbit embedded in an attractor for a class of chaotic systems that are topologically conjugate to symbolic dynamics. To this end, first, a control law is designed in the sequence space such that the target periodic orbit becomes asymptotically stable. Next, the control law is transformed to the state space. We also apply the control method to a population model in ecosystem so that the number of individuals is fluctuated in a prescribed periodic way. This work is the first exposition that uses symbolic dynamics systematically in order to design control systems. The use of symbolic dynamics for design is effective in the sense that it is possible to stabilize any periodic orbit with arbitrarily small inputs, which is not an easy task with the conventional state space approach.

Transmission of Information and Synchronization in Active Channels of Communication

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Shannon's Capacity Theorem is the main concept behind the Theory of Communication. It says that if the amount of information contained in a message, to be transmitted through a physical channel of communication, is smaller than the channel capacity, the message can be transmitted with a low probability of errors. This theorem is usually applicable to ideal channels of communication in which the information to be transmitted does not alter the passive characteristics of the channel that basically tries to reproduce the source of information. Here, we show that for active (non-ideal) channels of communication, such as a complex network formed by elements that are dynamical systems (such as neurons, chaotic or periodic oscillators), the information signal entering the network might generate the ideal environment for its transmission by altering the information capacity of the channel. We also show in which conditions synchronization, in an active channel, implies more information transmission. Contrary to the current belief, we show that synchronization does not necessarily imply more information transmission. In particular, networks composed of non self-excitable systems (e.g. Rössler-type oscillators) achieve its maximal capacity to transmit information whenever the elements forming it are in complete synchrony. On the other hand, networks composed of self-excitable systems (e.g. neurons), achieve its maximal information capacity when there is still at least one time-scale which is out of synchrony. Most of the previous results were derived for time-independent chaotic networks. Then, we will discuss under which conditions such results can be extended to non chaotic time-independent networks. Under such conditions, the amount of information that can be measure in one node of the network about a time-dependent arbitrary signal perturbing the network in some other node, is given by the information capacity of an equivalent autonomous chaotic network. Finally, we will discuss which conditions one has to respect in order to construct a network that maximizes the amount of information transmission.

AUTOWAVES ON LOCALLY COUPLED RELAXATION OSCILLATORS

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In this work, we introduced a programmable network with a cloning template in order to generate autowaves. The presented model of the network can be easily implementable. The waves diffract from sources can be located on the network using the inputs of the network. Furthermore new waves on the network have been observed. Propagation of autowaves on the inhomogeneous network, formed by the fixed-state map on the network is presented.

CONTROL MECHANISM OF PHASE SYNCHRONISATION IN OSCILLATORS OF DIFFERENT KIND: EXPERIMENTAL RESULTS

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We demonstrate experimental results on a novel mechanism for controlling the phase synchronisation of coupled oscillators. In a recent paper [Belykh et al., *Physica D*, **200** 81 (2005)] presented a feedback control method for automatic phase-locking of regular and chaotic oscillators. Interestingly enough, this method allows for synchronisation among oscillators of different kind. In the particular set-up considered in our work, we consider a chaotic oscillator (Rössler) and a regular (van der Pol) one. Within this setting, one acts as a master unit, while the other is the slave. The feedback mechanism is implemented in the following way: a multiplier works as a correlator between two variables of the dynamical systems. This mechanism acts separating the sum of the frequencies of both variables and the difference. Only in the case of perfect phase synchronisation (frequency difference equal to zero) the feedback mechanism does not contribute to the dynamics.

We have designed electronic implementations of Rössler and van der Pol oscillators, and coupled them directionally through the feedback mechanism described above. We have experimentally verified that this mechanism can effectively control the synchronisation of both units, even though they have different inherent dynamic properties. We observe that the driven unit synchronises to the controller by means of the feedback mechanism above a critical coupling strength.

It is of particular interest for practical implementations also to consider alternative control mechanisms, that might be more robust to changes in the working conditions. With this aim, we replaced the feedback mechanism for a fuzzy controller. We found that phase synchronisation to master's frequency is also achieved.

DYNAMIC STABILIZATION AND CONTROL OF MATERIAL FLOWS IN NETWORKS AND ITS RELATIONSHIP TO PHASE SYNCHRONIZATION

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We study the self-organization and optimization of conflicting material flows on complex networks as it may take place in the case of vehicular traffic or the supply of goods in a production network. A decentralized control is used to approach a demand-driven switching between "on" and "off" states of the flow in a particular direction at intersections or merges represented by nodes in the corresponding networks. Whereas intrinsic oscillatory instabilities of material flows in networks usually have negative effects on the performance of the overall system, these self-organized oscillations allow to optimally use the available transportation capacity of the network. Under rather general conditions, our control approach leads to phase synchronization of the switching dynamics at the respective nodes, which is studied using a new framework for measuring the strength and homogeneity of frequency locking in networks of oscillatory components.

MULTISCROLL IN COUPLED DOUBLE SCROLL TYPE OSCILLATORS

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A unidirectional coupling scheme is investigated in double scroll type chaotic oscillators that unfolds interesting multiscroll dynamics. Instead of using two self-oscillating systems, in this scheme, double scroll chaos from one oscillator is forced into another similar oscillator in resting state. We explored this coupling scheme in Chua oscillator, a modified Chua oscillator and Lorenz oscillator. We modified the piecewise linear function of the Chua oscillator a little bit to derive a 3-scroll attractor. We observed 4-scroll, 6-scroll attractors in the driven Chua oscillator and modified Chua oscillator respectively in an intermittency regime of intermediate weaker coupling. We extended the coupling scheme to Lorenz system when more interesting multiscroll dynamics (3-, 4-, 5-, 6–scroll) is observed with decreasing coupling strength. One after another additional scroll appears in the driven Lorenz system when the coupling strength is gradually decreased in the weaker coupling regime. The origin of such multiscroll dynamics is explained using eigenvalue analysis and a bifurcation diagram. We present experimental evidences of multiscroll dynamics in Chua circuit and in electronic analog of Lorenz system.

A GENERALIZED MODEL OF ACTIVE MEDIA WITH A SET OF INTERACTING PACEMAKERS: APPLICATION TO THE HEARTBEAT ANALYSIS

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Some models treat the cardiac tissue as an active conductive system, taking into account oscillatory properties of heart cells. In this case the cardiac rhythms can be described on the basis of the dynamical system theory [Loskutov et al., 2004].

In this work we developed a general simplified model describing a network of oscillatory elements coupled by their response to internal depolarization of mutual stimulations. Our primary aim was to keep the model as simple as possible and to introduce a minimal number of parameters. Therefore, in our model the pacemakers are fully characterized by their intrinsic cycle length T. Their interaction is described by phase response curves (PRCs) . At first, we considered two interacting pacemakers to demonstrate the basic concepts of the model. Then we applied our approach to construct a pacemaker network model with global coupling. As a next step, this PRC based model of coupled pulse oscillators was applied to derive an additional, useful for controlling, model of three pacemakers of the cardiac conductive system. Our further intention was to go on to the next level and represent each pacemaker as an ensemble of interacting oscillatory elements. Extrapolation of the approach to the one- and two-dimensional matrices (or lattices) of pacemaker cells allows to construct active media with a set of oscillators coupled to nearest neighbors.

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ATOMIC PROBABILITY AMPLITUDE STABILIZATION WITH FEEDBACK CONTROL OPTICAL FIELD

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We demonstrate the possibility to stabilize the probability amplitude of the upper level for a single quantum two-level atom in a classical optical field with feedback control scheme.

SHELL MODEL OF OPEN-LOOP OPTICAL CONTROL FOR ATOMIC BEAM FOCUSING IN MOMENTUM SPACE

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We propose the simple shell model to describe the focusing of cool atomic beam interacting with open-loop modulated optical field. This model can be applied to form efficient splitting effect in momentum space.

MANIPULATING PHASES OF ALTERNATELY EXCITED SELF-OSCILLATORS: A WAY TO ORGANIZE HYPERBOLIC CHAOS AND SOME OTHER PHENOMENA OF COMPLEX DYNAMICS

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The report is devoted to constructing some models and phenomena of nonlinear dynamics on a basis of a special class of systems composed of two or more coupled oscillators with periodically modulated parameters (S.P.Kuznetsov, Phys. Rev. Lett. **95**, 2005, 144101). The subsystems become active alternately and transfer the excitation each other. Manipulating with phases of the transferred excitation by means of a proper selection of the coupling terms in the equations allows implementation of the desired models and phenomena. This class of systems is of interest as they allow realization e.g. as electron devices, or as systems of other physical nature (in mechanics, laser physics etc.). We present examples manifesting phenomena of nonlinear dynamics represented earlier only by mathematical constructions. In particular, we propose systems with hyperbolic chaos governed in some approximation by maps of Bernoulli and Arnold, a system with robust strange nonchaotic attractor of Hunt and Ott, a system demonstrating phenomena of complex analytic dynamics (Mandelbrot and Julia sets).

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A VARIATIONAL PRINCIPLE FOR STEADY FRICTIONAL FLOW IN NONLINEAR POROUS MEDIA[1]

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A Fermat-like principle of minimum time is formulated for nonlinear steady paths of fluid flow in isotropic porous media. The principle describes an optimal nature of nonlinear paths in steady Darcy's flows. An expression for the total path resistance leads to a basic analytical formula for an optimal shape of a steady trajectory in nonlinear flows of fluid. In the physical space an optimal path ensures the maximum flux or shortest transition time of the fluid through the porous medium. A sort of "law of bending" holds for the frictional fluid flux in Lagrange coordinates, which shows that - by minimizing the total resistance - a ray spanned between two given points takes the shape assuring that its relatively large part resides in the region of lower flow resistance (a 'rarer' region of the medium). This property makes one possible to predict shapes of related "rays" or paths of the fluid flow. This also leads to the description in terms of wave-fronts and related Hamilton-Jacobi theory which is derived in this paper from the optimization algorithm of the dynamic programming method. In a part our approach transfers to the realm of nonlinear Darcy's flows some results obtained in earlier treatments of heat transfer in the energy and entropy representation. However, instead of performing the analysis in the realm of paths, we concentrate on the wave-front description of the fluid flow and the corresponding Hamilton-Jacobi theory. The relevant physical picture refers to tracing of fluid propagation in Lagrange coordinates, where the fluid's flow through the porous skeleton is attributed to motion of the same fluid particles rather than to the fluid's passage through a fixed region of the physical space. When stressing differences between propagation of Darcy's and optical rays, it may be shown that while the simplest optical rays are described by Euclidean and Riemmanian geometry, it is rather Finslerian geometry that is valid for Darcy's rays.

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[1] For the title, try not to use more than 3 lines. Typeset the title in 10 pt Times Roman, uppercase and boldface.
[2] Typeset names in 8 pt Times Roman, uppercase. Use the footnote to indicate the present or permanent address of the author.
[3] State completely without abbreviations, the affiliation and mailing address, including country. Typeset in 8 pt Times Italic.
[4] Typeset author e-mail address in single line.

TAYLOR PREDICTOR IMPROVES CHAOS CONTROLLER

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Control of chaotic behaviours in dynamical systems has become one of the most rapidly developing topics in nonlinear science and engineering in the last two decades. Chaos controllers used for stabilizing unstable periodic orbits (UPO) and/or unstable steady states (USS) are very sensitive to unavoidable latency of the controlling feedback force. When the delay value exceeds some critical value, the controller fails to work.

We have investigated the possibility to improve chaos controller by adding in the feedback loop an analogue Taylor predictor. Analysis shows that even for small latency times, e.g. 10 ns, the derivative control technique fails to stabilize USS of a chaotic system oscillating at the fundamental frequency $f^* \approx 16$ MHz (the mean period $1/f^*$ is about 60 ns). The time lag in the control loop of only 17% does not allow achieving stabilization. Moreover, it gives rise to high frequency parasitic oscillations at about 20 MHz. Meanwhile the inserted Taylor predictor compensates the latency effects and ensures perfect stabilization of the USS. An important result from a practical point of view is, that the prediction time should not exactly match the latency time. In addition, the order of the Taylor predictor should not necessarily equal the order of the circuit, causing the latency effect. The PSPICE and experimental results obtained for a realistic third-order chaotic circuit qualitatively confirm the findings from a simplified mathematical model.

In this paper we employed the simplest RC differentiator based first order Taylor predictor. Evidently, higher order Taylor predictors can be used. In addition, more sophisticated analogue predictors, like active filters based circuits and extended Taylor−Lagrange predictors can be exploited.

Although the investigation has been performed for a specific system we expect similar results for other fast chaotic systems. The Taylor type predictors can be useful not only for the derivative control technique stabilizing USS, but also for various techniques designed to stabilize UPO, e.g. by the time-delayed feedback or by second order resonant negative feedback controllers.

WAVE MEDIATED SYNCHRONIZATION OF NONUNIFORM OSCILLATORY MEDIA

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We characterize the spatiotemporal evolution of a photosensitive Belousov-Zhabotinsky medium that is made up of coupled oscillatory cells with randomly distributed frequencies. The medium evolves from an initial state of multiple wave sources to a synchronized state governed by a single wave source. The synchronization occurs via a competition between the sources, which arises when the oscillators are not identical but have slightly different natural frequencies. The evolution of each cell is monitored to demonstrate frequency and phase synchronization of the inhomogeneous cellular medium, and a simple kinematic description for the advance of the phase-diffusion wave is presented.

EFFICIENCY ESTIMATION OF ITERATIVE CONTROL SYSTEM DESIGN METHOD: THEORETICAL AND EXPERIMENTAL ASPECTS

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In this paper theoretical and experimental aspects of an estimation of a design method efficiency of pulse energy converter (PEC) control systems are presented. The key idea of the proposed method is an iterative application of stage of classical frequency domain design, based on small signal modeling, with a consecutive nonlinear dynamics analysis. This method application and experimental confirmation is demonstrated on an example of control system design of direct current-direct current (DC-DC) buck converter. The result of the proposed method application: settling time was decreased in two times in comparison with the traditional frequency domain design.

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THE SPECTRA AND PSEUDOSPECTRA OF ELECTRIC POWER SYSTEMS

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In the report the application of the quadratic eigenvalue problem in the electrical power systems is examined. The spectra and pseudospectra of an electrical power system are defined. The quadratic eigenvalue problem in terms of the concept of a pseudospectra have a bright future in electrical enegetics. Electrical power systems experience the continuous action of signal and arametric disturbances (large load scatter and fluctuations, short circuiting, unauthorized disconnection of equipment, natural cataclysms, etc) inducing changes in the power station operation mode. The response of a power system to external perturbations is exhibited as variations in operation parameters (changes in the modulus and voltage phases, overcurrents and currents in elements, unstable rotation speed of synchronous and induction machines, etc.). The composition and magnitude of these variations depend on the topology of the circuits of the power system, its parameters (resistance and conduction, controls, characteristics of control devices, etc.) and many other factors, which are innumerable for large power systems. The parameters that are most sensitive to external disturbances are called sensors in electrical energetics. Sensors arise as a result of heterogeneities in a power system. Analysis of a power system and, primarily, its stability and robustness is rather complicated mostly due to the multidimensionality and multi-factor nature of analysis. The modern computation methods developed for the eigenvalue problem are helpful in this analysis.

A NEW APPROACH TO THE THEORY OF HIERARCHIC WAVE-OSCILLATION DYNAMIC SYSTEMS

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A set of new ideas and concepts (which the authors treat as a new version of the theory of hierarchic dynamic systems) are set fort in the article. In turn, the set of hierarchic principles is put in the methodological basis of this theory. As it is shown, a peculiar version of the theory of hierarchic waves and oscillations can be developed on the basis of proposed general theory.

MULTI-HARMONIC TWO-STREAM FREE ELECTRON LASER AS AN EXAMPLE OF THE WAVE-OSCILLATION HIERARCHIC SYSTEM

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It is shown that the multi-harmonic two-stream superheterodyne free electron laser (MTSFEL) can be treated as a hierarchic wave-oscillation electrodynamic system. A possibility of realization of the degenerated (multi-harmonic) version of the effect of superheterodyne amplification of electromagnetic waves in plasmas of relativistic two-stream electron beam is shown, too. Besides that, a new method of generation the femto-second electromagnetic packages is discussed, and a new model of the source of such packages is proposed. The analysis accomplished shown that such source can be constructed on the basis of MTSFEL. Therein, it can be do on the existing today technological level.

APPLICATION OF THE THEORY OF HIERARCHIC WAVE AND OSCILLATIONS TO NONLINEAR ANALISIS OF THE TWO-STREAM INSTABILITY

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***Abstract**. The calculation algorithm for quantitive nonlinear analysis of the multi-harmonic two-stream instability is worked up. It is done using the theory of hierarchic wave and oscillation as a methodical basis. The results obtained illustrate high effectiveness of practical application of the this theory for complex (from calculation point of view) nonlinear multi-harmonic wave-oscillation electrodynamic problems.*

INTRODUCTION

It is well known that nonlinear self-consistent resonant-wave problems in electrodynamics challenge many theorists over the last hundred years. In general case, mathematical description requires taking into account, at the same time, nonlinearity in right-hand parts of corresponding equations, partial derivatives in both their parts, wave nature of initial and boundary conditions etc. Up to now the number of effective methods solving problems of such type was limited [1-10]. These methods include the dispersion nonlinear equation method, the slowly varying amplitude method and a few other less widespread approaches. In studying the nonlinear mechanisms of higher orders (cubic and higher with respect to amplitudes of oscillations) all these methods are either too inaccurate (the method of nonlinear dispersion equation, for instance) or limited in their application (method of slow-varying amplitudes and other similar).

Thus, the problem of developing some new and more conventional approaches and improving the traditional ones is rather topical for the general theory of nonlinear oscillations and waves in electrodynamic systems. This paper to present such kind calculative technology, which, in turn, is based on the new version of the theory of hierarchic waves and oscillations [8-10]. We have referred the method of this group to as the *hierarchic method with use of the averaged transformations*. There are the methods of averaged characteristics, averaging kinetic, and quasi-hydrodynamic equations, the current-density equations methods [8-10], etc. The mathematical arrangement of all these methods is similar. Therefore let us illustrate their main ideas and practical algorithms using the method of averaging characteristics as a convenient example.

1. CONCEPT OF THE STANDARD FORM WITH PARTIAL DERIVATIVES

As analysis shows, the method of averaged characteristics is suitable for asymptotic integration of the *standard form* (or, the same, *standard system with partial derivatives*) [8-10]

$$A'(U,z,t)\frac{\partial U}{\partial t} + \left(Z'(U,z,t)\times\frac{\partial}{\partial z}\right)U + C'(z,t)U = R'(U,z,t)\,, \tag{1}$$

where A',Z',C',R',Z,R are square matrices of size $l\times l$, $U=U(z,t)$ is some vector function in Euclidean *n-dimensional* space R^n with coordinates $\{z_1,z_2,...,z_n\}$, i.e. $\forall z\in R^n z=(z_1,z_2,...,z_n)^T$, $\forall\, z_i \in (-\infty,+\infty)$, $i\in (1,2,\ldots,n)$, $R(\ldots)$ is a given weakly nonlinear periodical (*m*-fold, in general case) vector function, *t* is some scalar variable, for instance, the laboratory time. Therein, it is considered that some hierarchy of the dynamic values (in time or spatial coordinates) could be determined. It is not difficult to prove that in the case of typical electrodynamic problems the standard form (1) can be transformed into so-called *quasi-linear* (with respect to the derivatives!) *homogeneous equation*

$$\frac{\partial U}{\partial t} + Z(U,z,t)\frac{\partial U}{\partial z} = R(U,z,t)\,, \tag{2}$$

where all designations are self-evident in view of (1). Further in this paper we shall be oriented on the studying the standard equations (and systems of equations) of form (2).

CONTROL OF CHAOS AND HOMOCLINIC DYNAMICS OF THE VIBRONIC LASER

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It is known that chaotic behavior may exhibit in the autonomous nonlinear systems with at least three dynamical variables. Lasers constitute good examples of the experimental realization of such systems. In the class B lasers, described by two variables, the third variable has to be introduced additionally, e.g. the pump or loss modulation, feedback or saturable absorber. Herewith we present the model of the class B laser system, in which the third variable is the intrinsic feature of the material system. It is the solid state vibronic laser, in which the laser transition takes place between the vibrationally broadened electronic levels of the gain center, thus the laser action is accompanied by the creation or annihilation of the host lattice phonons. We treat the number of nonequilibrium host lattice phonons, involved in the laser operation, as the dynamical variable competitive to the number of optical photons, governing the laser operation and the laser stability. Moreover we have demonstrated that for certain values of experimental parameters the vibronic laser dynamics can be well described in terms of the homoclinic orbits and Shil'nikov chaos. The evolution of homoclinic orbits and chaotic dynamics of the system can be controlled by such parameters like power of the pump laser and the wavelength of the pump laser. The dependence of the pump wavelength is crucial in governing the character of the laser output. Thus, for short wavelengths, the system even has no time to oscillate around the unstable attractor. Instead, it starts oscillating between two unstable points and we have to do with self-pulsations of the laser output. For longer wavelengths the system keeps its stability for some time, but the attraction appears to be to weak and the system escapes following the homoclinic orbit. For long enough wavelengths the system exhibits regular CW operation. All cases predicted by us theoretically have been visualized experimentally on the example of the short-cavity alexandrite laser in its vibronic mode of operation. When the alexandrite laser is pumped by Ar-ion laser (short wavelength) its output becomes the train of the self-sustained oscillations. The oscillations have the homoclinic character when we use the second harmonic of the neodymium laser as a pump (medium wavelength), whereas in the case of the Kr-ion laser pump (long wavelength) the output of the alexandrite laser reaches its continuous state after few relaxation oscillations.

Moreover we present the possibility of control of the nonlinear dynamics of the system and the transition to chaotic behavior by means of the optical feedback.

NEGATIVE DIFFERENTIAL CONDUCTIVITY OF A SYSTEM DUE TO DEVELOPMENT OF TURING STRUCTURE

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It is well known that conducting systems can manifest a multi-valued current-voltage characteristics, which is specified as the appearance of the negative differential conductance (NDC). At the presence of the NDC, the homogeneous state of a spatially extended system may become unstable, while there may grow spatially non-homogeneous fluctuations. This results in the appearance of a dissipative structure. In semiconductor electronics, classic examples of dissipative structures are current filaments in devices that demonstrate the current voltage characteristic (CVC) of *S*-type and domains of high electric fields in samples showing the *N*-type CVC, see, e.g. [1].

In the present study, an example is considered where a dissipative structure itself is responsible for formation of the NDC of a system. The phenomenon is observed at studying a two-component reaction-diffusion model introduced earlier to interpret the occurrence of pattern formation in planar semiconductor-gas discharge devices [2]. A brusselator-like variant of the model is analyzed, where the global NDC does not exist. However, the spatially homogeneous state becomes unstable due to the diffusion (Turing) mechanism when control parameter reaches a critical value. In particular, the studied model demonstrates the existence of stationary localized states [2] in the subcritical domain, which are dissipative solitons (DS) [3].

The growth of the dissipative structure may proceed via the self-completion scenario, where an initial DS serves as the source of nucleation of a spatially extended Turing phase. Formation of a large amplitude structure is accompanied by essential increase of the overall activator quantity, which gives rise to increasing the conductance of the system. When an external load is incorporated into the theoretical model, the presence of the NDC of the *S*-type can be revealed, when solving equations numerically. It is suggested that complicated scenarios of further spatiotemporal self-organization can be realized due to the NDC. As an example, there can appear the oscillatory dynamic of a system, where Turing patterns exist in the bursting mode.

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A COMPARISON OF COLLISION AVOIDANCE METHODS EFFECTIVENESS IN A MOBILE AD-HOC NETWORK

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Wireless transmission is an increasingly more and more popular method of information exchange – almost every portable computer is equipped with some means of wireless transmission. In wireless networks, several problems appear that are not known from wired networks, but play an essential role for the efficiency and stability of medium access control protocols. Their influence can be especially observed in ad-hoc networks. These networks have irregular and rapidly changing structure and they suffer from lack of supervisory control station that coordinates operation of remaining stations.

In this article, two collision avoidance methods for wireless networks are discussed, namely, busy tone sensing and control information exchange. They seem completely different, but in fact are quite similar to each other. In both methods, a part of transmission band is sacrificed for sending of additional control information, defining link status. The difference, however, lies in the way the information is sent. Busy-tone based method keeps notifying of link status continuously during entire data frame transmission, while exchange of control frames, which allow determine link status, only precedes data transmission. Although it does not affect the networks that are either stationary or contain small number of stations of limited mobility, in case of complex ad-hoc network with large number of highly mobile stations it may cause network efficiency degradation.

Due to Raleigh and Rice fades, a mobile station traveling nearby the receiver's range continuously disappears and reappears in this range. If the receiver protects data transmission by busy tone, the mobile station is aware of this transmission every time it falls into range. If the receiver uses control frames exchange, it is quite likely that the mobile station will miss such a control frame due to fading.

In order to make collision avoidance effective, control frame transmission time must be less than the time between fades observed by a mobile station. It depends on radio frequency, transmission rate, some physical layer details and velocity of the mobile station. In the paper, a criterion is presented that shows when control frames exchange may be effective in a mobile ad-hoc network. Example calculations are done with data of IEEE 802.11 standard in its basic version.

COMPENSATION FOR THE IRON LOSS EFFECT IN EKF-BASED SPEED ESTIMATION OF VECTOR CONTROLLED INDUCTION MOTORS

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In vector controlled induction motor drives, the instantaneous rotor speed is measured using whether sensors or estimators. However, the use of speed sensors has two fundamental drawbacks, namely: cost and sensibility. For this fact, many methods have been suggested to estimate the motor speed, all of them may be classified under one of the following major techniques: open loop methods, MRAS methods, observer based methods, non-linear observers and artificial intelligence based methods. Since the basic Kalman filter is a state observer, its use in vector controlled schemes has received much attention. However, these schemes are based on the assumption that the existence of iron loss in an induction motor may be neglected. The paper shows the effect of iron loss on the extended Kalman filter performance that is designed on the basis if the ironless induction machine model. Simulation results are carried out to demonstrate this effect as well as the effectiveness of the suggested approach to minimise the speed estimation error without modifying the observer algorithm.

PRACTICALLY STABLE OBSERVER-BASED SYNCHRONIZATION OF DISCRETE-TIME CHAOTIC SYSTEMS OVER THE LIMITED-BAND COMMUNICATION CHANNEL*

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The paper is devoted to the synchronization problem of the discrete-time chaotic systems, coupled by the link ("*the communication channel*") with the limited bit-per-step rate. The observer-based full-order coder is designed, ensuring decay of the synchronization error asymptotically for the case when channel imperfections and computation errors are neglected. This result complies with the statement, that that if the capacity of the channel is larger than the Kolmogorov-Sinai entropy of the driving system, then the synchronization error can be made arbitrarily small.

It is shown that if the computations in the both master and slave nodes of the channel are identical, the synchronization error can be made close to the maximum achievable accuracy of the given computer (*computer epsilon*) depending only on the number of digits in the computer. Such a phenomenon can be called *practical synchronization*, by analogy with practical stability: the limit absolute value of synchronization error decreases unlimitedly if the accuracy of the computation increases unlimitedly. If the calculations in the coder and decoder are not identical (e.g., if the computers on these nodes have different number of digits), after the some time interval of decreasing the synchronization error, the mis-synchronization occurs due to unstable properties of the chaotic systems. For this case, the practical synchronization may be ensured applying the fixed-point arithmetic calculations.

The result is demonstrated by synchronization of chaotic Hénon systems.

Similar results for continuous-time systems were obtained (*A. L. Fradkov, B. Andrievsky, R. J. Evans*, Physical Review E, **73**, 2006, 066209).

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ALGORITHM OF MULTIPLE SYNCHRONIZATION FOR TWO-ROTOR VIBRATION UNIT WITH TIME-VARYING PAYLOAD

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New opportunities for development of vibration equipment, especially for vibrational transportation of materials can be provided by using multiple synchronous modes. It keeps constant the ratio of average velocities and/or phases of vibroactuators. In this paper an algorithm of multiple synchronization of two-rotor vibration unit with time varying payload is proposed. A time-varying payload attached to a platform allows to analyze dynamics of processing material. The speed-gradient algorithms developed in control engineering area have been applied previously to control of oscillatory motion and particularly to control of vibration units (Tomchina O.P, Kudryavtseva I.M. Controlled Synchronization of Unbalanced Rotors with Flexible Shafts in Time-Varying Vibrational Units. Proc. 2nd Intern. Conf. “Physics and Control”, IEEE, St.Petersburg, 2005, pp.790-794). In contrast to the previous results, in this paper a new goal variable – multiple difference of rotor velocities - is introduced. It allows the control system to stabilize the multiple synchronous rotation mode. For practical implementation of the algorithm it is important to ensure its stability and performance under restrictions imposed on the controlling torques, determined by the nominal power of driving motors.

It is demonstrated by intensive simulations that a stable multiple synchronous mode in vibration units is maintained with changing payload mass. It holds if the unit is loaded in a synchronous mode and controlling torques are bounded. The main dynamical properties of the multiple synchronous mode do not depend on the rate of payload mass changing and synchronization tim*e* is less than *3 – 4 s* if the unit is loaded in synchronous mode. Comparison of systems with bounded and unbounded controls shows that the system dynamics in both cases are equivalent. They differ only by the number of rotor turns made before the multiple synchronization is achieved. The final payload mass varies in our simulations up to the value of *25%* from the mass of the supporting platform which is equal to *9 kg*. The maximum rate of the payload mass change is $V^*=0.33 kg/s$. Instant values of controlling torques varied from *0,8* to *13 N·m*. In addition, the case of bounded controlling torques was studied, with upper bounds of controlling torques varying from *1* to *3 N·m*. In all cases the phenomenon of the multiple synchronization phenomenon was observed.

New opportunities for development of vibration equipment, especially for vibrational transportation of materials can be provided by using multiple synchronous modes. It keeps constant the ratio of average velocities and/or phases of vibroactuators. In this paper an algorithm of multiple synchronization of two-rotor vibration unit with time varying payload is proposed. A time-varying payload attached to a platform allows to analyze dynamics of processing material. The speed-gradient algorithms developed in control engineering area have been applied previously to control of oscillatory motion

STUDYING THE ISLANDS OF STABILITY IN A TOKAMAK WITH ERGODIC MAGNETIC LIMITER USING KAM THEORY

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The Ergodic Magnetic Limiter (EML) is used to generate chaotic magnetic field lines in the vicinity of the tokamak inner wall. The EML is a device designed to generate external magnetic fields which interact with the equilibrium tokamak field and cause a selective destruction of magnetic surfaces. Magnetic field lines dynamical behavior is studied by means of a two- dimensional symplectic map which is derived analytically. We have studied the poincare' surface of section for different values of perturbation parameter "p" and magnetic shear "s".When the perturbation strength "p" increases the poincare' surface of section begins to show besides the KAM tori, also higher order islands, which are structured around periodic orbits of the symplectic map with higher integer periods. The fixed points of period one and two are determined and the results are compared with the bifurcation diagram of this map. The location of the fixed point is important information since they identify islands positions and separations. With the help of KAM theory, we could obtain the rotational number of the magnetic islands and the epicyclic frequency for the secondary islands by using continued fraction which is observed in the poincare' surface of section. The size of an island of stability depends on the last KAM torus. As the perturbation parameter "p" increases the size of a given KAM curve increases. With decreasing the values of shear parameter "s" the width of the islands is increased.

VARIABLE STRUCTURE MRAC FOR A CLASS OF MIMO SYSTEMS

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A Variable Structure Model Reference Adaptive Controller using state variables is proposed for a class of multi input–multi output systems. Adaptation law is of variable structure type and switching functions is designed based on stability requirements. Global exponential stability is proved based on Lyapunov criterion. Transient behavior is analyzed using sliding mode control and shows perfect model following at a finite time.

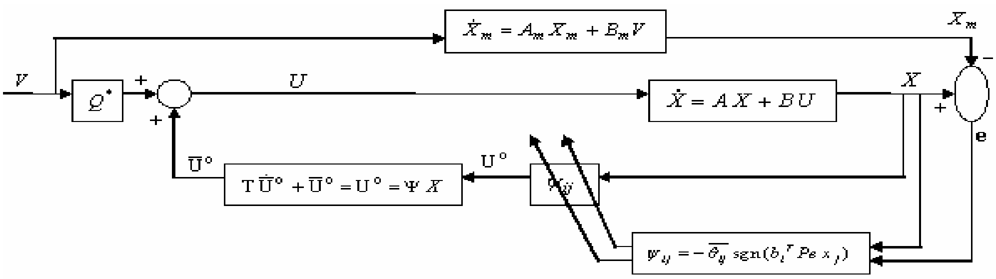
Consider a linear time variant plant with unknown parameters, which their bounds are known. Let the plant be of n-th order with accessible states and described by the differential equation

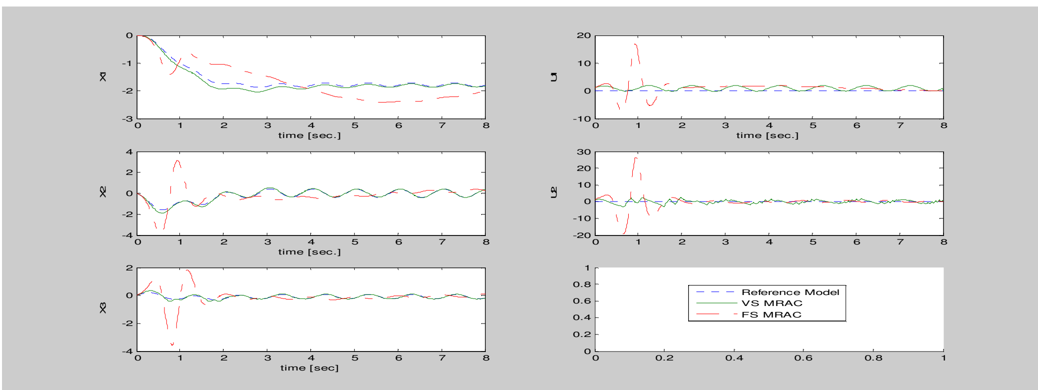
$\dot{X} = AX + BU$ where $n \times n$ matrix A matrix is unknown and of full rank, while the $n \times m$ matrix B is assumed to be known and partitioned as $B = [b_1 \quad b_2 \quad \dots \quad b_m]$. U is a m-dimensional control vector, and (A,B) is controllable.

The reference model is characterized by the linear time invariant differential equation $\dot{X}_m = A_m X_m + B_m \mathrm{V}$ where A_m is a $n \times n$ asymptotically stable matrix, B_m is a known matrix, and V is a m-dimensional input vector with bounded elements. The purpose is to find control U such that the state error $e = X - X_m$ exponentially tends to zero in a finite time.

The control U to the plant, is generated introducing control law $\mathrm{U} = \Psi X + Q^* \mathrm{V}$ where $m \times n$ feedback matrix Ψ, with the elements ψ_{ij} are adjusted using VS approach by designing switching functions ψ_{ij}. introducing the switching functions ψ_{ij} as $\psi_{ij} = -\overline{\theta_{ij}} \operatorname{sgn}(b_i^T Pe\, x_j)$, $\overline{\theta_{ij}} > |\theta_{ij}^*|$.

This controller has some significant advantages compared to the conventional model reference adaptive controller. Global exponential stability is proved without requirements on persistence of excitation. Then it was shown that, it is always possible to introduce sliding mode into the system. Transient behavior was analyzed and showed perfect model following at a finite time. Insensitivity with respect to input disturbances was investigated and showed preference to the conventional schemes. Simulation was presented to clear the theoretical results. simulation results are presented to show the performance of the proposed schemes and comparing these with the conventional schemes.





Noise- and delay-induced dynamics near a global bifurcation

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A generic model exhibiting a saddle-node bifurcation on a limit cycle is investigated. The model has served as a prototype example of excitability, strongly related to the existing global bifurcation, and coherence resonance, when a stochastic force is added. We extend the system including time-delayed feedback control according to the Pyragas scheme and study it both in the presence and absence of Gaussian white noise. We find that the delay itself is able to create multistability of periodic orbits and the fixed point. Homoclinic bifurcations, period-doubling and saddle-node bifurcations of limit cycles are found in accordance with Shilnikov's theorems. A bifurcation diagram in the $K-\tau$ plane is given (K being the strength of the control force and τ the time delay). Finally, we switch on Gaussian white noise. We compare our results to those of the uncontrolled system, in particular, the coherence resonance curve and features of the oscillations and the corresponding power spectra.

PHYSICAL QUANTITIES SENSORS PARAMETERS MEASURER

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The task of operating speed measuring instruments (MI) creation is very important, especially in systems of centralized acquisition and processing of measuring information. Usually the operating speed of MI, as of metrological system, is determined mainly by response of sensor (primary measuring converter) - the least operating speed node MI. Owing to wider use of various physical quantities sensors in engineering the question of their output parameters (R, L, C) measuring obtains the primary significance. In this paper it is described the mode and device allowing to determine measuring circuit (MC) parameters by separate instant value of transient in the circuit at connection to it the voltage of direct current (dynamic measuring method).The unknown parameter is determined by results of two measurings at arbitrary value of reference voltage. In this case the measuring time doesn't depend of time constant of circuit unknown element, but is determined mainly by instant values measuring time of transient and realization of measured values processing algorithm. The realization of proposed measuring mode allows to provide high operating speed and to raise the measuring accuracy. The measurer can be used in systems of centralized acquisition and processing of measuring information.

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THE EFFECT OF HIGHER ORDER HOPPING INTEGRALS ON PERSISTENT CURRENT OF A MESOSCOPIC NORMAL METAL RING

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For the last few decades, many probes have been concentrated on magnetic response of mesoscopic normal metal rings and have been obtained many exotic results as a consequence of phase coherence of the electrons in the mesoscopic scale.

We have used the tight-binding model to describe a mesoscopic normal metal ring with N sites, and the Hamiltonian in this model can be achieved as follows:

$$H = \sum_i \varepsilon_i c_i^+ c_i + \sum_{i \neq j} v_{i,j} [e^{i\theta_{ij}} c_i^+ c_j + h.c.]$$

where ε_i 's are the on site energies and the phase factors are $\theta_{ij}=2\pi|i\text{-}j|/\Phi_0 N$. We have taken the hopping integral between any two sites i and j; in the form $v_{ij}=v exp[\alpha(1-|i-j|)]$, where v is the hopping strength between any two neighboring sites. By using this Hamiltonian, we have evaluated the total persistent current for the mesoscopic normal metal ring. We have presented the diagrams of the total persistent current versus the magnetic flux that show saw-tooth behavior which are diamagnetic for even or odd number of electrons.

We have also obtained the difference between persistent currents of various successive order hopping integrals versus the magnetic flux for even or odd number of electrons.Whenever this difference approximately approaches to zero, we can neglect the higher order hopping integrals in calculation of the physical transport properties of the system and as a result, the enough number of hopping integrals is intensively depends on the number of electrons in the ring.

DISSIPATIVE PROCESSES AT PHASE SYNCHRONIZATION IN THE NONLINEAR OSCILLATORS' LATTICE AND HEAT EMISSION AT THE PREMELTING STAGE

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Synchronization processes in 2D lattice of coupled Rossler oscillators are studied. Computational modeling was carried out for the system with dimensions from 5x5 to 500x500 of oscillators with periodic boundary conditions. Euler method with the time step of 10^{-3} was applied for modeling; frequency spread of the oscillators was $\Delta\omega=0.1$. It was determined that the systems with dimensions 5x5 ÷ 10x10 of oscillators are capable of full synchronization at certain coupling force values. An increase of system dimensions leads to clustering effect: at some threshold values of γ parameter separate synchronized areas with different lifetime form in the system. Starting from the oscillators' dimension of 50x50 there are no qualitative dynamic changes in the studied system. Dependence of synchronized cluster fraction on the chaotic mode and the coupling parameter has a threshold character. At the same time the part of the synchronized oscillators with a long lifetime even in intense chaos conditions reaches 5-10%. The synchronization effect is accompanied by potential energy decreasing of the system which turns to kinetic oscillators' energy. The transition of a part of nonlinear oscillator interaction potential energy into kinetic energy can be used to explain the experimentally observed heat emission effect when approaching the melting point of crystalline substances. The given qualitative model of premelting process of crystalline substance using phase synchronization of thermal atom vibrations as the main mechanism allows explaining such experimentally observed premelting effect features as a possibility of appearance of both endo- and exothermal effects, macroscopic fluctuation ability, existence of temperature rage of premelting effect onset.

ONE SIDE INVERTIBILITY FOR IMPLICIT HYPERBOLIC SYSTEMS WITH DELAYS

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This work deals with left invertibility for implicit hyperbolic systems with delays in Hilbert spaces which are either left or right invertible (hereafter called "one side invertible") and described by

$$(\Sigma)\begin{cases} E\ddot{z}(t)+\alpha\dot{z}(t)+A_0z(t)+A_1z(t-h)=Bu(t)\\ y(t)=Cz(t)\end{cases}$$

where $z(0)=0$, $\dot{z}(0)=0$ et $z(t)\equiv 0$, $\forall t\in[-h,0[$, $h>0$, $\alpha\geq 0$, E, A_0, A_1, B and C are linear (unbounded) operators on real Hilbert spaces. The system (Σ) can be rewritten as follows:

$$(\widetilde{\Sigma})\begin{cases} \widetilde{E}\dot{w}(t)=\widetilde{A}_0w(t)+\widetilde{A}_1w(t-h)+\widetilde{B}u(t)\\ \widetilde{y}(t)=\widetilde{C}w(t)\end{cases}$$

As usual, u, w, $\widetilde{y}$ represent respectively the input, state and output of the system $(\widetilde{\Sigma})$.

The setting is very general in the sense that $\widetilde{E}$ is not invertible, $\widetilde{A}_0$, $\widetilde{A}_1$are unbounded operators, $\widetilde{B}$ and $\widetilde{C}$ are restricted to be bounded, uniqueness of the solution is not required, and an explicit solution, will even not be demanded. The concept of left invertibility is the problem of determining the conditions under which a zero output $y(.)$ corresponding to a zero initial state ($w(0)=0$) can only be generated by a zero input $u(.)$.

The aim of this paper is to extend this notion in the direction of infinite dimensionnal linear systems with delays and to give necessary and sufficient conditions for the system to be left invertible. Furthermore, from a decomposition procedure, invertibility for this class of systems is shown to be equivalent to the left invertibility of a subsystem without delays.

EXCITATION OF RESONANCE PHENOMENA DURING THE MAGNETRON SPUTTERING OF THIN METALLIC FRACTAL FILMS

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Application of nano-dimensional objects with the fractal self-similar structure presents wide field for their application in the most different devices. For understanding of their nature and behavior it is necessary to consider the phenomena, which earlier into the examination did not start. Also should be searched for the new methods of their description with a simultaneous study of the properties of such objects. . In this case should be isolated not only physical properties as, for example, electrical conductivity. Should be also investigated both geometric properties and their connection with the physical properties. . It was revealed the anomalous behavior of thin films and the effect of "memory", which was expressed in the "memorization" of the highest value of resistance, achieved with the heating by the films with the self-affine structure of surface. This effect is explained by the registered by the authors redistribution of energy in the spectrum in the installation for the magnetron evaporation. In this case are observed the changes in the surface structure of metallic thin film. Studies showed, that the resonance which leads to the redistribution of energy of the fluctuations of electromagnetic field, is the reason for this.

CONTROL OF AN ACTIVE DAMPER BASED ON MAGNETO-SENSITIVE FLUID AND RUBBER

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Magneto-rheological (MR) fluids and magneto-sensitive (MS) rubbers are a class of smart materials whose mechanical properties change instantly by the application of a magnetic field. The damper based on MR fluids is one of the most promising new devices for structural vibration reduction. We present an original model of active MR damper with MS rubber element:

$$\frac{d^2x}{d\tau^2} + \gamma(1+u_f)\frac{dx}{d\tau} + (1+u_r)x = f(\tau) ,$$

where x is the relative axial displacement of the dampers piston, $\tau = (El/m)^{1/2}t$ is the dimensionless time, $\gamma = \nu(mEl)^{-1/2} \ll 1$ is the dimensionless viscosity of the damper without magnetic field, $u_f \approx 1.27\,\delta_f H^2 \left(H_f^2 - H^2\right)^{-1}$ $(|H| < H_f)$ is the additional viscosity of MR fluid and $u_r = k_r H^2$ $(|H| \leq H_r)$ is the additional rigidity of MS rubber in a magnetic field with density H, $k_r = \delta_r \mu_r \mu_0$ is the coefficient of magnetic sensitivity of MS rubber, $\mu_0 \approx 1.26 \cdot 10^{-6}$ is the magnetic permeability of a vacuum, $f(\tau)$ is an external dimensionless force. Here m is the mass of loading damper, ν is the viscosity of MR fluid without magnetic field, l is the length of MS rubber element, μ_f and μ_r is the magnetic permeability of MR fluid and MS rubber, respectively; δ_f and δ_r is the iron particle volume fraction in MR fluid and MS rubber, respectively.

The problems of the parametric control of damping and generation of harmonic oscillations for the presented dynamical system are solved by the Lyapunov method. All theoretical results are based on the theorem about asymptotic stability in reference to the part of variables as well as the Barbashin-Krasovski and Chetaev theorems.

Synchronization of 4 identical chaotic systems

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Synchronization is a general phenomena occuring in systems of coupled oscillators. Many natural systems show synchronous behavior when weak coupling is present between the components of the network but the nature of the coupling is a research topic. Moreover, for artificial networks the possibility of an analytical coupling term is still to be developed. In this work we propose an efficient and new general analytical coupling for a system of four identical oscillators. The algorithm is applied to any system $d\mathbf{x}/dt = \mathbf{F}(\mathbf{x})$ and the network including the coupling has the following form: $d\mathbf{x}_i/dt = \mathbf{F}(\mathbf{x}_i) + (\mathbf{H} - d\mathbf{F}(\mathbf{s}_i)/d\mathbf{s}_i)(\mathbf{x}_i - \mathbf{s}_i)$. The matrix $\mathbf{H}$ is a Hurwitz matrix[a] and can be chosen to be as simple as possible. The network is chosen of all-to-all (each oscillator is connected to all the other), ring (each oscillator is connected only to its neighbours on a ring) and star (a central oscillator connected to the others). For each of these networks analytical terms are proposed and the synchronization is numerically verified. Each oscillator has the form of a system from the Sprott's collection[b]. The conclusion is that the synchronization is achieved faster in all-to-all network than in the ring and star case.

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Closed-Loop Simulation of Kelvin Probe Force Microscopy based on Reduced Finite Element Cantilever Modeling

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In single-pass Kelvin Probe Force Microscopy (KPFM), the contact potential difference (CPD) and the topography of a sample are imaged simultaneously. To this end, dynamic Atomic Force Microscopy (AFM) operation is extended to multi-frequency excitation. In mere AFM application, the microcantilever is mechanically driven at the first normal bending resonance frequency, while nested feedback loops keep the oscillation parameters (amplitude and frequency) constant under the influence of nonlinear interatomic forces acting between the cantilever tip and the sample surface. Especially, in frequency modulation mode (FM-AFM), the frequency setpoint is controlled by adjusting the tip-sample distance to a constant value. Thus, the topographical information is contained in the frequency control signal. In KPFM, the cantilever is additionally excited by an electrostatic force through application of a bias voltage to the cantilever tip. The bias voltage is composed of a static and a harmonic component at the modulation frequency f_{mod}. The resulting electrostatic force at f_{mod} is forced to vanish by adjusting the static component of the bias voltage by an additional feedback control loop. The static voltage then corresponds to the CPD of the surface. In this work, a simulation model of single-pass KPFM is presented. The cantilever dynamics are represented by a reduced order Finite Element (FE) model. This approach allows to accurately describe complicated cantilever geometries which are e. g. suggested to enhance the sensitivity of the simultaneous imaging mode. The closed-loop model of KPFM, which contains all essential electronic components, i. e. demodulation stages and feedback controllers, can be used to test such cantilever geometries under realistic conditions. Furthermore, the model enables the application and evaluation of advanced control strategies. Simulation results demonstrate the operation principle of single-pass KPFM and the effects of uncompensated CPD on topography imaging.

CURVATURE INDEX FAILURES IN THE DYNAMICS OF AN ELECTRIC COUPLED OSCILLATOR

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The stability of a limit cycle emerging from a Hopf bifurcation can be determined by computing the curvature indexes or Lyapunov coefficients. There are several methods to obtain these coefficients but most of them require the system to be previously reduced to the normal form of the Hopf bifurcation. Different techniques, such as Poincaré normal forms, Lyapunov functions, power series expansion, etc., can be applied to achieve the reduction. Nevertheless, in higher dimensional systems this task may be cumbersome. Sometimes, depending on the system nonlinearity, the frequency domain method provides a simpler way for computing analytical closed form expressions to calculate the curvature indexes. This approach uses some well known tools like harmonic balance, Nyquist stability criterion and state space representations.

The dynamics of an electric oscillator is analyzed in this article. The attention is focused on computing Hopf bifurcation curves and the conditions on the physical parameters leading to the first and second curvature index failures. In this example, the analytical expressions of the indexes have been easily obtained using the frequency domain method, since the nonlinearity depends only on one variable of the system. Thus, the frequency domain approach is used to calculate analytical expressions of the indexes to establish the location of the first two curvature singularities and the dynamical scenario emerging from these degeneracies are obtained using AUTO. A relatively complex structure of nested limit cycles has been found near these degeneracies. In addition, some global phenomena including connections of cyclic fold bifurcations and cuspidal points of cyclic fold bifurcations are also described.

Lie algebra on synchronization of different systems: a generalized function for Hodgkin-Huxley neurons

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The goal of this work is to provide some remarks on the diffeomorphisms between vector fields; the Lie algebra of vector fields representing the dynamical model of parametrically different Hodgkin-Huxley neurons. To begin with, the original vector fields are transformed to a linearizable triangular form. These transformations are diffeomorphic and invertible. On these transformed coordinates, it is possible to determine a synchronization function, which allows to describe for the complete synchronization, even in the case of parametrically different neurons. The diffeomorphic transformations are found solving a partial differential equation for the internal dynamics of each vector field. Similar results can be obtained since the neurons are only different on their parameter values. On the original coordinates this complete synchronization becomes generalized, since the synchronization function is obtained from the composition of diffeomorphysm of each neuron.

The contribution of the work is to show that by using Lie algebra, it is possible to explicitly derive a generalized synchronization function for a class of neuron model. The result presented provide information on the synchronization manifold, which is obtained from the relation between the corresponding diffeomorphic transformations. This result can be applied to a network of Hodgkin-Huxley neurons, where the synchronization manifold plays an important role in stability issues.

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Reconstruction of System Dynamics from Short Data Sets

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Abstract

Long data sets are the prime requirement of the time series analysis techniques to reveal the dynamics of various systems. However, acquiring long data sets is always not possible and often we end up with only short data sets. Given the fact, is it possible to extract and understand the complete dynamics of the underlying systems ? This is the question we address in our study. The answer to this question lies on the simple fact that however short the time series may be, it still has some potential to describe something about the system dynamics. We try to harvest the information present in such short data sets using the idea of recurrences in phase space and generate a long time series. The so generated long segments are capable of imitating the dynamics of the underlying systems.

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VARIATIONAL FORMULATION FOR THE OPTIMAL CONTROL PROBLEMS OF ELASTIC BODY MOTIONS

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The initial-boundary problem for the linear theory of elasticity is considered. Based on the method of integrodifferential relations a new dynamical variational principle in which displacement, stress, and momentum functions are varied is proposed and discussed [1–4]. To minimize the nonnegative functional under initial, boundary, and partial differential constraints arising in this approach a regular algorithm for approximation of the unknown functions is worked out. The algorithm gives us the possibility to estimate explicitly the local and integral quality of obtained numerical solutions. An effective numerical method for the optimization problems of controlled motions of elastic bodies with quadratic objective functionals is developed. As example, the 3D problems of optimal longitudinal motions of a rectilinear elastic prism with a quadratic cross section are considered for the terminal total mechanical energy to be minimized. The numerical results and their error estimates are presented and discussed.

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A NEW STRATEGY OF DEFIBRILLATION: SUPPRESSION OF THE SPIRAL WAVE TURBULENCE BY MOVING PACEMAKER(S)

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The suppression of the turbulent dynamics of excitable media, which appears through a set of coexisting spiral waves, by means of a small periodical (almost) point excitations is a very important area of current investigations in view of application in cardiology. The dominating hypothesis in the current theory of excitable systems is that fatal cardiac arrhythmias, fibrillations, occur due to the creation of numerous autowave sources, spiral waves or vortex structures (i.e., spatiotemporal chaos, see, e.g., [1] and references therein), in cardiac tissue.

The current methods for stabilizing such regimes by means of single electrical pulses (including those from implanted defibrillators) are very inflexible and are not necessarily successful. However, recent investigations open new possibilities. A large-amplitude pulsed action is not directly necessary and can be weakened in a number of cases [2]. Moreover, the turbulent regime in many excitable media can be stabilized by a weak periodic parametric [3, 4] or force actions (pacing) applied to certain medium regions [5-7].

However, main disadvantage of all these methods is that suppression strongly depends on the phase of the pacing and the location of the external electrode. In our present investigations we show that these dependencies can be eliminated if we use slowly moving pacemaker(s). This new strategy of defibrillation seems to be more effective therapy in practice because in this case the overall success rate is higher.

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Entanglement generation by dispersive interactions

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We have study the dynamics of the entanglement between two non interacting two-level atoms weakly coupled and far from the resonance with the same single mode field. We find that a dispersive vacuum can generate maximum entanglement between them when there is a single photon to share. We emphasize that in the dispersive regime, the atomic energy is not exchanged with the single mode, so the single mode is required to be only the mediator between the two two-level atoms effective interaction. This effect can not be generated by classical field because classical fields can not couple the two atoms, at any intensity. When they are initially in a type of Werner state, the entanglement is in general zero at high energy, but the so called *Entanglement-beats* effect take place and the narrow beats are separated by the *Entanglement Dead Valleys*. In other words, in that regime, the initial entanglement amount is periodically recovered in a sudden manner, only for a short moments separated by the time scale $\pi\Delta/g^2$. The wide of a E-beat is inversely proportional to the energy of the single mode. Besides, in that atomic initial condition the entanglement does not change when the single mode is initially in the vacuum state. However, we have already seen that the vacuum initial state makes an important effect when each atoms starts in a pure state. A physical implementation of this Hamiltonian interaction between two two-level system and a single mode can be performed with two quantum dots interacting with a boson mode. Another physical implementation could be implemented considing the Zeeman's level structure in a ^{138}Ba cold ion moving in a linear Paul trap in a standing wave configuration.

OSCILLATION CONTROL OF A PENDULUM WITH SLIDING MASS AND PERTURBATION IN THE PIVOT

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We present a controller design based on parametric resonance concepts for a pendulum with erratic bounded motion of the support point and an actuator consisting of a sliding mass along the bar. The control algorithm is supported on relations of potential/cinematic energy in synchronized manner according to principle of parametric resonance. In this way, the induced nonlinear oscillation of the pendulum is damped down using a generic control law. A bifurcation study is made for the Simulations and lab experiments with a prototype illustrate our approach.

QUALITATIVE BEHAVIOR PREDICTION OF TRANSITION STATES IN A CONVECTION LOOP

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In this work a procedure to qualitative long-term prediction of limit sets of a convection-loop system is presented. The procedure employs estimation of system parameters of a previously defined process structure with time-varying coefficients and an interpolator to track in advance the path of the parameter vector on a basin of stationary limit sets. Numeric simulations with a convection-loop system illustrate the features of the approach.

Efficient control of excitability to prevent the spread of pathological activity

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Spatio-temporal excitation patterns in various neurological disorders constitute examples of excitable behaviour emerging from pathological pathways. During migraine, seizure, and stroke, an initially localized pathological state can start to spread indicating a transition from unexcitable to excitable medium. We investigate this transition in the generic FitzHugh-Nagumo (FHN) system of excitable media. Our goal is to define an efficient neuromodulation minimizing the volume of invaded tissue. The question of such a therapeutic optimization is whether structures in control theory can be treated as a structure in differential geometry by regarding parameter plane S of the FHN system as a differential manifold endowed with a Riemannian metric. We suggest to equip S with a metric given by pharmacokinetic-pharmacodynamic models of drug receptor interaction.

Non-holonomic distributions and dynamical systems

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A distribution Δ of rank k on a smooth n-dimensional manifold M is a smooth rank k sub bundle of the tangent bundle T M. The iteration of the Lie bracket of vector fields in Δ yields the flag of modules of vector fields $\Delta^1 \subset \Delta^2 \subset \cdots \subset \Delta^l \cdots \subset \mathrm{T\,M}$, where $\Delta^1 = \Delta$ and $\Delta^{i+1} = \Delta^i + [\Delta, \Delta^i]$. The distribution is said to be non-holonomic or bracket generating, if for each $p \in \mathrm{M}$, there exist a positive integer m for which $\Delta_p^m = \mathrm{T}_p\,\mathrm{M}$.

We take $\mathcal{G}$ to be the Lie algebra $\Delta_p^m = \mathrm{T}_p\,\mathrm{M}$, and we shall assume that $\mathcal{G}$ is nilpotent. An inner product in $\mathcal{G}$ determines a natural decomposition $\mathcal{G} = \mathcal{H}_p \oplus \mathcal{V}_p$, in terms of the horizontal vector space $\mathcal{H}_p = \Delta_p$ and the vertical vector space $\mathcal{V}_p = \mathcal{H}_p^{\perp}$.

An absolutely continuous curve $t \mapsto p(t)$, is said to be horizontal, if $\dot{p}(t) \in \Delta(p(t))$, almost everywhere. A sub-Riemannian metric on is defined by a smooth varying inner product $p \mapsto \langle \cdot, \cdot \rangle_p$ in $\Delta(p)$. For horizontal curves the length and the energy functionals are defined as usual, and for curves parametrized by arc-length, the variational problems for both are equivalent.

In this paper we consider nonlinear dynamical systems given by a non-holonomic distribution of real vector fields. We approach the problem as a sub-Riemannian geodesic problem, that is, the one of minimizing the energy functional in the class of horizontal curves. We use the Hamiltonian formalism to set the problem as an optimal control problem, we integrate some cases of the Hamiltonian equations and derive some geometric properties of the geodesics.

INFLUENCE OF INTRINSIC NOISE ON THE PROGRESSION OF PROCARYOTIC GENE EXPRESSION

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It is by now an established fact that intrinsic noise of biochemical reactions plays an important role in cellular processes. Such fluctuations cause, for example, phenotypic variability in populations of isogenetic cells. Moreover, noise can potentially attribute to the long-term accumulation of gene regulatory defects with age by inducing unfavorable, rare, yet possible, transitions events between system states.

Stochastic modeling approaches, using the framework of the chemical master equation (CME), are thus necessary to correctly identify and describe these processes.

Here, we investigate the influence of noise on the long-term temporal dynamics in prokaryotic gene expression.

A novel approach to solving the CME is presented that establishes the use of phase-type (PH) distributions in biological systems. We show both through modeling and experiment that the event times to reach certain gene product, i.e. protein, concentrations are phase-type (PH) distributed.

[1] Typeset names in 8 pt Times Roman, uppercase. Use the footnote to indicate the present or permanent address of the author.

OPEN LOOP CONTRO OF LYAPUNOV EXPONENTS IN FIXED POINTS OF NONLINEAR OSCILLATOR

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Here we discuss the case of Kapitza dimensional nonlinear damping oscillator driven by sin- or cos- rapidly oscillating periodical force. We use the averaging procedure with respect to the rapidly changing movement and start from the effective potential energy of the pendulum [1]. Our purpose is to investigate how the open-loop (feewforward) control scheme influences on the structure of the Lyapunov spectrum in the fixed points of the dynamical system [2].

The model has one dimensionless parameter $2gl/a^2\gamma^2$ depending on the amplitude *a* and the frequency γ of the control modulation. Changing its value we construct the phase portraits of the systems in the neighborhood of the fixed points and demonstrate the Lyapunov spectrum under the application of different forms of feedforward control for the both cases of the horizontal and vertical modulation at the origin (0,0), at the inverse position ($\pi, 0$) and at the non-trivial point (the last in the case of the horizontal modulation). We can observe the conversion of the Lyapunov spectrum from the focus to the saddle point.

Our results can be easily extended for the case of non-harmonic modulation.

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Recurrence analysis of strange nonchaotic dynamics

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We present new methods to detect the transitions from quasiperiodic to chaotic motion via strange nonchaotic attractors (SNAs). These procedures are based on the time needed by the system to recur to a previously visited state and a quantification of the synchronization of trajectories on SNAs. The techniques are then applied to detect transitions to or from SNAs in representative quasiperiodically forced discrete maps. The fractalization transition to SNAs—for which most existing diagnostics are inadequate—is clearly detected by recurrence analysis. These methods are robust to additive noise, and thus can be used in analyzing experimental time–series.

TIME–DELAYED CONTROL OF CHAOS IN THE IKEDA SYSTEM

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In recent years the problem of controlling chaos has attracted a considerable interest in nonlinear dynamics. Usually it means stabilization of initially unstable periodic orbits of a dynamical system by small controlling forces. Among the controlling chaos techniques the most popular is the time-delayed autosynchronization method suggested by K. Pyragas [*Phys. Lett. A*, 1992, **170**, 421] when an additional feedback path (FP) is applied, with the delay time approximately equal to the period of motion to be stabilized. In this paper, we develop a generalization of the Pyragas method for distributed systems which itself possess time-delayed feedbacks. The proposed method is based on introduction of an additional feedback loop with parameters chosen so that the fundamental frequency components after passing through different FP appear in phase, while the most unstable sidebands appear in antiphase, thus suppressing each other. We demonstrate the capability of the method for the example of the well-known Ikeda system [K. Ikeda *et al.*, *Phys. Rev. Lett.*, 1980, **45**, 709] that is a ring-loop resonator partly filled with a nonlinear dispersive media and forced with an external harmonic signal. The model of the system is described by the Nonlinear Schrödinger Equation (NSE) with time-delayed boundary conditions.

First we examine a simplified model which could be reduced to the discrete 4D map that we refer as modified Ikeda map. For this map, we derive analytical predictions of the control and robustness. We show that for properly chosen delays and phase shifts of the feedback loops the increase of the amount of control feedback results in suppression of self-modulation instability and provides stable single frequency oscillations even when the dynamics of the system without control is chaotic. We perform extensive numerical simulations of the modified Ikeda map, as well as for the initial spatio-temporal system described by the delayed feedback NSE. Numerical results are in good agreement with the theory. In conclusion, the proposed scheme of controlling chaos opens a way to improve performance of practical devices at microwave or optical frequencies.

The work is supported by the Russian Foundation for Basic Research grant No. 05-02-16931.

THE EXPLOITATION EFFECT ON BOTH GENETIC VARIETY AND DYNAMIC BEHAVIOR OF MENDELIAN LIMITED POPULATION: NON-STATIONARY AND STATIONARY STRATEGY OF HARVEST

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The two types of issues appeared when attempts of ecological and population-genetics theory combination were made. The first type of issues is investigation of evolution factors effect (most of all the natural selection) on genetic structure changes and dynamic behavior of population under the limited ecological resources. The second one is analyses necessity of evolutionary-ecological consequences of harvest.

The conception of maximal equilibrated catch asserts that harvested populations are not in the same ecological conditions as non-harvested ones. So the conditions of selection and hence fitnesses of genotypic groups can changes in harvested populations.

The consequences of optimal harvest in the model of density-depended natural selection are considered in our work. So, it has been shown even in very simple model situation, that the optimal stationary harvest with constant quota can change the stability of model equilibriums and consequently can result in not only dynamics regime character changes but even in essential changes of population's genetic structure.

In this research we compare stationary harvest strategy (exploitation with constant quota) with non-stationary one for those cases generally, when exploitation with constant quota doesn't result in stabilization of population dynamics.

It is shown with some examples, that non-stationary strategy of harvest sometimes may be more preferable then stationary one.

Extended Kalman and particle filtering for sensor fusion in mobile robot localization

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State estimation (or filtering) is a research field of primary importance for industrial systems operation. It is well known that the optimal filter for linear models with Gaussian noise is the Kalman Filter. State estimation for nonlinear systems with non-Gaussian noise is a difficult problem and in general the optimal solution cannot be expressed in closed-form. Suboptimal solutions use some form of approximation such as model linearisation in the Extended Kalman Filter (EKF). The Extended Kalman Filter is an incremental estimation algorithm that performs optimization in the least mean squares sense and which has been successfully applied to neural networks training and to data fusion problems. In this paper the EKF has been employed for the localization of an autonomous vehicle by fusing data coming from different sensors. In the EKF approach the state vector is approximated by a Gaussian random variable, which is then propagated analytically through the first order linearization of the nonlinear system. The series approximation in the EKF algorithm can, however, lead to poor representations of the nonlinear functions and of the associated probability distributions. As a result, sometimes the filter will be divergent.
To overcome these shortcomings, a new kind of nonlinear filtering method, the so-called Particle Filtering, has been proposed. Particle filtering has improved performance over the EKF, since it can provide optimal estimation in nonlinear non-Gaussian models. Particle filters can estimate the system states sufficiently when the number of particles (estimations of the state vectors which evolve in parallel) is large. However the method has not yet become popular in industry because implementation details are missing in literature, and because its computational complexity has to be handled in real-time applications. The particle filtering algorithm reminds of the genetic algorithms where a number of N particles is subject to a mutation mechanism which corresponds to the prediction stage, and to selection mechanism which corresponds to the correction stage.
In this paper implementation and tuning issues of particle filtering are discussed. The performance of the proposed methodology is evaluated against EKF in the problem of sensor fusion for the localization of an autonomous mobile robot. The problem is to succeed an accurate estimation of the state vector of the mobile robot fusing measurements from odometric and sonar sensors. At a second stage the estimated state vector is used by a nonlinear controller in-order to make the mobile robot track a desired trajectory.

RELIABLE BEAM MODELING IN CONTROL PROBLEMS

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The approaches to modelling and optimization of controlled dynamical systems with distributed elastic and inertial parameters are considered. The general integro-differential method for solving wide class of initial-boundary value problems is developed and criteria of solution quality are proposed. The numerical algorithm for discrete approximation of controlled motions is worked out and applied to design the optimal control low steering an elastic system to the terminal position and minimizing the given objective function. The polynomial control of plane motions of a homogeneous cantilever beam is investigated. Such type of system disturbances can induce essential elastic deflections and lead to sufficient computational difficulties when the conventional approaches are used. The optimal control problem of beam transportation from the initial rest position to given terminal state, in which the full mechanical energy of the system reaches its minimal value, is considered. The obtained numerical results are analyzed and compared with the conventional Fourier's solution.

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CURE KINETICS OF EPOXY RESIN AND DISTRIBUTED THERMAL CONTROL OF POLYMERIC COMPOSITE STRUCTURES MOULDING

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The development of mould heating distributed control model for polymerization of the composite spar for helicopter main rotor blade's is presented in this work. An obligatory condition of such system control is a considering of exothermal heat at polymerization of epoxy resin matrix, and change of a thermal capacity at transition from fluid to solid state. The kinetic model of cure epoxy resin designed on basis of the differential scanning calorimetry (DSC) experiments was proposed. This kinetic model is a component of the implemented in SIMULINK control system synthetic model which includes also heat transfer finite element (FE) based model of a mould with composite spar, and proportional-integral-differential (PID) controller model equipped by forecasting module for compensation of a mould thermal inertance. For speed up of joint controller model and FE model simulation the FE meshing reduction technique was proposed. Developed model was shown the good conformity with measured dynamic temperature field in full-scale setup, having allowed to optimize of the mould structure, to composite spar cure conditions and to supply its required quality.

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EXPERIMENTAL AND COMPUTER MODELING OF INTELLIGENT POLYMERIC COMPOSITE STRUCTURES WITH NEURAL-NETWORK BASED CONTROL

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The problem of cantilever polymeric-composite plate vibration damping with piezoelectric sensors and actuators was examined. On the basis of finite element and neural network technologies the synthetic numerical model of active damping vibrations was created. Our numerical simulations have shown a good correspondence with experimental results on thin composite cantilevered plate active vibration damping. Use of a unique scalar signal of control not taking into account spatial distribution of amplitudes on vibration modes allows reducing in three and more times of vibrations intensity. Transient analysis after switch on of actuator show that originally harmonic forced vibrations on the first eigenfrequency are modulated by a signal with frequency about 1 Hz and decreasing amplitude, what cannot be stipulated by any mechanical process. Thus the change of the feedback influences only on vibration damping intensity but not on frequency. The identification of a nature of this phenomenon that has been not marked earlier by other researchers is a necessary for effective design of intelligent systems for active suppression of aircraft structures vibrations.

NEURAL NETWORKS APPROACH TO BLIND SOURCE SEPARATION VIA ADAPTIVE INDEPENDENT COMPONENT ANALYSIS

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An original self-organizing neural network models for solution of blind source separation problem via adaptive independent technique is proposed. The purpose of research consists in generalization of a wiled-known method of independent component analysis to adaptive neural networks model. We develop an algebraical approach to unsupervised learning rule of heterogeneous neural nets with adaptive flexible activation. In frame of this approach we develop new information adaptation filtering model with entropy-based learning rule for self-organizing neural network. The main feature of our model is a flexible non-linearity of neuron activation that can be tuned in accordance to a true signal distribution. This approach allows accurately separating informative components of vector signals with different types of probability distribution functions. The article focuses an extended independent component analysis algorithm for mixtures of arbitrary signals with non-gaussian distributions.

The underlying principle involved in BSS-problem solution is formulated as an independent component analysis (ICA). We apply self-organizing neural networks (NN) which demonstrated that a self-organizing neuron with linear Hebbian learning rule was capable of extracting the maximum amount of information, in a least square sense, from the observed data. Several algorithms based on information maximization approach in blind separation and blind deconvolution problems via entropy or high-order statistics criterions have been developed. ICA and the related BSS (Blind Source Separation) problem are currently studied extensively in neural learning and statistical signal processing. But the vast majority of described algorithms is oriented to stationary statistical characteristics. However, in many practical tasks we need to analyze a non-stationary vector stochastic processes and phenomena's. The applications of this problem arise in speech and sound recognition, machine vision of dynamic scene, technical diagnostic. This task leads to a nesesety of realization an on-line adaptation for such processes analysis. Solution of problem can be founded in implementation of on-line adaptive signal processor with adaptation to non-stationary of statistical data.

Control of unstable steady states in semiconductor lasers by time-delayed feedback methods

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Time-delayed feedback methods can be used to control unstable periodic orbits as well as unstable steady states. We present an application of extended time delay autosynchronization introduced by Socolar et al. [1] to a semiconductor laser system with undamped relaxation oscillations implemented as a model of Lang-Kobayashi-type. We show that the control method is able to enhance the local stability of the lasing fixed point leading to cw-operation by suppression of unwanted intensity pulsations. Due to the self-feedback, multistable behavior can also occur in the form of delay-induced limit cycles and fixed points for certain choices of the control parameters.

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ADEQUATE CONTROL IN HIERARCHICAL SYSTEMS DURING SELF-ADJUSTING PROCESSES

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Random corrections, caused by low-level decisions based on self-made short-term and short-scale estimations, make the trajectory of complex hierarchical system rather "rough". The more complicated is the motion, the more unstable becomes the system and the higher becomes the fractal dimension of the attraction channel of its trajectory. To survive, these systems will attempt to restore the "directed" development due to adequate interactions of the all levels of hierarchy. This self-adjusting process stands for the adequate control of the system.

As the theoretical analysis of the self-adjusting in real systems is quite complicated the experimental study was carried out. The stock-market system (the Sberbank-Russia) was chosen as a study object. The temporal price-variations of the Sberbank-Russia stocks were studied from March 2006 to June 2007. The fractal dimension d_f as a measure of complexity of the attraction channel and intermittency exponent μ - local dissipation intensity characteristic - were estimated by means of time-series analysis. The existence of short- and middle-term substructures with various life-time $\Delta\theta$ was revealed. The disrupt of the sign of the $<\Delta d_f/\Delta\mu>$-ratio is observed for short- and middle-term substructures when the system evolution switches to another attraction channel. For reversible Sberbank-index decreases (18-19.04 and 26-27.04 2007, for example) the sign the averaged derivative $<\Delta d_f/\Delta\mu>$ changes from negative to positive with increase of life-time $\Delta\theta$ of dynamic substructures. But for irreversible index decrease (10.05 and 11.05 2007) the sign the averaged derivative $<\Delta d_f/\Delta\mu>$ changes from positive to negative with increase of life-time $\Delta\theta$.

To explain the obtained results, it was used the approach based on Kolmogorov theory of turbulence. According to this approach, the inertial force, caused by the nonuniformity of evolution of the system in the space/time, provides the transfer of energy through the system of cascades with minimum possible losses. As long as the sign of the averaged derivative $K=<\Delta d_f/\Delta\mu>$ is positive, the increasing of evolution irregularity and (as result of it) the growing of intermittency exponent μ leads to increase of the fractal dimension d_f. In its turn, this leads to increase of chaotic components in the system motion. To avoid the uncontrolable d_f-increasing and system creeping to chaos the system must switch the sign of the averaged derivative $<\Delta d_f/\Delta\mu>$ from positive to negative. In terms of control theory, one can say, that the surviving of the system is reached by the transition from positive to negative feedback between the growth of the evolution irregularity (measured as the $\Delta\mu$-increasing) and the increment Δd_f of the fractal dimension. This switching of the feedback makes it possible adaptation of the system to a new reality in the presence of forcing.

All-optical noninvasive control of unstable steady states in a semiconductor laser

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All-optical noninvasive control of a multi-section semiconductor laser by means of time-delayed feedback from an external Fabry-Perot cavity is realized experimentally. A theoretical analysis, both in a generic model as well as a device-specific simulation, points out the role of the optical phase. Using phase-dependent feedback we demonstrate stabilization of the continuous-wave laser output and noninvasive suppression of intensity pulsations.

ABOUT THE PROBLEM OF CYCLE-SLIPPING IN DISCRETE SYSTEMS WHIS PERIODIC NONLINEAR VECTOR FUNCTION

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In this paper we consider a multidimensional discrete phase system

$$\begin{aligned} z(n+1) &= Az(n)+B\xi(n), \\ \sigma(n+1) &= \sigma(n)+C^*z(n)+R\xi(n), \\ \xi(n) &= \varphi(\sigma(n)), \quad n=0,1,2,\ldots \end{aligned} \tag{1}$$

Here A,B,C,R are real matrices of order $(m\times m)$, $(m\times l)$, $(m\times l)$, $(l\times l)$ respectively and the symbol * is used for Hermitian conjugation. The pair (A,B) is controllable, the pair (A,C) is observable and all eigenvalues of A lie inside the open unit circle. Function $\varphi:\mathbf{R}^l\to\mathbf{R}^l$ is a vector-valued function with the property $\varphi(\sigma)=(\varphi_1(\sigma_1),...,\varphi_l(\sigma_l))$ for $\sigma=(\sigma_1,...,\sigma_l)\in\mathbf{R}^l$. Every component $\varphi_j(\sigma_j)$ is Δ_j-periodic, belongs to $\mathbf{C}^1$, has a finite number of zeros on $[0,\Delta_j)$.

In this paper the subject of cycle–slipping for discrete phase systems, which has been investigated for the case of scalar nonlinear function ($l=1$), is developed. Investigation is carried out by second Lyapunov method and by Yakubovich–Kalman frequency–domain theorem. That is why all the results are formulated in terms of the transfer matrix of the linear part of system (1) $K(p)=C^*(A-pE)^{-1}B-R$ $(p\in\mathbf{C})$, where E is a unit matrix.

Central hypothesis of any theorem proved in this paper is a frequency–domain inequality with varying parameters. For instance

$$\Re e\{æK(p)-K^*(p)\varepsilon K(p)-\eta\}\geq 0, \quad |p|=1, p\in\mathbf{C}, \tag{2}$$

where $(l\times l)$-diagonal matrices æ, $\varepsilon>0$, $\eta>0$ are varying.

It is established that if there exist such diagonal matrices $\varepsilon>0$, $\eta>0$, æ and such positive integers $m_1,m_2,...,m_l$ that the inequality (2) (or a more complicated frequency–domain inequality) is true and certain additional algebraic inequalities are satisfied then for any solution $(z(n),\sigma(n))$ of (1) the estimates $|\sigma_j(n)-\sigma_j(0)|<m_j\Delta_j$ $(j=1,2,...,l)$ are true for all natural n.

MICROSTRUCTURE AND MAGNETIC PROPERTIES OF CO-C AND CO-PD FILMS WITH THE INTERNAL BEND OF A LATTICE

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The explosive crystallization processes in nanocrystalline Co-C and Co-Pd films have been studied by transmission electron microscopy and electron diffraction methods. In the presented work the physical and chemical processes occuring at plastic deformation of alloys of Co-C and Co-Pd systems are considered. In work it is shown, that features of structural reorganization during mechanosyntesis can be described within the limits of the share transformation zone (STZ) theory based on model of excited atoms [1]. The analysis of bend extinction contour has shown on microphotographies the considerable internal bend (~100º/micron) of crystalline lattice. On the basis of the experimental data we founded the correlation of magnetic properties and lattice curvature. In present paper the shear transformation zone theory was used for attempt to explain the mechanism and kinetics of the explosive crystallization in Co-C and Co-Pd films. The comparison of microstructure of the nanocrystalline Co-C and Co-Pd films containing bend contours with the results of saturation magnetization measurements has been made. Microstructure and magnetic properties of Co-C and Co-Pd crystallizing with the internal bend of a lattice are being compared. As it has been observed on the electron microscopic patterns, for the samples with the maximal density of bend contours the saturation magnetization is several times less as compared to the initial nanocrystalline state.

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RECURSIVE ACTIVE CONTROL FOR CONTROLLING CHAOS IN NONLINEAR BLOCH EQUATIONS

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The problem of chaos control in the nonlinear Bloch equations is considerd based on a new control technique. The new control technique combines a recursive approach and active control mechanism to design control functions that suppresses chaotic behaviours in nonlinear Bloch equations. The effeciency of the proposed Recursive Active Control (RAC) is demonstrated with numerical simulations.

FLIGHT AUTOMATIC CONTROL SYSTEMS FOR THE WING-IN-GROUND EFFECT CRAFT BUCHON-1

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Wing-in-Ground (WIG) Effect vehicles use the influence of the supporting surface applying the aerodynamics characteristics of special aerofoil, which result in the increase of lift and the decrease of induced drag. Undisplacement vessels successfully used advantages of motion close to the supporting surface long ago. For the WIG-craft the flight near the surface is the natural mode of motion, but many control problems arise at providing the safety and effectiveness of such flight.

Nowadays some countries have taken deep interest in this technology and started to work in the development of this promising and advanced kind of transport. The Venezuelan WIG Effect craft project called BUCHON-1 is one of them and it is projected to be used as a transport vehicle in the Caribbean Sea. The velocity of WIG-flight for the Buchon-1 would be around 200-250 km/h. The vehicle length would be 13 m and the altitude has to be in the range from 0.5m to 3m. Methods of providing stability to WIG Effect flight by special automatic control systems and the development of special altimeters are analyzed especially considering the BUCHON-1 and the experiments and tests extensively carried out using its prototype.

The flight parameters measuring system was designed for WIG-craft It is intended for control and record of flight parameters: altitude of flight up to 5 m with accuracy 5 cm; speed up to 180 m/s with accuracy 0.1-0.2 m/s; roll and pitch angles with accuracy 0.1-0.2 deg; vertical overloads up to 3g with accuracy 0.06g; considerable sea waves height up to 1.5 m with accuracy 5 cm.

The characteristics of specially designed radioaltimeter (RA) are: Altitude (or distance) measured - 0-10m; easurement error - not more than 5 cm; measured parameter frequency range - 0-50 Hz; the operating RF - from X-range (9000 MHz); power consumption - 2 W; mass - 1.2 kg.

The structure of integration algorithm for altimeters and vertical accelerometer output signals involves: The block of recalculation of measurements RA on a point of installation Inertial Unit (IU); the block of recalculation of an estimation of altitude from a point of installation IU on CG; the filter of altitude; the filter of vertical acceleration.

The measuring system allows to track the profiles of sea waves in three points, corresponding to the points of RA installation at a nose and both sides of the vehicle, with the accuracy 10 cm at seaway number 4.

The following criteria of automatic control quality for BUCHON-1may be considered: stability provision of motion in the longitudinal plane; rise of seagoing ability of a vehicle, i.e. its capability to move in given direction and to solve another functional tasks at the largest number of sea conditions; reduction of fuel consumption; depression of vehicle rocking for creating the favorable conditions for crew and passengers or for functioning of on-board equipment. It is impossible to reach the extremum of all these criteria simultaneously and each concrete case requires appointing the only main criterion of control effectiveness, and transforming other ones to the rank of limitations.

The demanded characteristics of vehicles for flight close to surface can be achieved only by the use of the new capabilities of perfecting the systems of navigation and motion control created by modern means of supply with flight information and by resources of on-board computers. in this paper.

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GEOMETRICAL SYNTHESIS OF ROBUST REGULATOR, BASED ON THE SYMMETRIZATION OF PHASE LIMITATIONS

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One of the actual problems of the objectives of control is the problem of synthesizing the law of control, effective under the conditions of various indeterminacy and limitations on motion properties. At the same time the deriving of the robust laws of control is very important under the conditions of illegible data. In this work it is shown, that the solving of the mentioned problem comes to solution of some certain logarithmic correlations from the specially created connected phase plane. As far as smooth phase limitations are concerned, these correlations can be converted into algebraic equations, according to the synthesized law of control. The investigation in the cases of uneven limitations, which describe linear polyhedrons in state space, is performed in this work. It is shown, that in case of being symmetrical to set point of the coordinate system the solvability of synthesizing problem is all defined by the random apex of the polyhedron. If the required condition of the symmetry is not fulfilled, than the minimum amount of the random polyhedron apexes is concerned for analyzing the solvability of the objective. The description (symmetrization) of the phase plane is concerned with the help of the polyhedrons, symmetrical in any way. At the same time the system` indeterminacy is considered straight according to the algebraic correlations of the symmetric polyhedrons` apexes.

STRUCTURE AT INFINITY AND THE STRUCTURE OF INTERACTOR OF LINEAR MULTIVARIABLE SYSTEMS*

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The purpose of this paper is to discuss the relationship between the structure at infinity of a linear multivariable system and its interactor matrix.

An interactor was originally defined by Wolovich and Falb as the system invariant under dynamic compensation, which is a lower left triangular polynomial matrix and has been used in various types of control systems for linear multivariable systems. However, in general, an interactor can be defined by any polynomial matrix which cancels all zeros at infinity of a given plant transfer matrix by premultiplying. This implies that the interactor can be regarded as another expression of the structure at infinity of the plant, and hence, there must be a direct relationship between the structure at infinity of the plant and the structure of degrees of it's interactor. However, although the structure at infinity is determined uniquely, the interactor and even its structure of degrees are not determined uniquely. In this paper, to establish this explicit relationship, the regular interactor in defined as the interactor whose row degrees coincide with the structure at infinity of the plant. It will be proven that the interactor is regular if and only if the interactor is row proper.

NONLINEAR GYROMOMENT SPACECRAFT ATTITUDE CONTROL WITH PRECISE POINTING THE FLEXIBLE ANTENNAS

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Recently, new approach was developed for description of physical hysteresis, which is based on set-valued differential equation with discontinuous right-side. The paper briefly presents new results on modelling a hysteresis damping and describes in detail their application to a communication spacecraft (SC) attitude guidance and robust digital gyromoment control with precise pointing the large-scale flexible weak-damping antennas.

Applied general approach to synthesis of a *nonlinear* control system with a partial measurement of its state is presented, moreover the method of *vector Lyapunov functions* is used in cooperation with the *exact feedback linearization* technique. Comparison of linear and hysteresis modelling the SC structure weak-damped oscillations was developed. Obtained results are close, but resonance "peaks" on "frequency characteristics" have very narrow form for hysteresis modelling. New results on multiply filtering the incomplete discrete measurements and robust digital control are presented, moreover the discrete filtering efficiency is evidently demonstrated. Some results of computer simulation are presented, including additional angular deflection by antenna's flexibility both at pointing, target tracking and guidance by a rotation maneuver. Conclusions formulate the paper principle results on modelling a physical hysteresis and it application for digital gyromoment attitude control of a flexible spacecraft structure.

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An adaptive chaotic secure communication scheme with channel noise and time delay

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In this paper, by using synchronization scheme of chaotic neural networks with delay, an adaptive secure communication scheme with channel noise and time delay is proposed. Based on the idea of chaotic masking-modulation, the transmitted message is encrypted by the chaotic signal, and via the adaptive feedback control techniques, the transmitter and the receiver are synchronized with channel noise, so the masked signal can be perfectly recovered by the receiver in the presence of channel noise. In light of the Lyapunov stability theory for stochastic differential equations, several theoretical results are rigorously established. Finally, a numerical example is provided to verify the effectiveness of the proposed scheme, and the time required for recovering the information signal and the performance of the recovered signal very sensitively depending on the time delay and the frequency of the information signal will also be found from the simulation results.

STABILITY ANALYSIS OF A "THYRISTOR VOLTAGE CONTROLLER – INDUCTION MACHINE" MODEL

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Soft starters based on thyristorised voltage controller (TVC) are used as induction motor controllers in many industrial applications. At present soft start devices are developed based on the pulse-phase control system (PPCS) with TVC. A complicated mathematical modeling and simulation is a disadvantage of the PPCS-TVC of induction machines (hereafter PPCS-TVC-IM). It's difficult to research the PPCS-TVC-IM behaviors in transient and stationary states. For example, stability of the stationary states has been researched with the help of linearized models of the PPCS-TVC-IM especially. The PPCS-TVC can operate under two types of synchronization: line voltage synchronization and phase current synchronization. Oscillation processes, characterized by deviation of angular velocity of IM exist in the stationary states of the PPCS-TVC-IM with voltage synchronization. An averaging modeling approach does not allow to investigate this problem and to analyze the model stability adequately. Therefore, both an analysis of the dynamic behaviors and control algorithm design must perform by non-linear model. In the paper, such complete (non-linear) model of the PPCS-TVC-IM is used for simulation and stability analysis. The parametric stability analysis of the stationary state, base on monodromy matrix numerical calculation is carried out for both types of the model synchronization. In conclusion, the periodical processes of the stationary state are stable in both the turndown of the control angle and range of the IM inertia moment $J=J_{rated}:J_{rated}\cdot 8$. However, the oscillation processes exist in the stationary states of the PPCS-TVC-IM with voltage synchronization in the IM inertia moment range $J=J_{rated}:J_{rated}\cdot 3$. As shown in paper, current synchronization of the PPCS-TVC-IM decreases the oscillations in the stationary state. It makes current synchronization of the PPCS-TVC-IM more attractive for implementation against the voltage synchronization. Especially, it can use in both the soft start devices and energy-saving drive systems.

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FROM AN EQUILIBRIUM TO QUASIPERIODICITY IN NON-SMOOTH SYSTEMS

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Considering a two-dimensional system of nonautonomous differential equations with discontinuous right-hand sides describing the behavior of a DC/DC converter with pulse-width modulated control, we demonstrate how a two-dimensional invariant torus can arise from a stable node equilibrium point. We determine the chart of dynamical modes and show that there is a region of parameter space in which the system has a single stable node equilibrium point. Under variation of the parameters, this equilibrium may collide with a discontinuity boundary between two smooth regions in the phase space. When this happens, one can observe a variety of different bifurcation scenarios. One scenario is the continuous transformation of the stable equilibrium into a stable period-1 focus. A second is the transformation of the stable node equilibrium into an unstable period-1 focus, and the associated formation of a two-dimensional (ergodic or resonant) torus.

The bifurcation phenomena observed for this system are distinguished from a classic Hopf bifurcation by the following characteristics:

First, the transition is connected with the disappearance of the stable equilibrium point, when it collides with a discontinuity boundary between two smooth regions in the phase space. It is not connected with the loss stability of equilibrium point as it occurs in the classic Hopf bifurcation.

Second, the disappearance of the equilibrium point gives rise to two types of bifurcation behavior:

(i) the stable equilibrium disappears and is replaced by a stable period-1 orbit, the amplitude of which is growing linearly from zero as the system moves away from the bifurcation point.

(ii) rather than as a stable node, the periodic cycle arising in the bifurcation is born as an unstable focus surrounded by a resonant or ergodic torus.