Dynamics Days 2006 – Bethesda Maryland

Poster Sessions

1. **Abrams, Daniel**

Strogatz, Steven H. - Cornell University McRobie, Allan - Cambridge University

A Coupled Oscillator Model of the Millennium Bridge Instability

On June 10, 2000, London's new footbridge across the Thames opened to great acclaim. Within 48 hours authorities were forced to close the bridge, citing a dangerous lateral vibration induced by the large crowds. Using methods taken from mathematical biology, we develop a model that explains the observed synchrony of crowd movement, and the origin of the unwanted wobble.

2. **Ahmadi, Amir Ali**

Ahmadi, A. A. (1), Rieser, J. (2), Tsang, Y.K. (3), Ott, E. (1,4) and Antonsen, T. M. (1,4) 1) Department of Electrical and Computer Engineering, University of Maryland, College Park; 2) Department of Physics, Georgia Institute of Technology; 3) Courant Institute of Mathematical Sciences, New York University; 4) Department of Physics, Institute for Research in Electronics and Applied Physics, University of Maryland, ECE, University of Maryland

Fractal patterns in chaotic fluid mixings

We consider the fractal properties of a passive scalar that is advected in a chaotic flow while experiencing a small amount of microscopic diffusion. As time increases, chaotic mixing causes the initially smooth scalar density to develop variations on a finer and finer scale until eventually the microscopic diffusion dissipates the scalar. In the asymptotic state the scalar decays exponentially in time and posses variations on all spatial scales.

3. **Albers, David**

Sprott, J.C., Physics Dept. University of Wisconsin – Madison, J. P. Crutchfield Center for Computational Science and Engineering, University of California - Davis, Max Planck Institute for Mathematics in the Sciences

Persistent chaos in high dimensions: the geometry of stability

Physical theory attempts to describe and predict the natural world by expressing observed behavior and the governing balance of forces formally in mathematical models---models that can only be approximate representations. Empirically, many natural phenomena persist even when control parameters and external conditions vary. In building a theory of a system exhibiting this kind of dynamical persistence, one hopes that despite its approximations, one's model also has this persistence. A century of analyzing nonlinear dynamical systems, however, has lead to an apparent inconsistency with this goal. Since the days of Poincar\'e's development of qualitative dynamics, mathematicians and physicists have probed differential equations to test their solutions for different kinds of stability. Poincar\'e's discovery of deterministic chaos demonstrated that at the most detailed level there was inherent instability of system solutions: change the initial condition only slightly and one finds a that different state-space trajectory develops rapidly. Later studies showed that there was also an instability in behavior if the equations or parameters were changed only slightly. Even arbitrarily small functional perturbations to the governing dynamic leads to radical changes in behavior---from unpredictable to predictable behavior, for example. The overall conclusion has been that nonlinear chaotic systems are exquisitely sensitive, amplifying arbitrarily small variations in initial and boundary conditions and parameters to macroscopic scales. We present an extensive statistical survey of universal approximators that shows that as the dimension of a typical dissipative dynamical system is increased.

4. Ando, Hiroyasu

Kazuyuki Aihara. Also at: Institute of Industrial Science, The University of Tokyo and ERATO, Aihara Complexity Modeling Project, JST Tokyo, Japan, Department of Mathematical Informatics, Graduate School of Information Science and Technology, The University of Tokyo

Detection of superstable periodic orbits in systems describable by a one-dimensional map

Sometimes it might be important to know the bifurcation structure of a system, but this is particularly difficult if the system dynamics is not explicitly known. In this study, we present a simple method, which can detect without a-priori knowledge of the system the location of periodic orbits and some types of bifurcations in a one-dimensional map, which has only one accessible parameter. We can detect all periodic points, either stable or unstable, as well as parameter values corresponding to superstable periodic orbits using only the maximum values of time series of fixed length and the number of steps till the maximum occurs for several initial values. The discontinuous points of the latter numbers with respect to the initial values correspond to periodic points. Furthermore, when varying the parameter value bifurcations and superstable parameters can be detected from the trajectories of those discontinuous points.

5. Arioli, Gianni

Dipartimento di Matematica, Politecnico di Milano

Recent results on the 3-body problem

The 3-body problem has been a subject of study for a very long time, but in recent years it has received particular attention, thanks to new developments in the field of variational methods and computer-assisted proofs. In this talk we describe some of the most recent results in this field.

6. Arkus, Natalie

Brenner, Michael, Harvard University

Assigning p-values to complex biological systems

Models of complex biological systems with many free parameters do not describe a unique data set, nor is a data set uniquely described by one of them. Their conclusions may therefore not reveal an underlying biological phenomenon, but rather be model or parameter specific. We propose a method of assigning p-values to these models and their conclusions. As an example, we consider feedback and open loop models of the e. coli heat shock response system. We determine to what degree properties associated with the feedback loops are a result of the loops themselves or of the model and its specific parameter regime.

7. Aumaitre, Sebastein

Petrelis, Francois, Laboratoire de Physique, Statistique de Ecole Normale superieure Paris, Mallikck, Kirone, Service de Physique Theorique, CEA Saclay, Haverford College, Haverford. PA

Effects of the low frequencies of multiplicative noise on the phenomenon of on-off intermittency

A dynamical system subject to multiplicative noise can exhibit on-off intermittency close to the instability threshold. However, this regime has been not observed in experiments where the control parameter, acting multiplicatively on the dynamical variable, is subjected to a random modulation. A possible explanation is the extreme sensitivity of this intermittency to the noise density spectrum, as we demonstrate here in the case of a simple dynamical system. We calculate the Probability Density Function (PDF) of the system subject to a random noise with arbitrary Power Spectral Density (PSD) and show that the intermittent regime is determined by the ratio between the departure from the threshold and the PSD of the noise at zero frequency. Consequently, a high pass filter greatly reduces the intermittency domain. These results are in agreement with numerical simulations. We suggest that these results will be helpful in understanding the behavior of the magnetic field emerging from a turbulent background flow of a conducting fluid.

8. Baek, Seung-Jong

Hunt, Brian R., Kalnay, Eugenia, Ott, Edward, Szunyogh, Istvan, University of Maryland

Estimating the state of a spatio-temporally chaotic system in the presence of model bias

We consider the problem of estimating the state of a spatio-temporally chaotic system from incomplete inexact measurements and knowledge of a system model which may not be an exact dynamical representation of the system. In previous work a technique called the Local Ensemble Kalman Filter (LEKF) was introduced for the purpose of state estimation of high dimensional dynamics in large spatio-temporally chaotic systems. Here we present a modification of the LEKF that incorporates the effect of forecast model bias. The method is based on augmentation of the atmospheric state by estimates of the model bias, and we consider different ways of modeling (i.e. parameterizing) the model bias. The effectiveness of the proposed augmented state ensemble Kalman filter is evaluated through numerical experiments incorporating various model biases. Our results highlight the critical role played by the selection of a good parameterization model for representing the form of the possible bias in the forecast model. In particular, the estimates can be greatly improved provided that a good model parameterizing the model bias is used to augment the state in the Kalman filter.

9. Bandi, Mahesh

Goldburg, Walter I., University of Pittsburgh, Cressman Jr., John R., Krasnow Institute, George Mason University, University of Pittsburgh

Structure of the Turbulent Energy Cascade

The cascade picture of turbulence finds its basis in Kolmogorov's phenomenological theory of 1941 where energy is transferred from large to small spatial scales, eventually undergoing viscous dissipation at smallest scales. The energy transfer itself is believed to occur due to local coupling between spatial scales. Despite wide use of these ideas, the cascade picture is difficult to verify experimentally. The cascade structure simultaneously spans both space and time, thereby making it difficult to invoke ergodic arguments to conduct spatial or temporal averages. A technique based on temporal cross-correlations of the energy flux between spatial scales will be discussed. The data is obtained from a two-dimensional cut through a three-dimensional incompressible fluid in a large tank of water stirred into a turbulent steady state. Preliminary results are presented.

10. Barreto, Ernest

Fan, Clayton (1), So, Paul (1,2,4), Schiff, Steven J. (1,3,4), Barreto, Ernest (1,2,4)

1. Program in Neuroscience, 2. Department of Physics & Astronomy, 3. Department of Psychology, 4. The Krasnow Institute for Advanced Study George Mason University Fairfax, VA 22030, George Mason University

Electric field effects on wave propagation: a computational model

Motivated by experimental observations that electric fields modulate both hippocampal seizures and wave propagation, we examined the effect of an imposed electric field on the spike propagation within a linear array of model neurons. Pinsky-Rinzel neurons were arranged linearly and synaptically coupled in a nearest-neighbor manner. Ephaptic interactions were enabled by embedding the coupled chain in a resistive grid, modeling the electrical properties of the extracellular medium. In addition, a potential difference was applied across the whole grid to model the effect of externally applied electric fields. Transient spiking activity was elicited at one end of the chain by a brief current pulse; this activity then propagated along the chain. We found that the speed of propagation can be modulated by the imposed electric field and that a sufficiently suppressive field can block propagation altogether. This effect is qualitatively consistent with analytically obtained solutions in a continuous medium. We clarify the role of ephaptic interactions and offer a dynamical analysis of the propagation suppression mechanism.

11. Benziger, Jay

Kimball, Erin, Department of Chemical Engineering, Princeton University, Kevrekidis, Ioannis G., Department of Chemical Engineering and Program in Applied Mathematics, Princeton University

Nonlinear dynamics of PEM fuel cells

PEM fuel cells exhibit complex non-linear dynamics resulting from an exponential dependence of proton conductivity with water content. Multiple steady states have been identified resulting from the balance between water produced and water removed. When the membrane water content was greater than a critical value the fuel cell current increased to a high value corresponding to an ignited state. The dynamics of fuel cell ignition and the dynamic response to changes in load are controlled by the accumulation of water in the polymer electrolyte. Because the membrane swells as it absorbs water the mechanical properties of the polymer are coupled with the dynamics of the reaction. The mechanical-chemical coupling gives rise to highly regular autonomous oscillations with periods of 10 000 s. Spatio-temporal dynamics have been followed in the flow channels of a PEM fuel cell reactor. Co-current flow of the hydrogen and oxygen resulted in current ignition at the outlet of the flow channel followed by a wave of high current density propagating toward the inlet. Counter-current flow of the hydrogen and the oxygen resulted in ignition at the center of the flow channels. Over time the ignition front fanned out from the center. These non-linear dynamic phenomena in PEM fuel cells are critical to the development of control systems and systems configurations to facilitate commercial development of fuel cells.

12. Berger, Carolyn

Berger, Carolyn M., Dobrovolny, Hana M., Zhao, Xiaopeng, Schaeffer, David G., Krassowska, Wanda, Gauthier, Daniel J., Duke University

Investigating a period-doubling bifurcation in cardiac tissue using alternate pacing

Bifurcations in the electrical response of cardiac tissue can destabilize spatiotemporal waves of electrical activity in the heart leading to tachycardia or even fibrillation. Therefore it is important to characterize the types of bifurcations occurring in cardiac tissue. Our goal is to classify the bifurcation that occurs in cardiac cells when an increase in pacing rate induces a transition from 1:1 to 2:2 phase-locked behavior. Current mathematical models assume that the transition is mediated by a supercritical period-doubling bifurcation. For such a bifurcation, small random noise is predicted to be amplified by greater amounts as the bifurcation is approached (Wiesenfeld, K., et al., PRL (1985)). We implement this technique experimentally in bullfrog myocardium by perturbing the pacing rate by small beat-to-beat alternations. Our results do not show amplification as the bifurcation point is approached. To explain this surprising result, we hypothesize that the transition to 2:2 behavior is mediated by border-collision bifurcation, which is predicted to show little pre-bifurcation amplification.

13. Blakely, Jonathan

Corron, Ned J., Pethel, Shawn D., Quantum Optics and Nonlinear Science Group, US Army RDECOM (AMRDEC) Redstone Arsenal, AL

Optimal chain length for long-term anticipation of chaotic dynamics

Anticipating synchronization can be used to predict the future evolution of a chaotic system to times exceeding characteristic time scales of the dynamics. Typically, large anticipation times are achieved by uni-directionally coupling a chain of response oscillators, each with a short individual anticipation time to a single drive oscillator. However, long chains of oscillators are susceptible to noise-driven convective instabilities. Here we examine the effectiveness of chains of uni-directionally coupled oscillators in achieving a large total anticipation. We view the chain as a complex coupling between a single drive oscillator and a single response oscillator. The signal transmitted from the drive to the chain of response oscillators is quantized to introduce noise into the response chain. We find that larger anticipation times are obtained at the cost of reduced synchronization quality. Significantly, for any desired anticipation time there is an optimal chain length that provides the highest quality synchronization. We also observe that the optimal length scales roughly linearly with total anticipation time.

14. Block, Michael

Drasdo, Dirk, IZBI University, Leipzig Härtelstrasse 16-18, 04107 Leipzig, Germany Schöll, Eckehard, Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany, Institut für Theoretische Physik Technische, Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

Modeling cell-population growth of in-vitro monolayers

How molecular mechanisms determine the growth kinetics and phenotypes of tumors is still largely unknown. An experimental tool, used extensively by biologists, are in-vitro cultures since they permit to study systematically how modifications of the growth conditions may affect the tumor growth dynamics. However, even in-vitro not all influences are known and different competing hypotheses may account for the same observation and can often not be distinguished. Here mathematical modeling can help to identify potential growth scenarios and predict under which conditions different mechanisms should generate a distinguishable phenotype. We here present computer simulations of growing monolayers that permit a systematic analysis of the effect of migration, cell-cell adhesion, apoptosis, the cell cycle time distribution, biomechanical influences, mutations and medium properties on the growth dynamics (tumor diameter, cell population size, critical surface properties) of expanding monolayers. For this purpose we consider a kinetic Monte Carlo approach on a random lattice on which, as we explicitly show, lattice artifacts are eliminated. The model is calibrated according to off-lattice models that represent kinetic and bio-physical parameters explicitly ([1]). We compare our simulation results quantitatively with experimental findings by Bru et. al. ([2]) and propose alternative mechanisms that may explain the growth kinetics observed in expanding monolayers and make predictions that permit to validate our approach. For example, we find that apoptosis can amplify the effect of mutations and mutation can significantly affect the growth kinetics. [1] Drasdo, D. and Höhme, St., Phys. Biol. 2, 133-147 (2005). [2] Bru et al., Biophys J. 85, 2948-61 (2003).

15. Block, Michael

Schöll, Eckehard, Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany

Time-delayed feedback control of stochastic growth equations

Various growth phenomena in general, and especially crystal growth, can be described by continuous stochastic differential equations. Utilizing a forward-backward Euler algorithm we solve various growth equations in 1+1 and 2+1 dimensions. The focus is on the exponents describing the time-evolution of a surface: the growth exponent, the roughness exponent and the dynamic exponent, where only two of those are independent. We apply two different time-delayed feedback control methods to the stochastic growth equations with the aim of controlling the surface roughness. Different coupling schemes of the control force are investigated and compared. In particular, we propose a digital control scheme and a differential control scheme, where the difference between the desired growth exponent and the actual local growth exponent enters into the control force in a digital or differential way, respectively. These schemes are applied to the Kardar-Parisi-Zhang equation and the so called MBE (Molecular Beam Epitaxy) equation. It is shown that the growth exponent β and thus the temporal evolution of the rms surface roughness, can be adjusted within certain ranges. Limitations of those control schemes are investigated in detail.

16. Breban, Romulus

Vardavas, Raffaele, Blower, Sally, Department of Biomathematics, UCLA

Growing networks and the basic reproduction number in ODE epidemic models

To predict outbreaks of infectious diseases such as SARS influenza and smallpox, the basic reproduction number, R0, is generally calculated from an epidemic-level model. R0 specifies the average number of secondary infections caused by one infected individual at the start of an outbreak. It is generally assumed that R0 signals epidemic growth as follows: if R0>1 the outbreak generates an epidemic and if R0<1 the outbreak becomes extinct. Here we construct a novel class of individual-level models that generate the same temporal incidence and prevalence pattern as an epidemic-level model. We calculate R0 directly from our individual-level models. Surprisingly, we show that many different R0 values are compatible with the epidemic-level model and that an epidemic can occur even when R0<1. Thus we show that R0 can produce extremely misleading estimates of outbreak severity and of the strength of the interventions that are necessary for control.

17. Burke, John

Knobloch, Edgar, University of California, Berkeley

Localized states in the generalized Swift-Hohenberg equation

The Swift-Hohenberg equation with quadratic and cubic nonlinearities exhibits a remarkable wealth of stable spatially localized states. The presence of these states is related to a phenomenon called homoclinic snaking. Numerical computations are used to illustrate the changes in the localized solution as it grows in spatial extent and to determine the stability properties of the resulting states. Several distinct classes of snaking are identified. The relation between homoclinic snaking and the Maxwell points of the non-localized states is also examined. The evolution of the localized states outside the stationary (pinning) region is illustrated using direct simulations in time.

18. Cain, John

Department of Mathematics, Virginia Commonwealth University

Criterion for stable reentrant excitation in a ring of cardiac tissue

Under certain circumstances, ring-shaped paths of excitation can form in cardiac tissue, allowing unidirectional recirculation of action potentials. When such reentrant circulation persists, the period of circulation is typically faster than the period of the heart's natural pacemaker cells. Reentrant circulation has been linked to the initiation of faster-than-normal cardiac rhythms such as ventricular tachycardia and atrial flutter. In this presentation, using a particular kinematic model of wave propagation in a ring of cardiac tissue, we derive necessary and sufficient conditions for sustained reentry with a fixed period. The model, which exploits the restitution and dispersion properties of the tissue, is presented as a system of difference equations. These equations have a unique steady state, the stability of which determines whether reentry persists with a fixed period. Linear stability analysis leads to a characteristic polynomial of degree equal to the number of cells in the ring. Applying the Jury stability test, we derive a simple criterion (in terms of slopes of restitution and dispersion curves) for all roots of the characteristic polynomial to lie inside the open unit disc.

19. Carroll, Thomas

Naval Research Laboratory

Period adding chaos with an extremely broad spectrum

Period adding chaos, in which a driven system makes transitions such as period 2-chaos-period 3-chaos-period 4, is well known. In most cases, however, the frequency of the chaotic signal is close to the frequencies of the periodic signals. I have done experiments with a simple circuit in which the chaos has a very broad power spectrum, covering 6 orders of magnitude. I have confirmed this broadband feature in numerical simulations of the circuit. These experiments have technological implications, because they show that a narrow band high frequency signal could produce broadband interference in even simple circuits.

20. Castro, Victor

Monti, Marco, Pardo, William B., Walkenstein, Jonathan A., Nonlinear Dynamics Laboratory, Department of Physics, University of Miami, Coral Gables, FL 33146, USA Rosa, Jr., Epaminondas, Illinois State University, College of Arts and Science, Department of Physics, 312B Moulton Hall, Campus Box 4560, Normal, IL 61790-4560 USA, University of Miami

Characterization of the Rössler system in parameter space

We characterize the Rössler system by means of a map associating colors to various intervals of largest Lyapunov exponent values in parameter space. This color map allows quick access to quantitative information about the dynamics of the system. The map also permits parameter space navigation while intentionally maintaining the system in a desired state and avoiding regions where the system's behavior would be undesirable. In addition, the map exhibits a rich structure of stability clusters composed of affine-similar repetitions of basic elementary cells.

21. Catlla, Anne

Silber, Mary, Northwestern University, Porter, Jeff, Universidad Complutense de Madrid, Duke University

Non-smooth forcing of Faraday waves

When a layer of fluid is forced via periodic vertical shaking of sufficient strength, standing wave patterns form on the surface. Previous work suggests how to choose a multifrequency forcing function to control three-wave interactions affecting pattern formation in the weakly nonlinear regime. We consider non-smooth forcing functions (specifically, a series of delta functions or piecewise constant functions) and utilize the Zhang-Vinals model of Faraday waves, which is valid for weakly viscous, deep fluid layers. We derive exact analytic expressions for onset parameters and for the coefficients in relevant bifurcation equations describing the dominant modes near onset. We also explore the extent to which results from multifrequency forcing can be applied to non-smooth forcing functions. Our results suggest that lessons drawn from the multifrequency forcing problem can be used to select a sequence of impulses which would favor particular patterns of waves in the laboratory.

22. Chu, Yu-Waye

Chu, Yu-Waye (1), Sidorov, Igor, (2) Dimitrov, Dimiter (2), Gress, Ronald (1) Experimental Transplantation and Immunology Branch, CCR, NCI, (2) CCR, NCI-Frederick, National Cancer Institute, NIH

Effects of exogenous IL-7 on CD4+ T-cell homeostasis by mathematical modeling of deuterated glucose kinetics in mice

Understanding dynamic changes in T-cell homeostasis has important implications in designing therapies to preserve and/or enhance immune reconstitution in states of immunodeficiency and in the context of hematopoietic stem cell transplantation. Cytokines such as interleukin-7 (IL-7) have been shown to be critical regulators of T-cell homeostasis with respect to T-cell proliferation and survival. However, to date, little is known about the quantitative changes with respect to these parameters, as well as effects of cytokines on other components of T-cell homeostasis such as cell trafficking among different immune compartments. Such studies in human subjects are severely hindered by limited access to tissue other than peripheral blood, which prevents meaningful measurement of total peripheral and organ-specific T-cell population size. We therefore used in vivo labeling with deuterated glucose to measure parameters of CD4+ T-cell homeostasis in mice treated with IL-7. Normal young adult mice were given three-week continuous infusions of murine IL-7 vs. diluent via subcutaneous osmotic pumps. Through a four-day period at the beginning of IL-7 treatment, mice were given continuous deuterated glucose in the drinking water. Measurement of deuterated glucose by liquid chromatography-mass spectrometry and mathematical modeling of cell numbers and deuterated glucose incorporation in each of five cell compartments—total thymocytes, lymph node (LN) naïve CD4+, LN memory CD4+.

23. Conrad, Emery

Sabouri, Mohsen, Tyson, John J., Virginia Tech Math Department

Incorporating bifurcation structure into a parameter optimization scheme

Complex biochemical regulatory networks can be effectively modeled by a system of nonlinear ordinary differential equations. One difficulty in using such a modeling technique is that we often have quite a large number of control parameters, which are poorly constrained by data. Techniques of parameter optimization typically attempt to minimize parameter values by using least squares minimization on the time series data or a higher abstraction derived from the time series data. In many cases, though, modelers know exactly what type of qualitative bifurcation structure their model must exhibit in order to produce the expected dynamical behavior. Here we describe a new method of parameter optimization for systems of nonlinear ODEs that utilizes bifurcation structure to quickly hone in on probable regions of parameter space.

24. Corron, Ned

He, Xue-Zhong, School of Finance and Economics, University of Technology, Sydney, Australia, Westerhoff, Frank, Department of Economics, University of Osnabrueck, Germany, U. S. Army RDECOM, Redstone Arsenal, Alabama USA

Butter mountains, milk lakes and optimal price limiters

Imposing lower price limiters may lead to huge buffer stocks, e.g. to butter mountains or milk lakes, and this is a real problem for regulators since storage costs may become impossible to finance over time. There may exist some optimal price limiters, which require only weak market interventions and thus provide rather inexpensive options to regulate commodity markets. Using a simple commodity market model, we explore the relation between price limiters and the growth rate of the buffer stocks and show that these optimal price limiters are simply the minimum values of unstable periodic orbits of the underlying deterministic system.

25. Danforth, Christopher

Yorke, J.A., Department of Mathematics, University of Maryland

Making forecasts for chaotic physical processes

Making a prediction for a chaotic physical process involves specifying the probability associated with each possible outcome. Ensembles of solutions are frequently used to estimate this probability distribution. However, for a typical chaotic physical system H and model L of that system, no solution of L remains close to H for all time. We propose an alternative. This letter shows how to "inflate" or systematically perturb the ensemble of solutions of L so that some ensemble member remains close to H for orders of magnitude longer than unperturbed solutions of L. This is true even when the perturbations are significantly smaller than the model error.

26. Das, Atin

Das, Pritha, Dept. of Mathematics, B. E. S University, Howrah 711103, India

Fractal route to chaos in artificial neural network model

Here we present a mathematical model of Artificial Neural Network (ANN) which depending on its parameter value shows fractal dynamics in its transition to chaotic regime from stable one. It serves as an example to understand the relation between fractal and chaos, which are among the most important factors involved in complex dynamical system.

27. Das, Pritha

Das, Atin, N. H. School 1/257, Naktala, Calcutta 700047, India

Fractal analysis of different eastern and western musical instruments

In this paper, we attempt musical analysis by measuring fractal dimension (D) of musical pieces played by several musical instruments. We collected solo performances of popular instruments of Western and Easter origin as samples. We attempted usual spectral analysis of the selected clips to observe peaks of fundamental and harmonics in frequency regime. After appropriate processing, we converted them into time series data sets and computed their fractal dimension. Based on our results we conclude instrumental musical sounds may have higher Ds than those computed from vocal performances of different types Indian songs.

28. Daw, Stuart

Wagner, Robert, Edwards, Dean, Finney, Charles, Braiman, Yuri, Oak Ridge National Laboratory

Experimental observations of bifurcations in the transition from conventional to HCCI combustion in a spark ignition engine

We report experimental observations of a complex sequence of bifurcations and chaos in a spark ignition engine undergoing a parametrically driven transition between ordinary propagating combustion and volumetric combustion in the form of homogenous charge compression ignition (HCCI). The latter mode of combustion is of considerable interest to the engine research community because of its potential to greatly reduce combustion temperature and emissions of nitrogen oxides. A key feature of HCCI is that it is typically unstable under ordinary combustion conditions, and it can only be sustained by the introduction of very high levels of exhaust gas recirculation (EGR). The high levels of EGR coupled with the highly nonlinear kinetics of the ignition process create an ideal scenario for the evolution of low-dimensional nonlinear features that can be conveniently described in terms of relatively simple iterated maps. We demonstrate the application of symbol sequence analysis and polynomial fits of the low dimensional maps for characterizing the different dynamic states and for potentially implementing predictive controls.

29. Dawes, Andrew

Illing, Lucas, Clark, Susan M., Gauthier, Daniel J., Duke University

All-Optical Switching: The Weak Controlling the Strong

We report on an all-optical switch that operates at low light levels. It consists of laser beams counterpropagating through a warm rubidium vapor that induce an off-axis optical pattern. A switching laser beam causes this pattern to rotate even when the power in the switching beam is much lower than the power in the pattern. The observed switching energy density is very low, suggesting that the switch might operate at the single-photon level with system optimization. This approach opens the possibility of realizing a single-photon switch for quantum information networks and for improving transparent optical communication networks.

30. Demergis, Vassili

Glasser, Alexander, Miller, Marshal, Antonsen, Jr., Thomas M., 2, 3, Ott, Edward, 2, 3, Anlage, Steven M., 1. 1. Also with the Center for Superconductivity Research. 2. Also with the Institute for Research in Electronics and Applied Physics. 3. Also with the Department of Electrical and Computer Engineering, University of Maryland, Department of Physics

Delayed feedback and chaos on the driven diode-terminated transmission line

A simple model of a distributed, non-linear circuit that produces chaos at GHz frequencies is introduced and tested experimentally. The model circuit is a driven, diode-terminated transmission line with the transmission line impedance mismatched to that of the source. This model is motivated by the need to understand the mechanisms for RF upset in computer interconnect transmission lines as well as for the potential generation of wideband sources for chaotic communication. Experimental tests of the model were performed with driving frequencies of 10 MHz to 1.2 GHz, driving powers of -30 to +50 dBm, and delay times from 3 to 20 ns. Diode reverse recovery times ranged from 4 to 100 ns. As a result of many experiments, it was found that chaotic behavior was strongly dependent on the reactance of the system as seen by the driving source, and influenced by an applied DC voltage-bias across the diode. In the experiments that showed period-doubling and / or chaos, the reverse recovery times of the diodes were on the order of both the driving period and the delay time of the circuits. Comparisons between theory and experiment are in general agreement. Chaos at 1.105 GHz has been observed experimentally. Work supported by the DOD MURI for the study of microwave effects on electronics under AFOSR Grant F496200110374 and AFOSR DURIP Grants FA95500410295 and FA95500510240.

31. Dmitrochenko, Oleg

Bryansk State Technical University

Steady relative motion of a heavy rotating string with a fixed top point

A heavy rotating string with a single fixed top point is considered in full nonlinear formulation. The known fact is that non-trivial positions of relative equilibrium are possible and they are unstable (see, e.g., works by Lemon & Fraser as well as by Silverman et al.). Main result of this study is about steady motion of the system: there is either stable steady motion like self-excited oscillations near positions mentioned, or ‘very slow, non-exponential’ instability in sense of KAM-theorem. The numerical simulation shows possibilities of the two scenarios. Analytical and numerical research of the rigid-body models of the system is considered, such as double spherical pendulum.

32. D'Orsogna, Maria

Chuang, Yao-li, Bertozzi, Andrea, Chayes, Lincoln, UCLA Mathematics Department

Pattern formation, collapse and stability in 2D driven particle systems

We consider a non-linear system of self-propelled particles interacting via pairwise potentials. For certain soft-core and even hard-core interactions, flocks and localized vortex solutions exist. Here, agents may rotate all in the same direction, or along coexisting clockwise and counter-clockwise vortices. We discuss the connections between H-stability of the interactions and the resulting collapsed or stable behavior. We also discuss the coarse grained equations obtained through the Kirkwood-Irving approach.

33. Dovzhenko, Alexander

Rumanov, E.N., Rumanov, I.E., Institute of Structural Macrokinetics and Material Science, Russian Academy of Sciences, Chernogolovka, 142432 Russia

Non-stationary autowaves

We consider a simple model of autowave in one-dimensional approach. As is known, narrowness of reaction zone allows one to obtain a nonlinear integral equation on burning velocity. Near propagation limit, the wave velocity varies slowly. It makes be possible to reduce this equation to an ordinary differential equation of 1st order. We termed it quasi-stationary equation (QSE). The QSE solutions describe an approach to uniform propagation of the wave above the limit. Below the limit, they are suitable for a slow stage of the wave quenching that determines characteristic time of the process. According to QSE, the wave susceptibility diverges as the limit is approached. This results in onset of chaotic pulsating of the wave velocity and magnitude. Maximal deviations in the pulsating are comparable in scale to corresponding mean values - as at fully developed turbulence. In their spectra, low frequencies prevail. The low-frequency peak narrows with parameter displacement toward the limit. The wave numerical simulation shows a good qualitative agreement with the QSE solutions. At the same time, the QSE is not valid in the case of small diffusivity: the wave becomes non-stationary before the limit. From the numerical simulation, we see transition to chaotic modes through a sequence of period doublings. Then frequent transitions between the chaotic modes occur, and the spectrum tending from discrete to continuous form. However, it returns sometimes to concentration near a several 'lines'. We treat this as a manifestation of frequency locking. If parameters correspond to such a concentration, intermittency is observed in time evolution of the wave velocity. Just above the limit, a fully developed chaos takes place in sub-limit region of parameters.

34. Dutta, Anirban

Triolo, Ronald, Department of Biomedical Engineering, Case Western Reserve University, Motion Studies Laboratory, Stokes, Louis, VA Medical Center, Cleveland, OH

Stability analysis of surface electromyogram (sEMG) based functional electrical stimulation (FES) assisted overground ambulation after incomplete spinal cord injury

The surface electromyogram (sEMG) is the electrical activity recorded at the surface of the skin that is generated by a contracting muscle. The volitionally modulated sEMG can be used to drive the functional electrical stimulation (FES) of the less-functional synergists during a cyclic activity like gait. A pattern of volitional muscle activation exists during finger-switch activated, FES assisted gait in some incomplete spinal cord injured (iSCI) subjects. The pattern of volitional sEMG was used to trigger and modulate the stimulation patterns during FES assisted gait. The joint kinematics was studied using phase-plane potraits and first return-maps in able-bodied (4 subjects) and iSCI (1 subject) subjects [1]. The dynamic stability of the able-bodied gait was compared with the auto-trigger and sEMG based FES-assisted iSCI gait. 1. Hurmuzlu, Y. and Basdogan, C. 'On the measurement of stability in human locomotion', ASME Journal of Biomechanical Engineering, Vol. 116, pp. 30-36 1994.

35. Fertig, Elana

Liu, Junjie, University of Maryland, Li, Hong, Kalnay, Eugenia, Szunyogh, Istvan, Kostelich, Eric, Arizona State University, Todling, Ricardo, NASA Goddard, University of Maryland

Data assimilation with the local ensemble transform Kalman filter on NASA fvGCM

Weather forecasts deviate from the true behavior of the atmosphere. This deviation is in part caused by errors in weather models, but also is due to errors in the initial conditions of those models. Data assimilation schemes improve forecasts by improving these initial conditions. The Local Ensemble Transform Kalman Filter (LETKF) applies the Ensemble Transform Kalman Filter technique (Bishop et al. 2001) to update an ensemble of initial conditions. Because LETKF is applied on local regions (as in the LEKF approach of Ott et al. 2002, 2004), the scheme can take advantage of the low-dimensional subspace to reduce the required ensemble size. LETKF is applied to the NASA fvGCM weather model to assimilate simulated grid-point and rawinsonde observations. The results from this scheme are compared with those obtained from the operational PSAS data assimilation scheme.

36. Foukzon, Jakov

Israel Institution of Tech.

High-resolution numerical-analytical internal S. Albeverio path-integral development of infinite dimensional Fokker-Planck equations and its application in stochastic and quantum gravity

We study the existence of shock wave and chaotic solutions for systems, stochastic partial differential equations of stochastic [1] and quantum gravity in the context of Colombeau's theory [3] of generalized functions for Einstein Langevin equations and another corresponding dynamical system. High-resolution numerical-analytical method (a non-Monte-Carlo and a non optimal-path algorithm) for S. Albeverio path-integral is proposed. The proposed new mechanism for quantum chaos generates in quantum gravity. [1] Bei Lok Hu, Enric Verdaguerm, Stochastic Gravity: Theory and Applications: Living Reviews in Relativity. Published by the Max Planck Institute for Gravitational Physics, Albert Einstein Institute, Germany, 2001. [2] J. Foukzon, New Scenario for Transition to Slow Turbulence. Turbulence like quantum chaos in three dimensional model of Euclidian quantum field theory. Preliminary report. Notices of the AMS 2004, Volume 51, Number 9. [3] F. Villarreal, Electronic Journal of Differential Equations, Vol. 2000 (2000), No. 21, pp. 117. [4] S. Albeverio, J.E. Fenstad, R. Hoegh-Krohn, T. Lindstrem, Nonstandard methods in stochastic analysis and mathematical physics, Academic Press, Inc., 1986, 590 pp.

37. Gilbreth, Christopher

Christopher Gilbreth, Scott Sullivan, Myles Adams, Michael Dennin
University of California, Irvine

Velocity Profiles in Steadily Sheared Foams

Foams behave elastically under low stress, and past a critical threshold they begin to flow; however, the dynamics of flow in complex fluids, such as how it arises by individual particle rearrangements and the requirements for and overall characterization of flowing states is not well understood. We examine the distribution with respect to radial distance of the tangential velocities of individual bubbles of a monolayer foam when it is steadily sheared in a circular trough, and compare our results to predictions of the presence of two distinct states, elastic and fluid-like. We look for the presence of a critical radius which cleanly separates the two states and the dependence of its location on the parameters of the system, namely the shearing rate and total area of foam. We also examine its relationship to the rotational stress exerted by the system on a centrally located torsion pendulum.

38. Gonzalez, Marta

P. G. Lind, H. J. Herrmann
Stuttgart University

A system of mobile agents to model social networks

We propose a model of mobile agents to construct social networks, based on a system of moving particles by keeping track of the collisions during their permanence in the system. We reproduce not only the degree distribution, clustering coefficient and shortest path length of a large data base of empirical friendship networks recently collected, but also some features related with their community structure. The model is completely characterized by the collision rate and above a critical collision rate we find the emergence of a giant cluster in the universality class of two-dimensional percolation. Moreover, we propose possible schemes to reproduce other networks of particular social contacts, namely sexual contacts.

39. Han, Sejin

Losert, Wolfgang, University of Maryland

Characterize the network formation of type 1 normal and mutant collagen

We study the self-assembly of type 1 Collagen termed fibrillogenesis. Homozygous mutations resulting in replacement of type 1 normal heterotrimers (a1 (I)2 a2 (I)) by a1 (I)3 homotrimers cause mild to severe Osteogenesis Imperfecta (OI) in humans and mice. Recent studies of fibrillogenesis of type I homozygous mutations revealed a substantial difference in the kinetics of fibrillogenesis, in particular rapid growth of fibers and the absence of lag time in homotrimers. We developed a technique for differential fluorescent labeling of collagen combined with laser scanning confocal microscopy for time dependent observation of fibrillogenesis kinetics and structural properties in 3D. We found that hetero- and homotrimers in mixtures co-assembled within the same fibrils during fibrillogenesis, despite their very different fibrillogenesis kinetics. Turbidity measurements of fibrillogenesis of mixture of heterotrimers and homotrimers showed the normal S-shaped curve with a lag time typical of heterotrimers that depended on mixing ratio. Relatively slow kinetics of homotrimers fibrillogenesis was observed in OI-mice tail tendon, despite a previous report of rapid growth of homotrimers. We characterized the structural topology of the collagen 3D network through Betti numbers, which can be the maximum number of cuts without dividing a surface into two separate pieces comprising the geometric structure. Changes of Betti numbers monitored during fibrillogenesis provide direct information about the structural aspects of assembled collagen networks. We found that homotrimers has fewer intersections per disjoint fiber than normal heterotrimers, demonstrating finer and straighter network structure in images.

40. Harrison, Mary Ann

Institute for Scientific Research Inc., Fairmont, WV, Frei, Mark G., Flint Hills Scientific, L.L.C., Lawrence, KS, Osorio, Ivan, University of Kansas Medical Center, Kansas City, KS and Flint Hills Scientific, L.L.C., Lawrence, KS, Institute for Scientific Research, Inc.

Tracking spatiotemporal evolution of epileptic seizures using unstable period orbit analysis

According to conventional understanding, partial seizures are the product of hyper-synchronous neuronal discharges, though recent research suggests that the onset of seizures may actually correspond to a decrease in neuronal synchrony. In either case, measures of synchronization are thought to be useful for detection of seizure precursors and of epileptic seizures. Recent theoretical work on coupled chaotic systems suggests that the onset of generalized synchronization.

41. Hart, James

Ed Ott, Tom Antonsen, University of Maryland

Time-domain Scattering from Chaotic Microwave Cavities

We report on the results of simulations of the time-domain scattering of microwaves off chaotic cavities, including calculations of the average and standard deviation of the reflected waves over ensembles of chaotic cavities.

42. Hartt, Kenneth

Physics Dept., Univ. of Rhode Island

Establishing noisy chaos with correlation integrals

The Gaussian-weighted correlation integral T(h) introduced nine years ago by Diks has led to significant advances in estimation of the noise accompanying a chaotic signal. Here, I contribute one enhancement and also a somewhat surprising application of T(h). My enhancement is to take a necessary, critical step towards establishing underlying chaos through identification of a nonlinear scaling region and evaluation of the goodness of fit between theory and data. To do this I first simplify and improve its implementation [1]. My application is to seek to rescue Grassberger and Procaccia's original correlation integral C(r) as a tool for noise estimation. To date, efforts at estimation of significant noise using C(r) have not been very successful. I prove that in some cases such estimates are based on unrealistic assumptions and cannot work. I then present a promising asymptotic analysis of C(r) that does not make these assumptions. My analysis makes use of (1) the connection between C(r) and T(r) and (2) analytic continuation of C(r) [1 2]. [1] Kenneth Hartt, unpublished work. [2] P.V.A. Yidana and K. Hartt, J. of Comp. Phys. 78, 481 (1988).

43. Hastings, Harold

Zaharakis, Alex, Hilaire, Christian, Hofstra University, Evans, Steven J., Beth Israel Medical Center, Hofstra University

Scaling behavior and a Markov model for ventricular fibrillation generated by ectopic beats

Sudden cardiac death is a major cause of death in the industrialized world, responsible for some 300,000 to 400,000 deaths per year in the United States alone. Although the cardiac electrical system normally produces one ventricular activation in response to each stimulus from the sinus node "spontaneous" activations, called ectopic beats or premature ventricular contractions (PVCs), can arise in the ventricles themselves, and propagate through the ventricles. Ectopic beats are usually harmless in the absence of underlying disease; however they can generate broken wavefronts when they encounter gradients of refractoriness generated by other (sinus or ectopic) beats. These broken wavefronts may generate spiral waves producing ventricular tachycardia, ultimately degenerating into ventricular fibrillation (VF), causing sudden cardiac death. When does a PVC lead to ventricular fibrillation? This is a stiff problem, involving time scales from milliseconds to many years (a probability 1/10 event in 30 years corresponds to a 300 year time scale). We overcome this stiffness problem by developing universal scaling properties for this process, and using these rules to drive a Markov process. We find two significant "amplifiers" in this process, show how the model readily fits Moise's German shepherd model which inspired it (thanks to Dr. Anna Gelzer at Cornell).

44. Hayes, Scott

US Army RDECOM, Redstone Arsenal, AL

Deterministic dynamics by random linear synthesis

Lorenz-like deterministic dynamics is shown to result from the linear superposition of a bi-infinite sequence of self-similar basis functions with random polarity. Thus the classical theory of random processes is connected in a simple way to the formalism of deterministic flows. The process can also be represented as a linear filter excited by randomly polarized delta functions.

45. Hemmady, Sameer (2, 3, 4)

Zheng, Xing (1, 3, 5), Antonsen Jr., Thomas M. (1, 2, 3), Ott, Edward (1, 2, 3) and Anlage, Steven M. (1, 2), Dept. of Electrical and Computer Engineering, University of Maryland, College Park, MD, USA

"The random coupling model" – experimentally uncovering universal wave-chaotic properties

Microwave cavities, with classically chaotic ray dynamics, have proved to be a fruitful test-bed for the experimental tests of Universal fluctuations in wave-chaotic systems. An experimental difficulty often faced in measurements of these universal fluctuations is the system-specific, "direct processes" introduced into the measured data. These direct processes arise from the non-ideal coupling between the driving ports and the chaotic cavity. The "Random Coupling Model" (RCM) [1,2] makes use of the frequency-dependent, radiation impedance matrix of the driving ports to characterize these direct processes. RCM provides a simple matrix-normalization process of the measured cavity impedance matrix with the measured radiation impedance matrix to yield a universally fluctuating impedance, admittance and scattering matrix for wave-chaotic systems. These fluctuating quantities are dependent only upon the degree of quantified loss in the chaotic cavity. We show experimental results that employ the RCM to recover universal fluctuations in the impedance, scattering and admittance properties of wave-chaotic systems driven by one [3] or two ports as a function of quantified loss. We experimentally test the statistical independence of the magnitude and phase of the one-port, wave-chaotic scattering coefficient, which leads to the Dysons' Circular Ensemble from Random Matrix Theory (RMT) [4]. We also show how RCM can be used to recover Universal Conductance and Transport Fluctuations in two-port systems, which is of keen interest to the quantum-transport community. The experimental results are in good agreement with predictions from RMT. These results are also general to any wave-chaotic system and valid for any driving-port geometry. This work is supported by the DOD MURI for the study of microwave effects under AFOSR Grant F496200110374 and AFOSR DURIP Grants FA95500410295 and FA95500510240. References: [1] X. Zheng, T.M. Antonsen and E. Ott, accepted by Electromagnetics, preprint cond-mat/0408327. [2] X. Zheng, T.M. Antonsen and E. Ott, accepted by Electromagnetics, preprint cond-mat/0408317. [3] S. Hemmady, X. Zheng, T.M. Antonsen, E. Ott and S.M.Anlage, Phys. Rev. Lett. 94, 014102 (2005). [4] S. Hemmady, X. Zheng, T.M. Antonsen, E. Ott and S.M. Anlage, Phys. Rev. E 71, 056215 (2005).

46. Hilborn, Robert

Erwin, Rebecca J., California Institute of Technology, Amherst College

Fokker-Planck analysis of stochastic coherence in models of an excitable neuron with noise in both fast and slow dynamics

Excitable systems often have two (or more) distinct time scales. Here we provide a detailed and quantitative Fokker-Planck analysis of noise-induced periodicity (stochastic coherence, also known as coherence resonance) in both a discrete-time model and a continuous-time model of excitable neurons. In particular, we show that one-dimensional models can explain why the effects of noise added to the fast and slow dynamics of the models are dramatically different. We argue that such effects should occur in any excitable system with two or more distinct time scales and need to be taken into account in experiments investigating stochastic coherence.

47. Hirata, Yoshito

Hideyuki, Suzuki, The University of Tokyo, Kazuyuki, Aihara, The University of Tokyo/ERATO, JST, Department of Mathematical Informatics

The stronger the wind is, the more useful the prediction is: predicting the wind using the spatial correlation

We are trying to predict the wind in a second or minute order for producing more electricity by adjusting wind turbines to the future wind. Our recent studies showed that the wind in this time scale cannot be predicted well from the observation at the predicted point only. To overcome this problem, we introduce another observation point and try to predict the wind better. When the second observation is at the upstream we can improve the predictability of the wind. Moreover, we also found that under this circumstance we can predict the wind better when the wind is strong.

48. Hoevel, Philipp

Eckehard Schoell Institute of Theoretical Physics, Technische Universitaet Berlin, Sekr. 7-1 Hardenbergstr. 36, 0623 Berlin, Germany

Time-delayed feedback control with variable phase-dependent coupling

During the last decade time-delayed feedback methods have been successfully used to control unstable periodic orbits as well as unstable steady states. In most of the theoretical analysis, this control method is considered in the realization of diagonal coupling, i.e., the control force applied to the i-th component of the system is a function of exclusively the same component. Although diagonal coupling is suitable for a theoretical investigation, it is often not feasible for an experiment. Therefore we consider the more general case where control is effected by a nondiagonal coupling matrix. Specifically, we investigate the time-delayed feedback scheme for a rotational coupling matrix parametrized by a variable phase. We present an analysis of the domain of control and show the application to optical systems where the optical phase is an additional degree of freedom.

49. Illing, Lucas

Gauthier, Daniel J., Department of Physics and Center for Nonlinear and Complex Systems, Duke University, Durham, North Carolina 27708 USA

Ultra-high-frequency chaos in a time-delay system with band-limited feedback

We report an experimental study of ultra-high-frequency chaotic dynamics generated in a delay-dynamical system. Our device consists of a transistor-based nonlinearity, commercially available amplifiers, and a transmission-line for feedback. The feedback is band-limited which allows tuning of the characteristic time-scales of both the periodic and high-dimensional chaotic oscillations that can be generated with the device. We develop a model and use it to compare the experimentally observed Hopf-bifurcations of the steady-state to existing theory and to numerically explore the route to chaos.

50. Indic, Premananda

Schwartz, William J., Paydarfar, David, Department of Neurology, University of Massachusetts Medical School, Worcester, MA 01655

Design Principles for Phase-Splitting Behavior of Coupled Cellular Oscillators: Clues from Hamsters with "Split" Circadian Rhythms

Rhythmic behaviors of higher organisms can emerge from the temporal coordination of cellular oscillators within tissues, and the control of intercellular synchronization within tissues is likely to underlie a variety of normal functions as well as certain pathologies. Here we analyze one biologically important behavior, an abrupt doubling of rhythm frequency. Theoretical analyses of coupled oscillators have suggested that a group of synchronized cellular oscillators could double its frequency by spontaneously splitting into two subgroups, each subgroup oscillating with a common frequency but now in antiphase, a phenomenon called 'phase-splitting'. Recently, a biological example of phase-splitting behavior was demonstrated in the suprachiasmatic nucleus (SCN) of the mammalian brain, the site of an endogenous timekeeping mechanism that regulates 24-hr (circadian) rhythmicity. The SCN is composed of multiple single-cell circadian oscillators coupled together to generate a circadian output signal. Hamsters housed in constant light can exhibit a phenomenon known as "splitting".

51. Jevtic, Nada

J. S. Schweitzer Physics Department, University of Connecticut and Stockton, Richard, College of New Jersey

Three-dimensional Poincare section return-time amplitude spectra: identification of dynamical resetting for efficient nonlinear noise reduction

Nonlinear time series analysis using time-delay phase space reconstruction is one way to deal with nonlinear signals that have broadband power spectra. However, the utility of this straightforward tool is limited by noise. We look at the effect of two types of noise for the case of a quasiperiodic nonlinear system. Noise that "spikes" the phase space point off a trajectory with subsequent resets back onto the trajectory is quite different from noise that "de-threads" trajectories. "Resetting" noise can greatly be reduced using local nonlinear projective noise reduction. A novel concept, the three-dimensional Poincare section return time (and hence, frequency) amplitude spectra is proposed as a tool to identify noise resetting and those systems whose output is amenable to nonlinear projective noise reduction.

52. Khain, Evgeniy

Sander, Leonard M., Department of Physics and Michigan Center for Theoretical Physics, The University of Michigan, Ann Arbor, Michigan 48109

Dynamics and pattern formation in invasive tumor growth

In this work we study the in-vitro dynamics of the most malignant form of the primary brain tumor: Glioblastoma Multiforme. Typically the growing tumor consists of the inner dense proliferating zone and the outer less dense invasive region. Experiments with different type of cells show qualitatively different behavior. Wild type cells invade a spherically symmetric manner, but mutant cells are organized in tenuous branches. We formulate a model for this sort of growth using two coupled reaction-diffusion equations for the cell and nutrient concentrations. When the ratio of the nutrient and cell diffusion coefficients exceeds some critical value, the plane propagating front becomes unstable with respect to transversal perturbations. The instability threshold and the full phase-plane diagram in the parameter space are determined. We also analyze the role of cell-cell adhesion.

53. Khakpour, Asha

CSUDH

Fixed-point iteration, fractal images, and chaos in dissipative and conservative dynamical systems

This is a survey article reviewing some of the highlights of iteration techniques as applied in fractal and chaos theories. Algorithms are implemented using Java GUI. The origins of fixed point iteration method in the work of Jamshid Kashi (c.1400) is reviewed. The Newton's iteration method and the resulting fractals are presented. Linear fractal models of some patterns of nature using iterations of an affine transformation of a plane figure or using language-based models are presented. Quadratic fractals such as Julia set and the related Mandelbrot set are reviewed. Nonlinear dynamical systems exhibit chaotic behavior in the case of both dissipative and conservative systems with underlying fractal patterns. In one dimension iterations of logistic and quadratic maps are presented. In two dimensions iterations of dissipative and conservative Henon maps are presented.

54. Knudsen, Steven

Harrison, Mary Ann, Institute for Scientific Research, Inc.

Using simulated data to verify and validate nonlinear measures for nondestructive evaluation of macrostructures

Nondestructive health monitoring is important for a variety of military and industrial systems. The goal of this monitoring is to reduce system maintenance costs, as well as predict or prevent catastrophic system failure. For example, mechanical vibration methods are frequently used due to their low cost, and their ability to both detect and localize damage on a macrostructure. To complement established linear methods, nonlinear methods based on attractor distortion, nonlinear prediction, and continuity have been developed previously for use on structures excited with chaotic vibration. These methods are applied to data from laboratory experiments, where damage to a structure has been introduced by a change in geometry to a structure, such as removal of bolts from a composite plate. To complement these experiments, we construct a phenomenological model consisting of a damped spring-mass model forced by a Lorenz signal, providing a controlled setting for systematic evaluation of the performance of nonlinear measures for damage detection and localization. We analyze both noise-free and data with additive Gaussian noise in order to establish the sensitivity of the measures to noise.

55. Krishnamurthy, V.

Center for Ocean-Land-Atmosphere Studies, Institute of Global Environment and Society, Calverton, MD 20705 and School of Computational Sciences, George Mason University, Fairfax, VA 22030

Dimensions and predictability in a large atmospheric dynamical system

A dynamical system representing a two-layer quasi-geostrophic atmosphere has been studied to understand the predictability and growth of errors in the system. The model is built with spectral expansion using suitable functions that represent the geometry and boundary conditions. The model is studied for various spectral truncations by including as many smaller scale features as necessary. The model is thus large enough to be studied as a dynamical system with precise computation but not as unmanageable as a general circulation model. The nature of the chaotic attractors as a function of forcing and spectral expansion is discussed. For each case, the predictability is understood by studying the local and global growth of initial errors. It will be shown that the dimension of the chaotic attractors is quite high even with the simple dynamical structure of the model and increases as the spectral truncation includes smaller scale features.

56. Kulp, Christopher

Tracy, E. R., Department of Physics, The College of William and Mary, Eastern Kentucky University

Control of multidimensional integrable Hamiltonian systems

In this poster, we study the controllability of a four-dimensional integrable Hamiltonian system that arises as a low-mode truncation of the nonlinear Schrödinger equation [Bishop et al. Phys. Lett. A 144, 17 (1990)]. The controller targets a solution of the uncontrolled dynamics. We show that in the limit of small control coupling, a Takens-Bogdanov bifurcation occurs at the control target. These results support our earlier claim that Takens-Bogdanov bifurcations will generically occur when dissipative control is applied to integrable Hamiltonian sytems. The presence of the Takens-Bogdanov bifurcation causes the control to be extremely sensitive to noise. Here, we implement an algorithm first developed in Kulp and Tracy [Phys. Rev. E 70, 016205 (2004)] to extract a subcritical noise threshold for the four-dimensional system.

57. Lai, Ying-Cheng

Park, Kwangho, Arizona State University, Zhao, Liang, University of Sao Paulo, Brazil, Arizona State University

Attack-induced cascades on complex networks

Complex networks arising in many natural and man-made systems are scale-free in that their connectivity (or degree) distributions follow an algebraic law. In such a network, a small subset of nodes can be significantly more important than others. From the standpoint of security, this means that the network can be fragile as attack on one or few nodes in this group can have a devastating effect. In particular, considering that those nodes typically handle a substantial fraction of loads necessary for the normal operation of the network, an attack to disable one or few of these nodes means that their loads will be redistributed to other nodes. Because the amount of the redistributed loads can be large, this can cause other nodes in the network to fail, if their loads exceed their capacities, which in turn causes more loads to be redistributed, and so on. This cascading process can continue until the network becomes totally disintegrated. Indeed, simulations show, for instance, that for a realistic power-grid network, attack on a single node can disable more than half of the nodes, essentially shutting down the network. We will present a prototype model for attack-induced cascades on scale-free networks and a physical theory based on phase-transition to understand the dynamical mechanism underlying the cascading process, and to discuss some practical strategies to prevent cascading breakdown.

58. Landsman, Alexandra

Schwartz, Ira B., Naval Research Laboratory

Generating ultra-harmonics using coupled arrays of limit cycle oscillators

The interaction between two arrays of limit cycle oscillators, modeled by Stuart-Landau equations is investigated. The coupling within the arrays is diffusive, nearest-neighbor coupling, with attractive (in-phase) coupling in one array, and repulsive (out-of-phase) coupling in the other. It was found that ultraharmonic oscillations can be induced in the in-phase coupled arrays when the two arrays are globally coupled. The mechanism behind this creation of ultraharmonic oscillations is explained and the conditions under which such oscillations occur are derived.

59. Lara-Cisneros,Gerardo

Gerardo Lara (a), Abigail Loredo-Osti (b), Elias Pérez (b), (a) CIEP-Facultad de Ciencias Químicas (b) Instituto de Física, Universidad Autónoma de San Luis Potosí. Alvaro Obregon 64, C.P. 78000, San Luis Potosí, México, Universidad Autónoma de San Luis Potosí México

Dynamics of formation of patterns periodic concentric with a system of equations Reaction-Diffusion-Evaporation

In this work we study the dynamics of formation of patterns periodic concentric (rings of Liesegang), on a glass surface, by mixtures of particles of colloids. The parameters that control the formation of these patterns are: the load and the size of the particles, the concentration of the mixtures and the speed of evaporation of solvent, related to the temperature of the experiment. We proposes also a model based on a system of equations Reaction-Diffusion-Evaporation (RDE), a supersaturation model is used to represent the kinetic for precipitate process; we also include a term of evaporation of solvent in PDE's system.

60. Lauga, Eric

Hosoi, Anette, Massachusetts Institute of Technology

Gastropod locomotion: How tuned are the properties of the mucus?

Common gastropods such as snails crawl on a solid substrate by propagating muscular waves of contraction on a viscoelastic mucus. Producing the mucus accounts for the largest component in the gastropod's energy budget, more than twenty times the amount of work used for crawling. Using a simple mechanical model, we show that the rheological properties of the mucus (shear-thinning) favor a decrease in the amount of mucus necessary for crawling, thereby decreasing the overall energetic cost of locomotion.

61. Le, Zheng

Castro, Victor, Pardo, William B., Walkenstein, Jonathan A., University of Miami, Rosa Jr., Illinois State University, University of Miami

Competing Chua phase synchronization between two superimposed sinusoidal functions

We show experimental and numerical results of the competition between two small sinusoidal inputs that try to phase synchronize to a chaotic Chua circuit. Our observations indicate that depending on the values of amplitude and frequency of the two sinusoidal functions, the Chua oscillator can stay phase synchronized to one of the inputs all the time, or can alternate synchronous states between them (*). This is a natural extension of the case where one periodic function entrains a chaotic oscillator. It can be regarded as a next step toward more complicated synchronization processes involving multiple oscillators. (*) R. Breban and E. Ott, Phys. Rev. E 65, 056219 (2002).

62. Lee, Tae

Yao, Guang, You, Lingchong, Nevins, Joseph, Duke University

Bifurcation analysis of the Restriction Point in cell cycle regulation

Restriction-point (R-point) refers to a position in the cell cycle where cells commit to proliferation given enough growth factors. Removal of growth factors before the R-point rejects the cells back to the quiescent state. However, removal of the growth factors after the R-point does not prevent completion of the cell cycle. In order to better understand the mechanisms underlying the R-point, we have investigated the role of the Myc/Rb/E2F pathway, which is known to play a central role in regulating the cell cycle entry and coordination. Understanding of the Myc/Rb/E2F pathway in governing the R-point may contribute to cancer therapy since most human cancers have mutations in elements of regulatory networks that define the R-point. Incorporating existing biological data and mechanisms, we have implemented a mathematical model. Our preliminary modeling results demonstrate a bistable switching behavior in the Myc/Rb/E2F pathway. These predictions and our current experimental knowledge of the cell cycle regulation have led us to hypothesize that the Myc/Rb/E2F pathway is a critical module that defines the R-point.

63. Lin, Kevin

Courant Institute, NYU

Entrainment and chaos in a Hodgkin-Huxley oscillator

I will speak about the response of a spontaneously spiking Hodgkin-Huxley neuron to periodic pulsatile drives. In particular, I will discuss the response as a function of drive period and amplitude. A wide range of qualitatively distinct responses can be found in this system, including entrainment to the input pulse train and persistent chaos. These observations are consistent with a theory of kicked oscillators developed by Qiudong Wang and Lai-Sang Young. In addition to general features predicted by Wang-Young theory, it is found that most combinations of drive period and amplitude lead to entrainment instead of chaos. This preference for entrainment over chaos is explained by the structure of the Hodgkin-Huxley phase resetting curve.

64. Lois, Gregg

Carlson, Jean, UC Santa Barbara

Long-range correlation in granular flow

We investigate the effects of long-range correlations in simulations of sheared granular materials. Measurements of spatial force correlations allow for a natural definition of average cluster size, which we find diverges at the jamming threshold and approaches two for dilute systems. When the average cluster size is small, predictions from kinetic theory match data for the shear stress and pressure; as the cluster size increases, kinetic theory is no longer applicable and theories that assume long-range correlation are introduced. These theories predict new constitutive relations, dependent on properties of the clusters that match measurements from simulation. Finally, the average cluster size is also shown to have a pronounced effect on the contact force distribution function, with the most likely value of the force decreasing as the average cluster size increases.

65. Luchinsky, Dmitry

Smelyanskiy, V.N., NASA Ames Research Center, Moffett Field, CA 94035 USA, M.M. Millonas Mission Critical Technologies Inc., 2041 Rosecrans Ave. Suite 225, El Segundo, CA 90245 USA, Mission Critical Technologies Inc., 2041 Rosecrans Ave. Suite 225, El Segundo, CA 90245 and Department of Physics, Lancaster University, Lancaster LA1 4YB UK

Nonlinear statistical model discovery for ecological data

The search for dynamical models (dynamical inference) underlying time-varying phenomena is of fundamental importance for understanding and controlling complex systems in science and technology. Often, however, only part of the system's dynamics can be measured and the state of the dynamical system remains invisible (or hidden). Furthermore, the measurements are usually corrupted by noise and the dynamics is complicated by the interplay of nonlinearity and random perturbations. The problem of dynamical inference in these general settings is challenging researchers for decades. No overall solution was previously available for this problem even in the deterministic case [1]. We solve this problem by applying a path-integral approach to fluctuational dynamics [2] combined with our recent result on dynamical inference of stochastic nonlinear systems [3,4], and show that, given the measurements, the system trajectory can be obtained from the solution of the certain auxiliary Hamiltonian problem in which measured data act effectively as a control force driving the estimated trajectory toward the most probable one that provides a minimum to a certain mechanical action. The dependence of the minimum action on the model parameters determines the statistical distribution in the model space consistent with the measurements. We illustrate the efficiency of the approach by solving an intensively studied problem from the population dynamics of predator-prey system [5] where the prey populations may be observed while the number of predators is difficult or impossible to estimate. We emphasize that the predator-prey dynamics is fully nonlinear, perturbed stochastically by environmental factors and is not known beforehand [6]. We apply our approach to recover both the unknown dynamics of predators and model parameters (including parameters that are traditionally very difficult to estimate) directly from measurements of the prey dynamics. [1] H.U. Voss, J. Timmer, J. Kurths, Int. J. Bifurc. and Chaos, v. 14, 1905 (2004). [2] R. Graham, Z. Phys. B, v. 26, 281 (1977). [3] V. N. Smelyanskiy, D. G.
Luchinsky, A. Stefanovska, P. V. E. McClintock, Physical Review Letters, 94, 098101 (2005). [4] V. N. Smelyanskiy, D. G. Luchinsky, D. A. Timucin, A. Bandrivskyy, Physical Review E, 72, 026202 (2005). [5] I. Hanski, H.

Henttonen, E. Korpima Äaki, L. Oksanen, P. Turchin, Ecology 82, 1505 (2001). [6] P. Turchin, S. P. Ellner, Ecology, v. 81, 3099 (2000).

66. Mahdi, Moghimi

Massah, H., Khoramaishad, H., Dept. of Mechanical Engineering, Iran University of Science and Technology

Application of Adomian Decomposition Method for Solving Oscillation Equations

In this paper, Adomian decomposition method has been applied to solve typical oscillation equations (Duffing and Van der pol equations) analytically with initial conditions. The method does not need linearization or weak nonlinearity assumption, perturbation theory. The ADM solution is compared with the numerical solution and the results shows a good agreement confirming the applicability of the method.

67. McHarris, Wm. C.

Michigan State University

Chaos and complexity meet quantum mechanics: Is quantum mechanics nonlinear?

Many of the paradoxes associated with the Copenhagen interpretation of quantum mechanics have more logical interpretations in terms of nonlinear dynamics and chaos. These range from quantization itself through exponential decay laws (extreme sensitivity to initial conditions, consistent with the Uncertainty Principle) to Bell-type inequalities (classical use of nonextensive entropy and correlated statistics) and even diffraction (order in chaos). Many of the objectors to the Copenhagen interpretation (i.a. de Broglie Bohm) toyed with ideas we now recognize as coming from nonlinear dynamics — had the founders of quantum mechanics had access to modern chaos theory quantum mechanics might well have developed along different lines. Perhaps both Einstein and Bohr were correct during their debates: chaos provides a bridge between the basic determinism so dear to Einstein, yet must be interpreted statistically in the manner of Bohr's school of thought.

68. McQueen, Philip G.

McQueen, Philip G. (MSCL/DCB/CIT/NIH), McKenzie, F. Ellis (FIC/NIH),MSCL/DCB/CIT/National Institutes of Health

A model of pathogens competing for the same prey: How red blood cell population dynamics can affect mixed-species malaria infections

The two most widespread agents of human malaria, Plasmodium vivax and Plasmodium falciparum, often co-infect the same host and compete for mutual prey, red blood cells (RBC). P. vivax parasitizes only the youngest RBCs, while P. falciparum apparently attacks RBCs of any age. Using a differential equations model to model the population dynamics of RBCs and parasites in co-infection, we describe the logical outcome of competition for the RBCs. The typical outcome is for one species to suppress the other, depending on their relative reproduction rates and timing of inoculation. But we show that if the species' reproduction rates are nearly equal, transient increases in RBC production stimulated by the presence of P. falciparum under a variety of circumstances may boost P. vivax parasitemia, while P. falciparum parasitemia is rarely enhanced and sometimes even suppressed. In addition, transients in RBC production induce coupled oscillations in the parasitemia of both species if the host survives long enough. These simulated outcomes are very robust to changes in model parameters. We discuss their relevance to clinical situations and how the host's immune system may modify them.

69. Mecholsky, Nicholas

Ott, Edward, Antonsen Jr., Thomas M., UMD

Dynamics of Swarms

The collective behavior via local interactions of animal groups (herds, flocks, etc.) provides a fascinating instance of a self-organizing system. In this poster we consider continuum model descriptions of animal groups with particular emphasis on dynamics and relaxation of the collective behavior of such groups. Topics considered will include equilibrium swarms, waves on swarms, relaxation to equilibrium, excitation of waves by obstacles and predators, and stability.

70. Miller, Bruce

Yawn, Kenneth, Maier, Bill, Texas Christian University

Exactly integrable cousin of an N body gravitating system

The first gravitational simulations employed a one-dimensional system consisting of N parallel mass sheets. In common with the famous Fermi-Pasta-Ulam problem, this system resists coming to equilibrium. Consequently it became of seminal interest in the new field of nonlinear dynamics. Exchange symmetry in acceleration partitions the configuration space of an N particle one-dimensional gravitational system (OGS) into N! equivalent cells. We take advantage of the consequent small angular separation of the acceleration in neighboring cells to construct a related, integrable version of the system, which takes the form of a central force problem in N-1 dimensions. The properties of the latter, including the construction of trajectories and possible continuum limits, are explored. Dynamical simulation is employed to compare the two models. For some initial conditions, excellent agreement is observed, yielding insight into the source of instability in the original system.

71. Miller, Bruce

Spellman, Cort, Texas Christian University

Wedge billiard with linear friction

Hamiltonian systems using accelerated billiards with different boundaries, such as the wedge, parabolic, and hyperbolic billiards, have been studied with theory, computation, and experiment. Mathematicians have rigorously investigated their ergodic properties. Experimentalists have used cold atoms to verify the theoretical and computational predictions. Here we examine a dissipative version of the wedge billiard that behaves, in a limiting case, like the original system. A spherical mass moves through a background medium between successive collisions with two straight, intersecting barriers inclined at equal angles to the direction of a uniform gravitational field. As the mass travels though the medium, it loses energy due to linear friction. When it collides with either boundary, the kinetic energy of the particle is increased by a fixed ratio. Depending on the wedge angle and energy amplification during boundary collisions, stable periodic motion resulting from mode locking and unstable behavior due to the existence of a strange attractor are both observed.

72. Moniz, Linda

Nichols, James D., U.S. Geological Survey, Patuxent Wildlife Research Center, Nichols, Jonathan, Naval Research Laboratory, U.S. Geological Survey

Information transport and synchronization in a spatially extended predator-prey model

In this research we use time-delay embedding techniques and information-theory techniques to investigate information flow in a spatially extended predator-prey system first introduced by Pascual, later studied by Little et al. Here we use a variant on the Continuity Test (Pecora et al. 1995) Time-Delayed Synchronization, as well as a variant on Prediction Error, CAAD, to see if there is information transport from one side of the gradient to the other. We also compare these results with those from an information statistic specifically designed to detect information flow in a dynamical system, the Transfer Entropy (Schreiber, 2002). We show that there are some interesting contrasts between information flow measured with transfer entropy and information flow measured with time-delayed synchronization and CAAD. We apply the results shown here to suggestions for optimal monitoring of a predator/prey system with varying resource gradient.

73. Moon, Sung Joon

Kevrekidis, Yannis, Sundaresan, Sankaran, Princeton University

Particle dynamics-based hybrid simulation of vibrated gas-fluidized beds of cohesive fine powders

We use three-dimensional molecular dynamics simulations of macroscopic particles, coupled with volume-averaged gas phase hydrodynamics, to study vertically vibrated gas-fluidized beds of fine, cohesive powders. The interstitial gas flow is restricted to be effectively one-dimensional (1D) in the beds of narrow cross-sectional areas we consider. This model captures the spontaneous development of 1D traveling voidage waves, which corresponds to bubble formation in real fluidized beds. We use this model to probe the manner in which vibration and gas flow combine to influence the dynamics of cohesive particles. We find that as the gas flow rate increases, cyclic pressure pulsation produced by vibration becomes more and more significant than direct impact, and in a fully fluidized bed this pulsation is virtually the only relevant mechanism. We demonstrate that vibration assists fluidization by creating large tensile stresses during transient periods, which helps break up the cohesive assembly into agglomerates. We also study spontaneous demixing in beds of a mixture of particles of different densities, so-called the 'phase separation', using an equation-free multiscale approach.

74. Morrison, Tina

Rand, Richard H., Cornell University

Instabilities in the Delayed Nonlinear Mathieu Equation

The purpose of this research effort is to investigate the dynamics of the delayed nonlinear Mathieu equation $\ddot{x}+(\delta+\epsilon\alpha\cos t)x+\epsilon\gamma x^3=\epsilon\beta x(t-T)$. There are three types of phenomenon occurring in this system: (\emph{i}) 2:1 parametric resonance (\emph{ii}) cubic nonlinearity and (\emph{iii}) delay. The method of averaging is used to analyze the stability of the origin and the associated bifurcations that accompany changes in stability for small ϵ. It is found that for certain parameter combinations of β and T, the slow flow equations are conservative, while for different combinations the system is dissipative. Therefore, the delay term $\emph{may}$ behave as effective damping in a conservative system.

75. Muller, Marie

M Muller: Paris 6 University France; A. Sutin: Stevens Institute of Technology Hoboken NJ; R. Guyer: University of Massachussets Amherst MA; M. Talmant: Paris 6 University France; P. Laugier: Paris 6 University France; P. Johnson: Los Alamos National Lab University of California Los Alamos NM.,Paris 6 University

Development of nonlinear-dynamical, elastic-wave approaches to damage diagnostics in bone

Recently it has been discovered that the presence of damage in solids can induce significant elastic wave distortion. Monitoring the distortion level shows that it increases with increasing damage volume as well as with dynamic wave amplitude. Simultaneously, the material experiences a nonlinear induced softening due to the interaction of the waves with the damaged region(s). We are attempting to apply nonlinear dynamics to monitor and ultimately characterize damage due to bone fracture and diseases, such as osteoporosis.

76. Nakai, Tonau

Yoshikawa, Kenichi, Kyoto University

Phase transition and segregation in a reconstituted chromatin from giant DNA

By single chain observation on reconstituted chromatin with fluorescence microscopy and atomic force microscopy, it is found that the density of nucleosomes is characterized by a bimodal profile, corresponding to dense and dispersed states. Based on an analysis of the spatial distribution of nucleosome cores, we deduced an effective thermodynamic potential as a function of the nucleosome-nucleosome distance. It is concluded that the essential feature of the folding transition is characterized in terms of a first-order phase transition. [Ref: T. Nakai et al. Europhys. Lett. 69, 1024 (2005).]

77. Newey, Michael

Mike Newey, Ken Desmond, Wolfgang Losert
University of Maryland

Characterizing band formation in a rotating drum of granular material

Particles of different size segregate into axial bands in a horizontal rotating tumbler. We aim to characterize the microscopic properties important for axial segregation through direct measurements of the motion of individual particles. Imaging the surface of the flowing material, we extract velocities, drift, diffusion, and flow angles for different particle types and mixtures of particles.

We observe that particles in small particle bands flow significantly faster then particles in large particle bands, and this can be observed even before visible band formation. Surprisingly, this increase in velocity does not correspond to an increase in the flowing angle. In fact, we find the flowing angle over a faster flowing small particle band to be lower then that of the large particle band. We also notice that the direction of surface drift and steepest flow angle do not coincide and that surface drift cannot explain the axial segregation in our mixtures. We also characterize the fluidity of the flowing layer from its response to gentle sideways forcing.

78. Ohzono, Takuya

Shimomura, M., FRS, RIKEN and Hokkaido Univ., Japan

Effect of gradual change in compressive direction on microwrinkle patterns

Microwrinkles on a surface-modified elastomer spontaneously appear upon sample cooling due to the elicitation of mechanical frustration such as Euler buckling, and exhibit stripe patterns as widely found in nature. Surface strain states can strongly influence this pattern. While most studies have focused on the wrinkle formation and equilibrium states, little is known about the pattern stability and dynamics under external mechanical or thermal perturbations, which are important for technological applications. On this point, we have reported that, at room temperature, the complex pattern reversibly changes the stripe orientation depending on external strain, and the original pattern is remembered [1] and other related results [2-4]. Here, we will show the effect of gradual change in compressive direction on microwrinkle patterns. The motion of topological defects and the stripe reordering process will be analyzed and discussed. [References] T. Ohzono and M. Shimomura [1] Phys. Rev. B 69 (2004) 132202. [2] Langmuir 21 (2005) 7230.

79. Olshevskiy, Alexander

Yazykov, Vladislav, Olshevskiy, Alexey, Bryansk State Technical University

The application of the fast algorithm for wheel-rail contact simulation in railway vehicle dynamics problems

The fast algorithm is an approximate model of wheel-rail contact, which does not lead to stiff equations of motion and can be used for the contact of bodies with non-quadratic shapes. The dynamics solution was performed using Universal Mechanism program package (www.umlab.ru). The FEM-based solution for different cases of the rail-wheel contact using DSMFEM program package (www.dsmsoft.ru) was used as the reference solution. The shapes of the contact patches and contact pressure distribution were analyzed for different profiles of wheel and rail and the accuracy of the fast algorithm was estimated. The difference between the solutions is discussed. The investigations show the possibility of application of the fast algorithm in contact simulation for rail and wheel in railway vehicle dynamics.

80. Orihashi, Kenji

Aizawa, Yoji, Applied Physics Dept., Waseda University

Scaling law and Lyapunov exponents of turbulent replicator dynamics with diffusion

We study the partial differential equation, which describes the 1-dimensional spatial interaction of 3-species Replicator Equation (RE). The same type of equation appears in Game Dynamics, and the equation is studied in the field of Population Genetics called Fisher's equation. Our motivation is the followings; when two or more hetero-clinic cycles interact, what kind of complex behaviors come out? The parameters of our system are the system size L, the diffusion coefficient D and the interaction matrix G, which characterizes the circuit matrix. We will report that turbulence (= spatiotemporal chaos) appears below a certain critical value after the Hopf-type bifurcation. The detailed analysis demonstrates that the correlation length of the turbulence becomes divergent at the critical point and has the scaling law for the bifurcation parameter. More detailed structure of the turbulence will be analyzed in terms of whole Lyapunov spectra and the behavior of their vectors.

81. Otani, Niels

Riccio, Mark L., Gelzer, Anna R., Lazarus, Matthew S., Gilmour Jr., Robert F., Cornell University

The role of memory in the dynamics of cardiac rhythm and action potential failure

The failure of action potential propagation at a finite distance from its source may be an important cause of life-threatening rhythm disorders in the heart. In this talk, we will describe the role played by action potential 'memory ' that is the dependence of action potential dynamics on its long-term history in creating this type of blockage. We studied the problem using two mapping models, each of which contains two memory quantities and the action potential duration (APD) as dynamical variables. One of these models was fit to experimental canine cardiac pacing data using a mathematical technique fundamentally grounded in the observed dynamics, a philosophy that may be useful in other modeling contexts. The other model helped in developing physiological insight into the dynamics. We found that memory destabilizes the eigenmode characterized by beat-to-beat alternations in the APD even though modifications due to memory were found to be relatively modest in experiments. Both models were then inserted into a spatially one-dimensional system and studied for their action potential propagation properties. The electrical pacing programs that produced propagation failure in a model fit to data from normal dogs were found to be quite different from those producing failure in a model based on dogs with inherited ventricular arrhythmias. The underlying dynamical mechanisms were also quite different--out-of-phase oscillations in APD produced block in the normal-dog model, while very tight coupling intervals produced failure in the affected-dog model. The existence of different block mechanisms suggests that different types of treatments should be used to prevent or cure the corresponding rhythm disorder. The study also spotlights the importance of fitting the dynamics as well as the data in developing relevant models of biological systems.

82. Pando, Carlos L.

Doedel, Eusebius, Concordia University, Montreal, Canada, IFUAP-Universidad ,Autonoma de Puebla

The onset of chaotic symbolic synchronization in the discrete nonlinear Schroedinger equation (DNLSE)

We discuss the origins of a new behaviour that takes place in a ring 1-D array of oscillators described by the DNLSE. As the energy of the system increases, by changing a suitable defect, there is a global, stochasticity behaviour where suitable, amplitude signals display chaotic symbolic synchronization. In the case of a system of weakly-coupled Bose-Einstein condensates, these signals are the population inversions of certain pairs of condensates. See C.L. Pando L. and E.J. Doedel, PRE v.69 036603 (2004); C.L. Pando L. and E.J. Doedel, PRE v.71, 056201 (2005).

83. Paoletti, Matthew

Nugent, Carolyn, Department of Physics, Bucknell University, Solomon, Thomas, Department of Physics, Bucknell University, University of Maryland at College Park

Synchronization via superdiffusive mixing in an extended fluid system

We present experimental studies of synchronization of an oscillatory process in an extended, flowing fluid system. We find that the key to synchronization is superdiffusive transport, characterized by Levy flights where tracers in the flow travel very long distances in a short period of time. The flow is an oscillating/drifting chain of vortices in an annular configuration. Numerical simulations and experimental particle-tracking data are used to illustrate the conditions for which superdiffusion occurs for a chain of vortices. These results are compared to experiments on synchronization of the Belousov-Zhabotinsky chemical reaction in the same flow.

84. Park, Se-Woong

Park, Se-Woong 1, Lee, Kyoung-Min 1,2, Lim, Yong Hoon 3, Kim, Han-Joon 2, Woo, Sung-Ho 1, Paek, Sun Ha 3, Jeon, Beom S. 1. Program of Cognitive Sciences, Seoul National University, Seoul, South Korea, 2. Department of Neurology, Seoul National University Hospital, Seoul, South Korea, Program of Cognitive Sciences, Seoul National University, Seoul, South Korea

Correlation between phase synchronization of neural activity in patients with Parkinson's disease and the clinical outcome of deep brain stimulation

Phase synchronization was measured in the basal ganglia of patients with Parkinson's disease (PD) while they underwent an implantation of deep brain stimulator (DBS) into the subthalamic nucleus (STN). Neural activities were recorded while a set of four microelectrodes were advanced toward STN, guided by a stereotaxic frame and three-dimensional MRI of the brain. The signals were band-pass filtered using a linear-phase FIR filter and the difference of the instantaneous phases, obtained from the Hilbert transform of each signal, was computed. We then calculated a synchronization index (SI) which was inversely related to the entropy of the distribution of phase differences between oscillatory neuronal signals for 200 ms-long time-windows and 10 Hz-wide frequency-bins. In the frequency range of local field potentials (< 150 Hz) higher SIs were observed at the lead position i.e. where a DBS electrode was implanted in patients with better post-operative outcome. Also, in the range of multi-unit activities (300-1000 Hz), the SIs were increased in the multiples of 130 Hz more clearly in patients with a greater post-op improvement in motor function. These results have the following implications: 1) The degree of phase synchronization of neural activities in STN may reflect the severity of pathophysiology in PD patients. 2) Measuring phase synchronization may serve as a good index for selecting the most effective lead position for DBS. 3) The characteristics of phase synchronization in PD patients may provide insights for optimizing DBS parameters.

85. Pavlick, Ryan

Pavlick, Ryan*, Department of Geography, University of Maryland, Kleidon, Axel, Department of Geography and Earth Systems Science Interdisciplinary Center, University of Maryland

Maximum entropy production and optimally adapted vegetation

In this study, we apply the concept of optimal adaptation to the parameterization of several vegetation properties in a coupled dynamic vegetation-climate system model. We hypothesize that vegetation adapts optimally in such a way that it maximizes its productivity thereby leading to a characteristic partitioning of energy and mass fluxes at the land surface. This approach stems from the principle of Maximum Entropy Production (MEP), which originates from the theory of statistical mechanics of non-equilibrium thermodynamic systems and has been fundamentally derived from information theory. The MEP principle states that the macroscopic steady state of a dissipative process given sufficient degrees of freedom is one at which the rate of entropy production is maximized. Previous studies have applied the MEP principle to vegetation activity and demonstrated that a maximization of photosynthetic activity, or gross primary productivity (GPP), leads to a maximization in entropy production. We compare the partitioning of the land surface fluxes from the simulated climates with optimized vegetation parameters to climate reanalysis products at the biome scale. With this comparison, we are able to evaluate the extent to which this optimization approach is useful in understanding the nature of land surface functioning in the climate system.

86. Paydarfar, David

Paydarfar, David, Department of Neurology, University of Massachusetts Medical School, Worcester, Massachusetts, Forger, Daniel B., Department of Mathematics, University of Michigan, Ann Arbor, Michigan, Clay, John R., NINDS National Institutes of Health, Bethesda, Maryland, University of Massachustts Medical School

Noisy inputs and the induction of on-off switching behavior in a neuronal pacemaker

Neuronal pacemakers can exhibit abrupt transitions between repetitive firing and quiescence in response to small perturbing stimuli. It has been proposed that such highly nonlinear properties may be an important mechanism for neural encoding and memory, but it is unclear whether such bistable pacemakers can reliably encode inputs that are inherently noisy. In order to address this, we recorded membrane potential in eight squid giant axons that exhibited bistable pacemaker properties following intracellular alkalinization. Stochastically varying current without offset was administered to the axon for 10-second periods. In axons with repetitive activity, low-level stochastic stimulation rapidly annihilated spontaneous action potentials (APs). At slightly higher amplitudes of stimulation bursts of regular APs alternated with irregular periods of quiescence. Further increases in the amplitude of stimulation resulted in shorter periods of quiescence. We show that over a broad range of stimulus intensities the membrane state just prior to stimulus cessation predicts which one of the two stable states the membrane exhibits following stimulus cessation, and we define the statistical features of inter-spike intervals during stimulation as a function of stimulus strength. Reverse correlation of the stochastic stimulation around the time of transition between repetitive firing and quiescence reveals that the likelihood of a transition strongly correlated with brief runs of phasic stimulation at the natural frequency of the membrane. In the quiescent state, phasic stimulation induces a crescendo increase in subthreshold oscillations in membrane potential culminating in a burst of repetitive firing. In the repetitive firing state, a brief phasic stimulus is associated with a switch to the quiescent state, but only if the phasic stimulus is timed ~180 degrees out of phase with repetitive firing. Analysis and simulation of mathematical models of bistable pacemakers provides insight into the mechanism of these transitions. Our findings show how noisy polysynaptic inputs can be encoded by a bistable neuronal pacemaker to produce changes in spike timing and bursting behavior over long time scales.

87. Pecora, Louis

Pecora, Louis, Nichols, Jon, Carroll, Tom, Naval Research Laboratory, Washington, DC USA, Moniz, Linda, US Geological Survey, Patuxent Wildlife Research Center, Laurel, MD, Naval Research Laboratory

A unified approach to attractor reconstruction

Reconstruction of attractors for dynamical systems has typically focused on solving seemingly separate problems of finding a proper time delay and then finding a proper embedding dimension. Techniques for solving these problems are somewhat heuristic. We show that the two problems of time delay and embedding dimension are actually the same problem. Using Taken's theorem we derive a mathematical criterion for building reconstruction vectors. We also show how our single statistic can solve at once the problems of determining time delays, getting embedding dimension, dealing with disparate time scales in data, and optimally choosing time series to use from a multivariate data set. In addition, we introduce a new statistic that resolves an unsolved issue for chaotic data, namely, when is the delay too long? This unified approach is compared to 'standard' approaches and is shown to be superior in requiring fewer embedding dimensions.

88. Peles, Slaven

Peles, Slaven, School of Physics, Georgia Institute of Technology, Atlanta, GA, Rogers, Jeffrey L., HRL Laboratories, LLC, Malibu, CA, Wiesenfeld, Kurt, School of Physics, Georgia Institute of Technology, Atlanta, GA, Georgia Institute of Technology

Synchrony in fiber laser structures with time dependant gain fields

Fiber lasers have small size, high conversion rates and excellent thermal properties. On the other hand they generally produce smaller output intensity than semiconductor lasers. Recent experiments reported that a small number of fiber lasers can be synchronized simply by coupling them with an optical waveguide coupler near the output end. As a result the output peak intensity increases as a square of the number of coupled lasers, and well focused beams of high intensities can be produced.

89. Periwal, Vipul

Chow, Carson, Laboratory of Biological Modeling, National Institute of Diabetes and Digestive and Kidney Diseases, LBM, NIDDK, NIH

Mathematical model of liver regeneration

Liver regeneration is a remarkable biological phenomenon, apparently known even to the ancient Greeks. If a rat's liver is partially resected (up to 70% resection), it grows back to regain a mass almost equal to its original mass, though the original lobular morphology is not regained. This process commences immediately after the partial hepatectomy and ends within a couple of weeks. The precise control of cell division evident in this process is believed to be due to a complex interplay between cytokines and growth factors. We present a simple mathematical model of liver regeneration, which fits available experimental data. Our model postdicts the observation that the regeneration following smaller resections is less complete than the regeneration obtained following larger resections.

90. Petermann, Thomas

Paolo De Los Rios Institute of Theoretical Physics, LBS, Ecole Polytechnique Federale de Lausanne - EPFL CH-1015 Lausanne, Switzerland., Unit of Neural Networks Physiology, Laboratory of Systems Neuroscience, National Institute of Mental Health, Bethesda, Maryland

Physical realizability of small-world networks

Supplementing a lattice with long-range connections effectively models small-world networks characterized by a high local and global interconnectedness observed in systems ranging from society to the brain. If the links have a wiring cost associated to their length l, the corresponding distribution $q(l)$ plays a crucial role. Uniform length distributions have received most attention despite indications that $q(l) \sim l^{-\alpha}$ exist e.g., for integrated circuits the Internet and cortical networks. While length distributions of this type were previously examined in the context of navigability, we here discuss for such systems the emergence and physical realizability of small-world topology. Our simple argument allows to understand under which condition and at what expense a small world results.

91. Pethel, Shawn

Corron, Ned, U.S. Army, Bollt, Erik, Clarkson University, U.S. Army Aviation and Missile Command

Controlling the symbolic dynamics of coupled map lattices

We apply symbolic dynamics to the problem of controlling spatio-temporal chaos in a coupled map lattice (CML). We show how to create a symbolic dynamical model that represents the global dynamics of coupled unimodal maps to arbitrary precision. From this we extract an approximate local model that can be applied at each lattice site regardless of the array size. The local symbolic dynamical model enables the practical calculation of perturbations needed to control chaos in CMLs. We give examples of the control of spatio-temporal patterns in large arrays using only small perturbations.

92. Pitruzzello, Ann M.

Idriss, Salim F., Duke University Departments of Pediatrics and Biomedical Engineering, Gauthier, Daniel J., Duke University Departments of Physics and Biomedical Engineering and Center for Nonlinear and Complex Systems, Krassowska, Wanda, Duke University Department of Biomedical Engineering and Center for Nonlinear and Complex Systems, Duke University Department of Biomedical Engineering

The restitution portrait reveals hidden heterogeneity in cardiac rhythm dynamics

Electrical restitution, which relates action potential duration (APD) to the previous diastolic interval (DI), is thought to govern the transition from a stable 1:1 rhythm in the heart to a 2:2 rhythm, or alternans. Restitution is typically measured experimentally using one of two methods: the dynamic protocol measures the steady-state relationship between APD and DI at many pacing cycle lengths, and the S1-S2 protocol measures the immediate change in APD in response to a perturbation from steady-state. Using these two protocols, rabbit epicardium was shown to have relatively homogeneous restitution properties. We have measured restitution in rabbit epicardium using the perturbed downsweep protocol, which simultaneously measures the dynamic, S1-S2, and transient responses. The combined responses measured with the perturbed downsweep protocol form the restitution portrait. We confirmed previous experimental findings that there are no significant spatial differences in the dynamic or S1-S2 restitution curves. However, we found that spatial heterogeneity exists in the transient response to a change in pacing cycle length. We furthermore found that the restitution portrait was dependent on the pacing site. This study demonstrates the importance of the restitution portrait rather than classical restitution measurements to elucidate spatial differences in restitution in cardiac tissue. These spatial differences may affect the stability of the cardiac rhythm.

93. Pomerance, Andrew

Erin Rericha, Wolfgang Losert
University of Maryland

Mechanical Properties of Actin Networks Near the Polymerization Transition

The cytoskeleton of motile cells is a highly dynamic, inhomogeneous polymer network. Forces of several pN are characteristically exerted at the leading edge of moving cells. We present studies of the mechanical properties of actin networks, a main component of the cytoskeleton, with focus on the response to large forces. The critical concentration (CC) for polymerization of actin varies by two orders of magnitude depending on the concentration of divalent ions in solution. By studying concentrated actin samples with and without added ions, we compare the behavior near and far above the CC. To study the response to large forces we use holographic laser tweezers to pull microspheres through an actin network. We have found that actin networks far above the CC strongly resist pulling, and have a well-defined relaxation time. Near the CC, beads are easily pulled through the actin networks, and the relaxation is far more variable, which indicates that the actin filaments may be more dynamic and breakable. We generate gradients in actin network structure using a thermal gradient. We observe that in actin networks near the CC, embedded beads are pushed towards the cold side (weaker network) at approximately 0.1 microns/second. This indicates that the flux of energy associated with the thermal gradient may generate forces in a partially polymerized filament network. Gradients in chemical potential, e.g. due to gradients in ABP may also lead to force generation. To study this, we have developed microfluidic devices that maintain a stable, quasi-static gradient in large macromolecules for roughly one hour. Work supported by NIH grant R21BE00328501.

94. Poole, Cory

Wolfgang Losert
University of Maryland

Deformations of Giant Unilamellar Vesicles

In an aqueous solution phospholipid bilayers self-assemble to form a closed surface which is called a vesicle or a liposome. Vesicles have been studied extensively due to their relevance as a model for biomembranes as well as their practical uses for chemical containment and transport. We use a holographic optical tweezer array to study the mechanical response of giant unilamellar phospholipid vesicles to applied stresses. By producing vesicles with encapsulated silica microspheres we can use the tweezers to indirectly manipulate the vesicle. Two or more spheres are used to stretch the vesicle membrane and subsequently the vesicle is allowed to relax back to its equilibrium shape. These deformations are imaged at a high frame rate with spatial resolution on the order of 20 nm and characteristic time and length scales of the relaxation are calculated. Further we are able to directly deform the membrane by pulling on the fluid utilizing an index of refraction mismatch between the inside and outside of the vesicle. We image the vesicle and extract the vesicle shape using an active contour algorithm. Fourier analysis is used to track the vesicle as it returns to equilibrium after being stretched.

95. Popovici, Irina

Baker, B. Mitchell, Kidwell, Mark E., USNA

A dynamical systems approach to membrane phenomena underlying cardiac arrhythmias

We study a two-dimensional dynamical system introduced by Baker and Kline to model the connection between membrane currents, action potential duration, and cardiac rhythm. These continuous, but not C1, plane systems have dynamical portraits significantly richer than their one dimensional (Collet Eckaman-like) counterparts. Our principal results give the existence and stability properties of escalator orbits (analogue to the one-dimensional family), the co-existence of stable orbits for fixed values of the period parameter, existence of bunny-ears orbits (purely two-dimensional phenomena). We consider the latter results our most important, owing to conjectures that such period parameter values produce arrhythmia.

96. Ranjan, Priya

Martin, Patrick, Intelligent Automation, Inc., Manikonda , Vikram, Intelligent Automation Inc., Rockville, Maryland

Moving boundary tracking using evolvable curves

In this work we extend the original scheme of tracking static boundaries by (Marthaler and Bertozzi, 2002) to track moving boundaries. Our schemes include explicit merging and splitting of boundaries under different application-specific factors. We illustrate that original scheme coupled with an adaptive communication sensing paradigm based on distance from neighbors is practical and achieves the goal of tracking moving boundaries satisfactorily. Basic theoretical modeling for dynamic boundary tracking framework and stability results in terms of number of robots and communication bandwidth and extensive numerical simulation will also be presented. Finally, we will show some movies depicting the moving boundary tracking in action with limited number of cooperating robots. This system has many practical applications like oil spill tracking, poison plum detection, and containment swarming etc.

97. Ray, Will

Adams, Bethany, Karst, Nathaniel, Roy, Rajarshi, Univ. of Maryland

Transition to coherence collapse in a semiconductor laser with optical feedback: Study of a crisis

A semiconductor laser under the influence of delayed optical feedback demonstrates a variety of chaotic fluctuations for a wide range of parameter settings. We experimentally and numerically characterize the dynamics displayed by the system at the boundary between the low-frequency fluctuations and coherence collapse regimes. For small increments of the injection current, we find that an interior crisis is responsible for the emergence of the coherence collapse dynamics. Simulations of the single-mode Lang-Kobayashi equations predict a similar crisis as the mechanism of this transition, and the experiment and model each display Type-I intermittency at the crisis point.

98. Recktenwald, Geoffrey

Rand, Richard, Cornell University

Stability of strongly nonlinear normal modes

We show how a wide class of conservative periodic vibrations can be expressed as a cosine function of time. The method involves reparameterizing time, and is applicable to systems of the form $x'+F(x) = 0$ where $F(x)$ is an analytic function. These include strongly nonlinear systems in which $F(x)$ has no linear term. The method is applied to determining the stability of nonlinear normal modes in two degree of freedom systems.

99. Richardson, A. S.

Tracy, E. R., Physics Dept., College of William & Mary, Zobin, N., Math Dept., College of William & Mary, Kaufman, A. N., LBNL & Physics Dept., UC Berkeley, Physics Dept., College of William & Mary

Vector WKB and the phase space path integral

Scalar WKB methods (also known as ray tracing or semi-classical asymptotics) can be derived as a stationary phase solution to a path integral on phase space [1]. We discuss the application of these methods to solve vector WKB problems, especially in the presence of resonance crossings where the WKB approximation breaks down. The treatment of resonance crossings (also known as mode conversion, Landau-Zener crossings, avoided crossings, etc.) has a large literature and much is known [2]. However, there are several cases of interest in applications that do not fit the standard formalism and their semi-classical treatment is still an open problem. This has led us to investigate the mathematical basis of the path integral, which involves group representation theory and symbols of operators. Ultimately, the goal is to develop practical ray tracing algorithms for computing the solutions to vector wave equations. In this poster we describe progress toward this goal. 1] F. A. Berezin and M. A. Shubin.

100. Rosa, Epaminondas

Dept. of Physics - Illinois State University

Synchronizing chaotic oscillators with superimposed signals

Chaotic oscillators show alternate synchronous states when driven by two superimposed forcing systems. This competition for synchronization reveals interesting behaviors observed in numerical simulations that are consistent with experimental results involving the Chua circuit (work done at the Nonlinear Dynamics Lab at the U. of Miami) and a plasma discharge (work done at Illinois State University).

101. Ross, Natalie

Bradley, Elizabeth, University of Colorado, Computer Science, Hertzberg, Jean, University of Colorado, Mechanical Engineering, Peacock, Thomas, MIT, Applied Math, University of Colorado, Computer Science

Dynamics-informed point-vortex models

Most fluid flow simulation methods, though accurate, are still too slow for real-time applications. In contrast, a point-vortex solver tracks only the vortices in a flow, providing speed at the cost of over-simplification. Correcting the model with observations of the fluid, a process known as data assimilation, could result in a simulation that is both fast and accurate if the assimilation is effective and its computational costs are low. Existing data assimilation strategies are computationally intensive, however, and we have found that some of the standard ones (e.g., Newtonian nudging) can actually be detrimental to a point-vortex simulation. We present an alternative assimilation strategy that uses the dynamics of the system to decide when corrections are required. Data is assimilated only in regions where velocity gradients are relatively large, permitting a significant reduction in computational cost as compared to periodic correction. In initial experiments, we were also able to increase the accuracy of the simulation by a factor of 2 to 200, on average, depending on the initial configuration of the vortices.

102. Sarika, Jalan

Max Planck Institute for Mathematics in Sciences, Inselstrasse 22, Leipzig-04103, Germany, Physical Research Laboratory, Ahmedabad-380009, India, 2) R. E. Amritkar, Physical Research Laboratory, Ahmedabad-380009, India, 3) J. Jost, Max Planck Institute for Mathematics in Sciences, Inselstrasse 22, Leipzig-04103, Germany,,Max Planck Institute for Mathematics in Sciences

Floating dynamical nodes in coupled map networks

We study the synchronization of coupled dynamics on networks. For large coupling strength nodes form different types of the synchronized clusters. There are some nodes which show floating behaviour, that is, intermittent behaviour between getting attached to some clusters and evolving independently. The residence time of these nodes in a cluster shows exponential distribution.

103. Schmidt, Laura

Zhang, Wendy, U. of Chicago

Length-scale selection in viscous entrainment of stratified fluids

When two stratified, fluid layers undergo vigorous thermal convection, a thin tendril of one fluid can become entrained in the other fluid. The persistence of these tendrils has been proposed as an explanation for long-lived, fixed structures in the Earth's mantle, such as hotspots. We obtain a self-consistent description of the entrainment process by requiring that the nearly flat interface far from the tendril joins smoothly with the nonlinear steady-state shape of the tendril. For strongly stratified layers the tendril radius is proportional to the interface deflection height for the case when no fluid is entrained.

104. Schroll, Robert

Zhang, Wendy, Physics Department and the James Franck Institute, The University of Chicago, Wunenburger, Regis, Casner, Alexis, and Jean-Pierre Delville - Centre de Physique Moleculaire Optique et Hertzienne Universite Bordeaux I 351 cours de la Liberation 33405 Talence Cedex France, Physics Department and the James Franck Institute, The University of Chicago

Flows and interface deformations driven by light scattering

Previous experiments show an intense laser beam can deform and even break a soft near-critical liquid interface [Casner and Delville, Phys. Rev. Lett. 90 144503]. After the interface is broken, fluid is transported along the laser beam in a jet. This transport is a consequence of optical streaming: light scattering off density fluctuations in the near-critical fluid produces a body force that pushes the fluid in the direction of light propagation. Such a forcing produces a large-scale flow in the fluid, which produces stresses that cause the interface to deform. We find good agreement between the predicted and measured interface deformations.

105. Sethia, Gautam C.

Sen, Abhijit, Institute for Plasma Research

Neural excitability in the presence of time delay

We investigate the dynamical properties of a model neuron consisting of a subcritical Hopf oscillator with a time delayed nonlinear feedback. Without time delay the system shows an infinite-period bifurcation for certain feedback strengths and exhibits typical neural spiking when subjected to an external periodic stimulus and noise. Finite time delay is found to significantly affect both the statistics and the fine structure of the spiking behavior. These dynamical changes are explained in terms of the fundamental modifications occurring in the bifurcation scenario of the system. Our proposed neuron model can be a useful paradigm for understanding the dynamical behavior of 'autapse' neurons as well as for gaining insight on propagation delay effects in collective neuronal activity.

106. Shaw, Leah

Schwartz, Ira B., Rogers, Elizabeth A., and Roy, Rajarshi, Naval Research Lab

Synchronization and time shifts of dynamical patterns for mutually delay-coupled spatio-temporal systems

A pair of mutually delay coupled erbium doped fiber ring lasers is used to explore the dynamics of coupled spatiotemporal systems. Synchronization is observed between the two lasers in both experiment and a stochastic differential delay equation model, and increases with coupling strength. When the time series from two lasers are shifted in either direction by the delay time, approximately equal synchronization is frequently observed, so that a clear leader and follower cannot be identified. We therefore investigate which laser leads the other when the synchronization is sufficiently different with one direction of time shift. Analysis of switches in leader and follower reveals that the frequency of switching between leader and follower increases with coupling strength. Moreover, when different internal noises are studied in the model, we find the surprising result that the switching frequency scales non-monotonically with noise, as in coherence resonance phenomena.

107. Sideris, Ioannis
Northern Illinois University

Taking advantage of the morphology of chaos: A new measure for time-independent and time-dependent systems

Morphological patterns can be used effectively for characterization of dynamical orbits as regular or chaotic. The new method focuses on local, epochal characterization of orbits as opposed to global characterization usually employed by most established measures. Thus, it can provide information about sticky epochs of chaotic orbits, as well as the transient chaos associated with time-dependent evolution. In this sense it can be employed to give extremely detailed pictures of the phase space of a system, as well as to provide characterizations early in the evolution of orbits. Moreover, the method applies generally; all that is required is a signal, of which an orbit is merely an example.

108. Slavov, Nikolai
Linse, Sara, Lund University, Sweden, Carey, Jannette, Princeton University

Dynamics in calcium signaling: Decoding the waveform of calcium oscillations

Experiments have demonstrated that three types of biochemical networks – gene expression networks, signal-transduction cascades, and oxidative phosphorylation – are sensitive to the frequency of calcium oscillations. Furthermore, indirect evidence suggests that such frequency sensitivity is a widespread mechanism for increasing both the specificity and the sensitivity of Ca+2 signaling. Yet, the underlying molecular mechanisms of this frequency sensitivity have been elucidated only for a few isolated and highly specific cases. We propose a general deterministic kinetic model in which the sensitivity to the waveform of Ca+2 oscillations arises as a dynamic property of the calmodulin mediated activation-inactivation cycle. The validity of the model is examined in an ongoing analysis of the parameter space over which the dynamic behavior of the model is sensitive to the waveform of calcium oscillations. We have also developed a TIRFS (Total Internal Reflection Fluorescent Spectroscopy) experimental setup for testing the model.

109. Sperl, Matthias
Duke University

Polynomial singularities in glasses, gels and granular systems

When the coefficients of simple polynomials are changed, one encounters singularities in the roots of these polynomials. The simplest of these singularities are fold, cusp, and swallowtail bifurcations, which are equivalent to the emergence of quadratic, cubic and quartic roots, respectively. For such singularities it is shown (1) that they emerge naturally from the microscopic equations of motion for a fluid (2) how they describe the slow dynamics seen at glass transitions, and (3) why they are also relevant to dense granular systems. The dynamics of a fold bifurcation is demonstrated for the mean-squared displacement in experimental data over eight orders of magnitude in time. Cusp and swallowtail bifurcations are identified at the transition between glasses and gels in data from molecular-dynamics simulations. For granular systems, one can use the fold bifurcation to interpret certain data for random-close packing.

110. Spiegel, Dan
Trinity University

Relaxation-Oscillation and Counterpropagating Phase Drift in Broken-Symmetry Electroconvection

We create a long narrow electroconvection pattern along a laser strip in which the translational symmetry is broken by a laser-induced thermal gradient. The electroconvection rolls counterpropagate into a sink point near the center of the strip and show a strong amplitude modulation near this point. The time dependence of the amplitude at a fixed point shows a clear relaxation-oscillation profile. On the basis of experiments on spacetime diagrams, wavenumber profiles, and drift-frequency measurements, we suggest that a simple qualitative model could be based on a hyperbolic-tangent solution to the Ginzburg-Landau equation in which the control parameter varies periodically with time due to the coupling of the amplitude and the advective heat transport.

111. Suetani, Hiromichi

Yanagita, Tatsuo, Hokkaido University, Aihara, Kazuyuki, The University of Tokyo and JST), Aihara Complexity Modelling Project, ERATO, JST

Crossing and overtaking of excitable pulses in two laterally coupled FitzHugh-Nagumo fibers

We study the dynamics of reaction-diffusion excitable systems composed of two laterally coupled fibers. Such systems have been investigated as models for the Purkinje fibers in the heart, trabeculae in the myocardial tissue, and parallel nerve fibers coupled through ephaptic (non-synaptic) interactions. It has been found that a system of two coupled fibers exhibits several types of collective behavior, including the synchronous pulses that propagate along the fiber and the reentrant, i.e., the repeated excitation of a region of the fiber. Understanding and controlling such dynamics are of great importance in cardiac disease and information processing in the brain. In this paper, using the FitzHugh-Nagumo equations as a model of the one-dimensional fiber, we investigate how the stability and the dynamical properties of the collective behavior depend on the difference between the parameters of the fibers such as the refractoriness and the diffusion constant. We show that under a certain condition, two propagating pulses do not annihilate upon collision but cross each other like soliton waves even in dissipative systems. Possibility of the occurrence of spatio-temporal chaos is also discussed.

112. Sumino, Yutaka

Nagai, Ken, Kitahata, Hiroyuki, Yoshikawa, Kenichi, Department of Physics, Graduate School of Science, Kyoto University

Self-running droplet driven by chemical Marangoni effect

We report the emergence of regular spontaneous motion in an oil-water system composed of an organic phase with potassium iodide and iodine and an aqueous phase containing stearyl trimethyl ammonium chloride (STAC). It is shown that random motion in an isotropic environment is changed into a regular motion accompanied by the reduction of the symmetry of the experimental system. The appearance of the regular motion is interpreted in terms of the mode switching of an active Brownian particle [1, 2]. We have also examined the spontaneous motion in a two-phase system of an alcohol (pentanol) and water. It is found that the spontaneous motion of an alcohol droplet changes markedly depending on the size of the droplet, and that regular motion is generated for suitable rage of the volume. Such a trend is discussed in relation to the instability of certain wavenumber, which is crucially dependent on the droplet size [3]. Reference [1] Y. Sumino, N. Magome, T. Hamada and K. Yoshikawa, Phys. Rev. Lett. 94, 068301 (2005), [2] Y. Sumino, H. Kitahata, K. Yoshikawa, M. Nagayama, S-i. M. Nomura, N. Magome and Y. Mori, Phys. Rev. E, 72, 041603 (2005) [3] K. Nagai, Y. Sumino, H. Kitahata and K. Yoshikawa, Phys. Rev. E, 71, 065301 (2005).

113. Sych, Denis

Faculty of Physics, Lomonosov, M.V., Moscow State University

Quantum information approach to physical problems

An enormous progress made over the last decade in experiments on manipulation with quantum information stored in various quantum systems leads to a necessity of deep theoretical analysis of this specific kind of information – quantum information that drastically differs from classical information and for which previously developed Shannon's theory of information does not work correctly. An approach based on calculation of one specific type of quantum information – compatible information, which takes into account both classical and quantum correlation, is discussed with examples of its use in analysis of different physical systems.

114. Tagg, Randall

Asadi-Zeydabadi, Masoud, University of Colorado at Denver and Health Sciences Center

Tissue dynamics, tissue morphometry and cancer

We are applying ideas from the study of pattern forming systems to the early detection of cancer. This includes analysis of tissue images in an attempt to measure local ordering and spatial scales. We also model the homeostasis of healthy tissues with the aim of identifying collective effects that could signify early stages of transition of cell populations towards diseased states.

115. Tagg, Randall

Asadi-Zeydabadi, Masoud, University of Colorado at Denver and Health Sciences Center

Chaotic ray propagation in periodically modulated waveguides

Waveguides with axial modulation of the refractive index profile exhibit parametric instability of the axial ray path as well as chaotic ray propagation. We present an exploration and quantitative evaluation of the instabilities and chaos. Then we describe potential applications to using short wavelength probes in the investigation of pattern forming systems.

116. Tanaka, Gouhei

Aihara, Kazuyuki, Institute of Industrial Science, University of Tokyo, ERATO Aihara Complexity Modelling Project, JST, Institute of Industrial Science, University of Tokyo

Deterministic coherence resonance in coupled neural oscillators

Spatiotemporal regularization in coupled neural oscillators has been intensively studied, which is thought to have close relations with information processing of biological systems. Such regularized phenomena involving spatial synchronization and temporal regularity are often influenced by various factors such as network topology, network size, network heterogeneity, coupling scheme, coupling strength, and noise. In this presentation, we report on a coherence resonance-like behavior in coupled neural oscillators without noise. This collective behavior, which we call deterministic coherence resonance (DCR), is due to the internal chaotic fluctuations and non-regular network topology. We will discuss on the effects of network characteristics on the DCR.

117. Tebaldi, Claudio

Department of Mathematics, Politecnico di Torino

Low-dimensional analysis by proper orthogonal decomposition

In the last years the study of many complex systems has taken strong advantage of the development of mathematical methods coming from the theory of nonlinear dynamical systems. Furthermore, for systems who show turbulent behaviour like fluids, the concept of coherent structures, i.e. strongly persistent spatio-temporal structures, has provided an efficient descriptive tool as well as the possibility of low-dimensional reductions. The introduction of the Proper Othogonal Decomposition (POD) has found to be a successful technique to find coherent structures. In connection with Galerkin method, POD can also be the technique leading to useful low-dimensional ODE approximations of PDE models, allowing to take full advantage of dynamical systems theory. As a first example and to facilitate comparisons, POD has been directly applied to N-dimensional dynamical systems dependent on an external parameter, obtained from the two-dimensional Navier-Stokes equations as Galerkin truncations. The transition to periodic behaviour with N=98 has been accurately described in a reduced 3-dimensional model. The case of quasi-periodicity has also been successfully considered

118. Toiya, Masahiro

Losert, Wolfgang, Univ. of Maryland

3D imaging of granular material during penetrometer testing

Penetrometer experiment with oil immersed spherical glass particles are imaged with laser sheet. Cross sectional images are recorded and analyzed to determine particle motion due to the penetrometer. Anisotropically prepared material show greater particle motion along the pre-formed stress chains.

119. Tolkacheva, Elena

Anumonwo, J.M.B., Jalife, J., SUNY Upstate Medical University, Institute for Cardiovascular Research, Syracuse, NY

Memory in Cardiac Myocytes

The role of calcium current background. Memory is the generic feature of periodically paced cardiac myocytes known as the dependence of an action potential duration (APD) on pacing history. In this study, we only refer to pacing history of the order of minutes, which might change excitability of myocytes thus causing memory. Memory plays an important role in the dynamics of cardiac myocytes. However, very few systematic studies of this phenomenon have been performed to date and very little is known about the ionic mechanisms underlying memory. We characterize two different aspects of memory: long-term and short-term memories. We associate long-term memory with the phenomenon known as APD accommodation, indicating that myocyte requires a certain time (of the order of minutes) to reach a steady-state after an abrupt change in pacing rate. We define short-term memory as the difference between the slopes of two restitution curves obtained using dynamic and S1S2 pacing protocols. In this study we investigated the rate-dependence of both short-term and long-term memory in periodically paced rabbit ventricular myocytes and determined the role of calcium currents in memory. Methods. We use the whole-cell current-clamp technique to record restitution portraits of rabbit ventricular myocytes that contain both long-term and short-term memories at different pacing rates (N=7 n=22). To investigate the role of calcium currents in memory, we use the following approaches: 1) nisoldipine (1μmol/L) to block L-type calcium current (N=2 n=11); 2) [Ca2+]o = 0 to remove calcium flux through calcium channels (substituted with MgCl2, N=3, n=10); 3) thapsigargin (200 nmol/L) and ryanodine (10 μmol/L) to block intracellular calcium cycling (N=4, n=15). To measure the peak calcium current we use voltage-clamping in the action potential clamp mode (N=3, n=12), where segments of restitution portraits were taken as action potential
profiles for different pacing rates. Results. Our results indicate that both short-term and long-term memories are frequency dependent. Long-term memory decreases as pacing rate increases. Short-term memory decreases at very slow and very high pacing rates. We show that blocking the L-type calcium current and removing extracellular calcium current have similar effects: both long-term and short-term memories disappear at all pacing rates. In contrast, blocking intracellular calcium cycling does not significantly affect memory. These results indicate that calcium currents through L-type calcium channels have a major

impact on memory. However, we demonstrate that peak calcium current is not responsible for memory (except for the very high pacing rate). We suggest that accumulation of calcium ions inside a cell plays a major role in memory along with other mechanisms (associated with influence of calcium current on other currents). Conclusion. Our study demonstrates for the first time that both short-term and long-term memories in rabbit ventricular myocytes are rate-dependent. We also show that calcium current plays a crucial role in memory.

120. Triandaf, Ioana

Oprea, Iuliana, Department of Mathematics, Colorado State University, Fort Collins, CO 80523, Schwartz, Ira B., Naval Research Laboratory, Code 6792, Plasma Physics Division, Washington, DC 20375

Karhunen-Loeve analysis of spatiotemporal chaos in a globally coupled Ginzburg-Landau system

We study a complex spatiotemporal pattern, identified as spatiotemporal chaos, that is obtained from the solution of a system of globally coupled complex, Ginzburg Landau equations governing the evolution of four travelling wave envelopes. The Ginzburg Landau system is derived directly from the weak electrolyte model for electroconvection in nematic liquid crystals when the primary instability is a Hopf bifurcation to oblique travelling rolls. The chaotic nature of the pattern is confirmed through a Karhunen-Loeve decomposition, and a time series analysis of the amplitudes of the dominant modes.

121. Tsaneva-Atanasova, Krasimira

Zimliki, Charles L., Center for Devices and Radiological Health, FDA, Sherman, Arthur, Sherman Laboratory of Biological Modeling, NIDDK, NIH, LBM/NIDDK/NIH

Effects of diffusion of calcium and metabolites in pancreatic islets

Cell coupling is important for the normal function of the beta-cells of the pancreatic islet of Langerhans, which secrete insulin in response to elevated plasma glucose. In the islets, electrical and metabolic communication are mediated by gap-junctions. Although electrical coupling is believed to account for synchronization of the islets the role and significance of diffusion of calcium and metabolites are not clear. In order to address these questions we analyze two different mathematical models of islet calcium and electrical dynamics. To study diffusion of calcium, we use a modified Morris-Lecar model. Based on our analysis, we conclude that intercellular diffusion of calcium does not play an important role in islet synchronization. Metabolic coupling is investigated with a recent mathematical model incorporating glycolytic oscillations (Bertram et al., Biophys. J. 200487:3074-3087). Bifurcation analysis of the coupled system reveals several modes of behavior, depending on the relative strength of electrical and metabolic coupling. We find that whereas electrical coupling always produces synchrony, metabolic coupling can abolish both oscillations and synchrony, explaining some puzzling experimental observations. We suggest that these modes are generic features of square-wave bursters and relaxation oscillators coupled through either the activation or recovery variable.

122. Virgin, Lawrie

Santillan, Sophia, Plaut, Ray, Duke University

Dynamics of a pinched, flexible loop

A thin strip is bent such that the two ends are brought together and clamped (pinched) to form a teardrop shape. The clamped end is held at various angles with the loop, either upright, horizontal, downward, or halfway between these positions. The length of the loop is increased, and the resulting equilibrium shapes, as well as small in-plane vibrations about equilibrium, are investigated analytically and experimentally. In the analysis, the strip is assumed to be an inextensible elastica that is unstrained when straight, and its self-weight is included. For free vibration a shooting method is applied to obtain numerical solutions to the nonlinear equilibrium boundary value problem and the linear vibration boundary value problem. For forced vibration (when the clamped base is shaken harmonically) a finite difference scheme is used, and large-amplitude motion is obtained. Polycarbonate strips are investigated in the experiments, and data are acquired with a laser vibrometer.

123. Vyawahare, Saurabh

Craig, Kate M., Scherer, Axel, Watson, Thomas J. Sr., Laboratories of Applied Physics, Pasadena, CA 91125, California Institute of Technology

Patterning lines with capillary flows

Looking at a soap bubble, one can appreciate how capillary forces cause unexpected patterns and shapes. Here, we report a general method for depositing controlled line patterns, based on capillary flows in thin films of liquids. In contrast to the ring residue patterns left behind by drops in the 'coffee drop' effect, we are able to pattern straight lines at any location by a combination of pinning and evaporation in surfactant solutions. We show that with quantum dots and microspheres, colloidal particles tend to concentrate in these lines if they are present in the solution. These lines can be many millimeters long with sub-micron widths. The physics of the process is analogous to that of foam and bubble formation. Under uniform evaporation conditions, the patterns grow linearly and attach to the solution with a parabolic shaped contact line. Line pattern formation is a general process and we demostrate a variety of foaming surfactant can be used. This provides a flexible, new way to self assemble one dimensional lines or wires.

124. Walder, Robert

Dennin, Michael, Department of Physics and Astronomy, University of California at Irvine, Dennin, Michael, Levine, Alex, Department of Chemistry, University of California at Los Angeles, University of California at Irvine

Mechanical properties of actin filament networks

Actin filament networks present a model system to study the mechanical properties of semi-rigid polymer networks. Because they are a network, the filaments can display behavior that deviates from continuum elasticity theory on sufficiently short length scales, resulting in interesting nonlinear response of the system to applied stresses and strains. We have developed a Couette (concentric cylinders) style apparatus to study monolayers of actin confined to the air-water interface. This poster will present initial results characterizing the response of the monolayer to continuous strain. We will report on initial measurements of the viscosity of the actin network as a macroscopic characterization. Also, we track tracer particles in the monolayer network to characterize the displacements in response to applied stresses and strains.

125. Walkenstein, Jonathan

Jonathan Walkenstein, Aaron Jozsef, William B. Pardo, Victor Castro, Zheng Le, Marco Monti, Robert O'Meara

Resistor Inductor Diode Chaos: A Vanishingly Simple Circuit with Extraordinarily Complex Behavior and far reaching potential applications.

This poster explores and documents the nonlinear behavior exhibited by a sinusoidal driven serial circuit consisting of a resistor, an inductor, and a diode (all available from Radio Shack). Power and frequency transitions to chaos are demonstrated. The circuit exhibits period doubling, transitions to chaos, and "transition synchronization" between two circuits. The potential for "Transition Synchronization Encryption" techniques are also documented and presented.

126. Willeboordse, Frederick

National University of Singapore

Quantum correlations with a classical apparatus

A deterministic, relativistically local and thus classical Bell-type apparatus is reported that violates the Bell-CHSH inequality by introducing a simple local memory element in the detector and by requiring the detector combinations to switch with unequal probabilities. This indicates that the common notion of the fundamental impossibility of a classical-type theory underlying quantum mechanics may need to be re-evaluated. (http://www.arxiv.org/abs/quant-ph/0502175)

127. Xu, Pei-min

School of Mechanical Engineering, Anhui University of Technology, P. R. China

Crisis Capture and Skeleton of Crisis Loci in Parameter Space

Mapping the behavior of a dynamic system in multi-parameter space may reveal some interesting phenomena. When two parameters of a dissipative system are varied simultaneously, the structure of the parameter space of the system may be directly investigated and constructed by numerical method (Pei-min XU 2004 Chinese Physics 13 618, Gallas J A C 1993 Phys. Rev. Lett. 70, 2714, 1995 Applied Physics B 60 S203). The parameter space of a dissipative system consists of a series of solution domains, which are enclosed by curves of static bifurcation and boundary (or interior for periodic window) crisis. Isoperiodic shrimps are only parts of the solution domains, the parts just below the accumulation curves of the period-doubling cascades. A perfect period-doubling cascade and a chaotic band merging cascade can be obtained when we cuts across the domain. It begins at a period n (^{3}1) static bifurcation (e.g. saddle-node bifurcation) and ends at a chaotic attractor of n pieces (bands). Such a domain is called P-n domain and the chaotic attractor I-n attractor. Here n is the period number of the domain or attractor. Most of the domains are of different period number while some of them have equal one. The borders of the domain are often smooth curves but they may lose their differentiabilities at some point on crisis loci, i.e. they may have double crisis vertexes (Gallas, J. A. C. Grebogi, C. and Yorke, J. A. 1993, Phys. Rev. Lett. 71, 1359, Stewart, H. B., Ueda, Y., Grebogi, C. and Yorke, J. A., 1995, Phys. Rev. Lett. 75, 2478). By use of phase diagrams and introduction of the concepts of basic set and generalized crisis, Stewart concluded that a typical double crisis vertex on border of a solution domain is the intersection of two boundary crisis loci (they are parts of the border), an interior crisis locus and a basin metamorphosis locus in the domain. There are infinite of

solution domains (shrimps) in parameter space. Crisis loci of different solution domains may intersect in parameter space. Recently, a so-called Landing phenomenon was reported by Pei-min. A narrow P-m domain firstly coexists with (lies on) a big P-n (m≥3n) domain. Then it goes into the chaotic area of the big domain and becomes period-m windows when two parameters of Hénon map are varied simultaneously. The co-existence of attractors disappears. There is interaction between the two domains in the course of landing. The landing phenomena are closely related with the double crisis phenomena. It is accompanied with an interior crisis locus (crisis step, Grebogi C, Ott E and Yorke J A. 1987 Physica D, 24 243) that connects the landing point to the double crisis vertex on the border of the big domain. The landing point is the intersection of the interior crisis locus of the big domain and the boundary crisis locus of the narrow one. The interior crisis loci and the basin metamorphosis loci come from interior of a domain. What will happen if we trace them into the domain? Could two interior crisis loci or two metamorphosis loci meet together? What interesting dynamics is expected to occur? Here we report intersections of two generalized crisis loci of the same type in one domain. The two loci intersect at a point in the parameter space and one of them disappears immediately after the intersection. We call it crises capture. The relationship among the three kinds of intersection of crisis loci is discussed and the skeleton of crisis loci in parameter space is described briefly.

128. Yang, Lingfa

Epstein, Irving R., Department of Chemistry and Volen Center for Complex Systems, MS 015, Brandeis University, Waltham, Massachusetts 02454-9110 USA

Pattern formation in reaction-diffusion systems

Turing patterns have been observed experimentally in different kinds of striped or hexagonal lattices, but never in stable square lattices. This raises the general question whether reaction-diffusion (RD) systems allow square symmetry. An analytic analysis has been made of pattern selection using coupled amplitude equations near both supercritical (cubic) and subcritical (quintic) bifurcations. Conditions have been found where squares can appear exclusively, or can coexist with other patterns. We also predict the existence of stable mixed modes between square and stripe solutions. We have verified some of these predictions in standard RD systems by reducing RD models with multiple scaling analysis. On the other hand, RD patterns pose several further challenges. Can one understand, for instance, within the framework of weak nonlinear theory, such phenomena as oscillatory square patterns, segmented wave trains, and solitary chemical waves (solitons and oscillons) in terms of their spatial periodicity, stationary or oscillatory properties.

129. Yazykov, Vladislav

Pogorelov, Dmitry, Bryansk State Technical University

Computer simulation of train dynamics

Considerable longitudinal dynamic forces arising in intercar couplings represent a big danger for train operation. These forces must be limited under conditions of train operation safety. For that it is necessary to carry out the detailed analysis of train longitudinal dynamics. A considerable part of problems of train dynamics can be solved using methods of computer simulation, which can model the behavior of a train. A mathematical model of train motion represents in the form of the system of nonlinear differential equations, which solving is complex and as a rule is performed with the help of numerical integration. When creating the model it is necessary to take into account many factors such as gas-dynamic processes in an air brake system, forces which resist moving the train forward (resistance forces), various types of intercar couplings, complex track profile, etc. A module for simulation of train dynamics is developed in the program package “Universal mechanism” (www.umlab.ru). This module automates the process of model creation and the analysis of obtained results. A train model in the program is represented as a multibody system. Every vehicle of the train in terms of “Universal mechanism” is a subsystem, which can be a model of any complexity. Though in most cases it is enough to create a single-mass model of a vehicle, more precise vehicle model can be included in the train model to make more detailed analysis of a separate vehicle in the train.

130. Zarringhalam, Kourosh

Short, Kevin, University of New Hampshire

Cupolets as periodic wavelets

We present a control scheme for stabilizing unstable periodic orbits based on the control scheme of Hayes, Grebogi and Ott. The resulting orbits have been dubbed cupolets and have been proven to be useful in the representation of oscillatory or quasi periodic signals such as appear in music compression. In this paper we show that these cupolets can be used to construct a periodic multi resolution analysis for the space of real valued functions of a discrete variable. This is demonstrated with an image compression example. Thus cupolets provide an interesting continuum between Fourier Analysis and Wavelet Analysis.

131. Zhao, Xiaopeng

Dankowicz, Harry, Department of Biomedical Engineering, Duke University, Mechanical and Industrial Engineering, University of Illinois at Urbana-Champaign

Characterization of intermittent contact in tapping-mode atomic force microscopy

Tapping-mode atomic force microscopy (AFM) has become the method of choice for high-resolution probing of the nanoscale surface and subsurface properties of soft and fragile structures. The interactions between the AFM probe tip and the sample are inherently nonlinear, for example, due to the intermittency of contact. Dramatic instabilities may occur as a result of the tip-sample interactions that deteriorate the imaging quality as well as result in damage to the sample surface. In this paper, analysis methods for piecewise-smooth dynamical systems are used to investigate the nonlinear dynamics of the vibrating probe tip. These methods trace the existence of parameter hysteresis and associated instabilities to discontinuity-induced saddle-node bifurcations and suggest ways to improve the repeatability of surface scans while significantly reducing damage to the measured structure.

132. Zhao, Xiaopeng

Schaeffer, David G., Berger, Carolyn M., Gauthier, Daniel J., and Krassowska, Wanda, Duke University

Theoretical analysis of smooth and nonsmooth period-doubling bifurcations in cardiac tissue

Cardiac arrhythmias can lead to sudden cardiac death, which is the number one cause of death in the United States. Cardiac alternans is recognized as a possible initiator of fatal arrhythmias. Cardiac alternans is characterized by long-short beat-to-beat alternation in action potential duration; it arises via period-doubling bifurcation in a myocardium paced at increasingly faster rates. Bifurcation theory indicates that a period-doubling bifurcation can occur via two different mechanisms: either through a classical period-doubling bifurcation as in return maps described by smooth functions or through a border-collision period-doubling bifurcation as in return maps described by piecewise smooth functions. To identify the true mechanism mediating cardiac alternans, this work investigates theoretically the differences between smooth and border-collision period-doubling bifurcations. Although, theoretically, bifurcation diagrams discriminate between the two bifurcations, we show that they may be hard to differentiate for discrete data and may even be misleading especially when decay of transient is too slow. We then show that alternating pacing, i.e., long-short beat-to-beat variation in pacing intervals, affords a more effective way to distinguish between the two bifurcations. Qualitative differences between the two bifurcations are significant and robust even in the presence of noise and other disturbances. Therefore, our theoretical findings provide an unambiguous technique that can be easily implemented in experiments to distinguish between smooth and border-collision period-doubling bifurcations.

133. Zheng, Xing

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Characterization of fluctuations of impedance and scattering matrices in wave chaotic scattering

In wave chaotic scattering, statistical fluctuations of the scattering matrix S and the impedance matrix Z depend both on universal properties and on nonuniversal details of how the scatterer is coupled to external channels. This paper considers the impedance and scattering variance ratios VR_z and VR_s where $VR_z=Var[Z_{ij}]/\{Var[Z_{ii}]Var[Z_{jj}] \}^{1/2}$ $VR_s=Var[S_{ij}]/\{Var[S_{ii}]Var[S_{jj}] \}^{1/2}$ and $Var[.]$ denotes variance. VR_z is shown to be a universal function of distributed losses within the scatterer. That is VR_z is independent of nonuniversal coupling details. This contrasts with VR_s for which universality applies only in the large loss limit. Explicit results are given for VR_z for time reversal symmetric and broken time reversal symmetric systems. Experimental tests of the theory are presented using data taken from scattering measurements on a chaotic microwave cavity.