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DEADLINE DATES

Hotel Registration
September 21, 1992

Advance Conference Registration
October 2, 1992

FUNDING AGENCIES

SIAM would like to thank both the Office of Naval Research , Department of Energy, and the National Science Foundation for their support in conducting this conference.

ORGANIZING COMMITTEE

Peter W. Bates (Co-chair)
Department of Mathematics
Brigham Young University

Christopher K.R.T. Jones (Co-chair)
Division of Applied Mathematics
Brown University

GET-TOGETHERS

SIAM Welcoming Reception
Wednesday, October 14, 1992
6:30 PM - 8:30 PM
Golden Cliff
(Level B of Cliff Lodge)
Cash Bar and mini hors d'oeuvres.

Business Meeting
SIAM Activity Group on Dynamical Systems
Friday, October 16, 1992
8:00 PM - 9:00 PM
Ballroom 1&2
Anyone interested in the activity group is welcome attend.

Poster Session
Saturday, October 17, 1992
7:30 PM - 9:30 PM
Golden Cliff
(Level B of Cliff Lodge)
Come and talk with your colleagues and enjoy comp mentary beer, sodas and chips.

Trip to Salt Lake City and
Mormon Temple (Tabernacle Choir)
Sunday, October 18, 1992
7:30 AM - 12:00 Noon
Board buses in front of Cliff Lodge at 7:45 AM. Y will enjoy a continental breakfast while a guide off a description of Little Cottonwood Canyon. This ca yon played a significant part in the settling of the S Lake Valley. Today, the canyon is home to a gigan genealogical records vault which is carved in the gra ite walls that line the canyon. Little Cottonwood is al home to two major ski resorts. Once in Salt Lake, whi is an hour's drive from Snowbird, you will stop Historic Temple Square for the live radio broadcast the Mormon Tabernacle Choir. Following the broa cast, you will visit the Capitol and Beehive House, ci founder Brigham Young's home. You will be serv refreshments on your trip back to Snowbird. C $25.00

DISCLAIMER

PROGRAM OVERVIEW

Following are subject classifications for the sessions. The codes in parentheses designate session type and number. The session types are Contributed (CP), Invited (IP), Minisymposium (MS), and Poster (P).

WEDNESDAY, OCTOBER 14

6:00 PM-8:00 PM
Registration opens
Ballroom Foyer

THURSDAY, OCTOBER 15

7:45 AM **Registration opens**
Ballroom Foyer

8:45 **Opening Remarks**
Peter W. Bates and Christopher K.R.T. Jones
Ballroom 1&2

9:00 IP1 **Metaphors, Models and Mathematics, or How Strange is Turbulence?**
Philip Holmes
Ballroom 1&2

10:00 **Coffee**
Golden Cliff Room

10:15 Concurrent Sessions

MS1 **Integrable Systems**
Organizers: Athanassios S. Fokas and Israel M. Gel'fand
Ballroom 1&2

MS2 **Geometric Methods for Maps of the Plane**
Organizer: Marcy Barge
Magpie Room

MS3 **Nonlinear Control, Dynamics, and Estimation**
Organizer: Christopher I. Byrnes
Wasatch Room

MS4 **AIDS Epidemiology and Dynamical Models**
Organizer: Ann Stanley
Maybird Room

CP1 **Computation of Global Structures**
Superior B Room

CP2 **Oscillation and Invariance 1**
Superior A Room

12:15 PM **Lunch**

1:30 IP2 **Ergodic Theory of Strange Attractors**
Lai-Sang Young
Ballroom 1&2

2:30 Concurrent Sessions

MS5 **Hyperbolicity in Skew-Product Flows**
Organizer: Russell A. Johnson
Magpie Room

MS6 **Turbulence and Wavelets**
Organizer: Katepalli R. Sreenivasan
Wasatch Room

MS7 **Coupled Oscillators**
Organizer: Steven H. Strogatz
Maybird Room

MS8 **Infinite Dimensional KAM Theory**
Clarence E. Wayne
Ballroom 1&2

CP3 **Spatial Structures**
Superior B Room

CP4 **Stability and Approximation**
Superior A Room

4:30 **Coffee**
Golden Cliff Room

5:00 IP3 **Complex Polynomial Dynamics**
John Milnor
Ballroom 1&2

6:00 Concurrent Sessions

CP5 **Dynamics of Motion**
Magpie Room

CP6 **Resonances**
Wasatch Room

CP7 **Chaotic Motion**
Maybird Room

FRIDAY, OCTOBER 16

7:30 AM **Registration opens**
Ballroom Foyer

8:30 IP4 **Chaos in Near-Integrable Systems**
David W. McLaughlin
Ballroom 1&2

9:30 **Coffee**
Golden Cliff Room

10:00 Concurrent Sessions

MS9 **Defects and Singularities**
Organizers: Paul Fife and Peter Sternberg
Ballroom 1&2

MS10 **Controlling Chaos**
Organizer: David F. Delchamps
Magpie Room

MS11 **Saddle Orbits**
Organizer: Eric Kostelich
Wasatch Room

CP8 **Phase Space Reconstruction and Time Series**
Superior A Room

CP9 **Oscillation and Invariance 2**
Superior B Room

CP10 **Symmetry in Dynamical Systems**
Maybird Room

12:00 PM **Lunch**

1:30 IP5 **Computational Complexity and Chaos**
Lenore Blum
Ballroom 1&2

2:30 Concurrent Sessions

MS12 **Dynamical Problems in Theoretical Chemistry**
Organizers: Gregory Ezra and and Stephen Wiggins
Magpie Room

MS13 **Stochastic Resonance**
Organizer: Kurt Wiesenfeld
Ballroom 1&2

MS14 **Recent Developments in Differential-Delay Equations**
Organizers: John Mallet-Paret and Roge[illegible] Nussbaum
Wasatch Room

CP11 **Taylor-Couette Flow**
Maybird Room

CP12 **Phase Space Reconstruction and Time Series [illegible]**
Superior B Room

4:30 **Coffee**
Golden Cliff Room

5:00 IP6 **Splitting Separatrices and Arnol'd Diffusion**
Giovanni Gallavotti
Ballroom 1&2

6:00 Concurrent Sessions

CP13 **Delay Equations**
Wasatch Room

CP14 **Fractals and Invariant Measures**
Superior B Room

CP15 **Homoclinic Orbits and Chaos 1**
Maybird Room

8:00 **Business Meeting**
SIAM Activity Group on Dynamical Systems
Ballroom 1&2

SATURDAY, OCTOBER 17

30 AM **Registration opens**
Ballroom Foyer

30 IP7 **Dynamical Systems Problems for the Superconducting Super-Collider**
James A. Ellison
Ballroom 1&2

30 **Coffee**
Golden Cliff Room

:00 **Concurrent Sessions**

MS15 **Invariant Manifolds**
Organizer: Kening Lu
Magpie Room

MS16 **Nonlinear Optics and Hamiltonian Systems**
Organizer: William L. Kath
Ballroom 1&2

MS17 **The Dynamics for Patterns in Excitable Media**
Organizer: James P. Keener
Wasatch Room

MS18 **Dynamics of Mechanical Systems**
Mark Levi
Maybird Room

CP16 **Control of Dynamical Systems**
Superior A Room

CP17 **Fluids 1**
Superior B Room

:00 PM **Lunch**

30 IP8 **Bifurcations and Traveling Waves in a Delayed Partial Differential Equation**
Michael C. Mackey
Ballroom 1&2

-30 **Concurrent Sessions**

MS19 **Dynamics of Infinite-Dimensional Problems**
Organizer: Shui-Nee Chow
Ballroom 1&2

MS20 **Nonlinear Optics**
Organizer: Jerome V. Moloney
Magpie Room

MS21 **Neural Networks**
Organizer: Stephen Grossberg
Wasatch Room

CP18 **Computational Dynamical Systems 1**
Maybird Room

CP19 **Physical Applications 1**
Superior A Room

CP20 **Fluids 2**
Superior B Room

30 **Coffee**
Golden Cliff Room

30 IP9 **Chaos and Fractals in Physiology and Medicine**
Ary L. Goldberger
Ballroom 1&2

30-9:30 **Poster Session**
Golden Cliff Room and Ballroom Foyer

SUNDAY, OCTOBER 18

7:30 AM **Buses leave for Salt Lake City tour and Mormon Temple**
Cliff Lodge

12:00 PM ***Buses return from tour***

12:00 **Registration opens**
Ballroom Foyer

12:30 – 3:00

MS22 **Inertial Manifolds and Low Dimensional Dynamics of PDEs (Part 1 of 2)**
Organizers: Yannis Kevrekidis and Edriss S. Titi
Ballroom 1&2

1:00 **Concurrent Sessions**

MS23 **Application of Dynamical Systems to Information Theory**
Roy L. Adler
Magpie Room

MS24 **Computer Techniques for the Numerical Study of Dynamical Systems**
Organizer: Celso Grebogi
Wasatch Room

MS25 **Bursting Oscillations in Biological Systems**
Organizers: David H. Terman and John Rinzel
Maybird Room

CP21 **Physical Applications 2**
Superior A Room

CP22 **Homoclinic Orbits and Chaos 2**
Superior B Room

3:00 **Coffee**
Golden Cliff Room

3:30 IP10 **Stationary and Turbulent Patterns in a Reaction-Diffusion System**
Harry L. Swinney
Ballroom 1&2

4:30 IP11 **Symmetric Chaos**
Martin Golubitsky
Ballroom 1&2

7:30 **Concurrent Sessions**

MS26 **Inertial Manifolds and Low Dimensional Dynamics of PDEs (Part 2 of 2)**
Organizers: Yannis Kevrekidis and Edriss S. Titi
Ballroom 1&2

MS27 **Signal Processing and Chaos (Part 1 of 2)**
Organizer: Louis M. Pecora
Magpie Room

MS28 **Qualitative Results for Partial Differential Equations**
Organizers: Norman Dancer and Peter Hess
Wasatch Room

MS29 **The Numerical Treatment of PDEs with Symmetry**
Organizer: Michael Dellnitz
Maybird Room

CP23 **Biological Applications 1**
Superior B Room

CP24 **Physical Applications 3**
Superior A Room

MONDAY, OCTOBER 19

8:00 AM **Registration opens**
Ballroom Foyer

8:30 IP12 **Stability, Instability and Bifurcation by the Energy-Momentum Method**
Jerrold E. Marsden
Ballroom 1&2

9:30 **Coffee**
Golden Cliff Room

10:00 **Concurrent Sessions**

MS30 **New Methods of Embedding and Analysis for Noisy Chaotic Data**
Organizer: Robert Cawley
Magpie Room

MS31 **Applications of Dynamical Systems Methods in Nonlinear Optics**
Organizer: Darryl Holm
Wasatch Room

MS32 **Chaotic Transport for Hamiltonian Systems**
Organizer: James D. Meiss
Maybird Room

MS33 **Signal Processing and Chaos (Part 2 of 2)**
Organizer: Louis M. Pecora
Ballroom 1&2

CP25 **Computational Dynamical Systems 2**
Superior A Room

CP26 **Biological Applications 2**
Superior B Room

12:00 PM **Conference Adjourns**

CP = Contributed Presentation
IP = Invited Presentation
MS = Minisymposium

THURSDAY MORNING, OCTOBER 15

7:45 Ballroom Foyer
Registration opens

8:45 Ballroom 1&2
Opening Remarks
Peter W. Bates, Brigham Young University and Christopher K.R.T. Jones, Brown University

9:00 Ballroom 1&2
IP1/Chair: Peter W. Bates, Brigham Young University
Metaphors, Models and Mathematics, or How Strange is Turbulence?

The speaker will reflect a little on the place of applied mathematics between the physical world and the world of pure mathematics, and on the relations between modelling and analysis. He will illustrate the general discussion by describing work on low dimensional models for the dynamics of coherent structures in turbulent flows done at Cornell over the past seven years by Armbruster, Aubry, Berkooz, Elezgaray Guckenheimer, Lumley, Stone and himself.

For turbulent flow one has an excellent mathematical model: the Navier-Stokes equation. The difficulty is, of course, that it appears insoluble in any reasonable sense, even if the technical difficulties of global existence in three dimensions could be overcome. A full numerical simulation certainly provides a "solution", but it provides little understanding of the process per se. However, three recent developments offer some hope: the discovery, by experiment, of coherent structures in certain fully developed turbulent flows, the suggestion, by Ruelle, Takens and others, that strange attractors and other ideas from dynamical systems theory might play a role in the analysis of the governing equations, and the introduction of the statistical technique of Karhunen-Loeve or proper orthogonal decomposition (by Lumley in the case of turbulence). The speaker will describe how these three threads might be drawn together to weave low dimensional models that yield understanding of basic mechanisms of turbulence generation.

Philip Holmes
Department of Theoretical and Applied Mechanics
Cornell University

10:00 Golden Cliff Room
Coffee

Note:
For presentations with two or more authors the speaker's name is in italics.

10:15 AM-12:15 PM
CONCURRENT SESSIONS

MS1 Ballroom 1&2
Integrable Systems

Many apparently disparate nonlinear systems exhibit integrable behavior, in particular they possess coherent structures (solitons, instantons, gravitons, dromions, etc.). The study of integrable phenomena has enhanced our understanding of certain physical nonlinear mechanisms and has also led to beautiful mathematical results such as the solution of the Schottky problem and the introduction of quantum groups.

The speakers in this minisymposium will discuss four new developments: A general and rigorous method for analyzing the asymptotics of integrable equations will be presented. The Painlève equations which apparently play in nonlinear physics the same role that the classical special functions play in linear physics, will be reviewed with emphasis on their appearance in 2D quantum gravity. Recent experimental and theoretical developments concerning commercial applications of solitons in fiber optics will be presented. The transition from integrability to stochasticity will be discussed for a discrete sine-Gordon equation.

Organizers: Athanassios S. Fokas, Clarkson University, and Israel M. Gel'fand, Rutgers University

10:15 The Painlève Transcendents in Nonlinear Mathematical Physics
Alexander R. Its, Clarkson University

10:45 Steepest Descent Method for Oscillatory Riemann-Hilbert Problems with Applications to Dynamical Systems
P. Deift, Courant Insitute of Mathematical Sciences, New York University and X. Zhou, Yale University

11:15 Statistical Critical Phenomena in a Near-Integrable Discrete Sine-Gordon Lattice
M. Gregory Forest, Christopher G. Goedde and Amarendra Sinha, Ohio State University, Columbus

11:45 Recent Progress on a Long-Distance and High-Bit-Rate Optical Soliton Communication System
Yuji Kodama, Ohio State University, Columbus

MS2 Magpie Room
Geometric Methods for Maps of the Plane

The introduction of certain topological techniques into the study of two-dimensional diffeomorphisms has yielded a deeper understanding of the structure of their periodic orbits and other minimal sets. These techniques include the Thurston Theory applied to the plane punctured by the removal of periodic orbits, continuum theoretic considerations on invariant one-dimensional subsets (such as the closure of the unstable manifold), and index arguments. The common theme of the presentations in this minisymposium is the coordination of the above methods to provide an understanding of various rotational behaviors for two-dimensional maps. Recent work along these lines has helped organize the dynamical complexity of periodically forced nonlinear oscillators and other such complicated systems that possess periodic orbits of infinitely many periods.

Organizer: Marcy Barge, Montana State University

10:15 Rotation Intervals for Diffeomorphisms of the Plane
Kathleen T. Alligood, George Mason University

10:45 Periodic Orbits Created by Rigid Rotati
Glen R. Hall, Boston University

11:15 Fixed Points in the Plane and Rotation Numbers
Richard Swanson, Montana State Universi

11:45 A Poincare-Birkhoff Theorem for Dissipative Maps of the Plane
Marcy Barge, Organizer

MS3 Wasatch Room
Nonlinear Control, Dynamics, and Estimatio

During the past decade, the field of nonlinear cont has reached a remarkable state of maturity, culminat in the development of several systematic methodo gies for the design of feedback laws achieving a vari of important control objectives. Indeed, theory simulation now suggest that the nonlinear control me ods have the potential to become comparable in sc to the method of classical and state space design me ods for linear systems - a view supported by curr design methods developed in the aerospace industr

In the early 1980s, nonlinear control theori returned en masse to the most basic yet challeng design problems that are now part of a systema design methodology for nonlinear control. This tr had its origin in two independent developments - discovery of necessary and sufficient conditions (local) linearization of a nonlinear system via st feedback and coordinate changes and for (loc decoupling of a disturbance channel via feedback coordinate changes. The geometric underpinnings these two important advances clarified a decade earlier work and, when combined with an increas application of nonlinear dynamics, has pointed the w to a host of other advances, including methods asymptotic tracking, disturbance attenuation and rej tion, feedback stabilization and modeling filter observer design.

The speakers will present some of the rec advances in control and estimation made possible the incorporation of concepts and techniques dra from nonlinear dynamics.

Organizer: Christopher I. Byrnes, Washington University

10:15 Global Solutions and Shock Waves for t Riccati Partial Differential Equations of Nonlinear Optimal Control
Christopher I. Byrnes, Organizer

10:45 On the Nonlinear Dynamics of Fast Filtering Algorithms
Anders Lindquist, Royal Institute of Technology, Sweden

11:15 Nonholonomic Systems and Control
Anthony Michael Bloch, Ohio State University

11:45 Dynamic Systems and Universal Observability
Clyde Martin, Texas Tech University, Lubbock

10:15 AM-12:15 PM

CONCURRENT SESSIONS

MS4/Maybird Room

AIDS Epidemiology and Dynamical Models

Mathematical models of the spread of AIDS have provided important insights into the dynamics driving the epidemic. Models have demonstrated the importance of certain key factors, including social structures, mixing rates between social groups, and variations in infectiousness with the course of disease. The spread of HIV is a nonlinear, nonlocal process, and, because of this, different types of social structures and transportation networks can result in very different epidemic patterns. Recent Monte Carlo simulations have demonstrated that correlations between random events can greatly influence the spread of the epidemic even in large populations.

Organizer: Ann Stanley
Iowa State University

10:15 Comparison of Deterministic and Stochastic SI Models
Carl Simon and John Jacquez, University of Michigan, Ann Arbor

10:45 The Importance of Interregional Mobility for Infectious Disease Spread in Bounded Geographic Areas
Lisa Sattenspiel, University of Missouri, Columbia

11:15 Title to be announced
Michael Altmann, University of Minnesota, Minneapolis

11:45 Social Mixing Patterns and the Spread of AIDS
Ann Stanley, Organizer

CP1/Superior B Room

Computation of Global Structures

Chair: Andrew M. Stuart, University of Bath, United Kingdom and Stanford University

10:15 Numerical Computation of Homoclinic Orbits
Stephen Schecter, North Carolina State University

10:35 Computation of Heteroclinic Connections in Gradient PDEs Part I
Fengshan Bai, University of Bath, United Kingdom and Tsinghua University, People's Republic of China; Alastair Spence, University of Bath, United Kingdom; and *Andrew M. Stuart*, University of Bath, United Kingdom and Stanford University

10:55 Computation of Heteroclinic Connections in Gradient PDEs Part II
Fengshan Bai, University of Bath, United Kingdom and Tsinghua University, People's Republic of China; Alastair Spence, University of Bath, United Kingdom; and Andrew M. Stuart, University of Bath, United Kingdom and Stanford University

11:15 Numerical Methods for Dissipative and Gradient Dynamical Systems
Antony R. Humphries and Andrew M. Stuart, University of Bath, United Kingdom and Stanford University

11:35 The Complex Ginzburg-Landau Equation: Numerical Schemes and Absorbing Set
Gabriel James Lord, University of Bath, United Kingdom and Andrew M. Stuart, University of Bath, United Kingdom and Stanford University

11:55 Accurate Computation and Continuation of Heteroclinic Orbits
Mark J. Friedman, University of Alabama, Huntsville; Eusebius J. Doedel, California Institute of Technology; and Anand C. Monteiro, University of Alabama, Huntsvil e

CP2/Superior A Room

Oscillation and Invariance I

Chair: Russell Johnson, Università di Firenze, Italy and University of Southern California

10:15 Breakdown of Stability of 2-Tori
Russell Johnson, Università di Firenze, Italy and University of Southern California and Ying-Fei Yi, Georgia Institute of Technology

10:35 Recurring Anti-Phase Behavior in Coupled Nonlinear Oscillators: Random Noise or Deterministic Chaos?
Kwok Yeung Tsang and Ira B. Schwartz, Naval Research Laboratory, Washington, DC

10:55 A Singularly Perturbed Nonlinear Oscillator with Applications to Structural Dynamics
Ioannis T. Georgiou, Anil K. Bajaj and Martin J. Corless, Purdue University, West Lafayette

11:15 Bifurcations and Chaos in a Bilinear Hysteretic Oscillator
Rudra Pratap, S. Mukherjee and F.C. Moon, Cornell University

11:35 Mode-Locking Structure in Billiards with Spin
Kwang Il Kim, Yoo Tae Kim and *Seunghwan Kim*, Pohang Institute of Science and Technology, Korea

11:55 On the Dynamics of Aeroelastic Oscillators with One Degree of Freedom
Adriaan P.H. van der Burgh and *Timber I. Haaker*, Delft University of Technology, The Netherlands

THURSDAY AFTERNOON, OCTOBER 15

12:15-1:30

Lunch

1:30/Ballroom 1&2

IP2/Chair: Christopher K.R.T. Jones, Brown University

Ergodic Theory of Strange Attractors

The theory of Sinai, Bowen and Ruelle tells us that for uniformly hyperbolic attractors the statistics of typical trajectories are governed by a very special invariant measure. The speaker will present and discuss recent results along similar lines for the Henon attractors.

Lai-Sang Young
Department of Mathematics
University of Arizona and University of California, Los Angeles

2:30 PM - 4:30 PM

CONCURRENT SESSIONS

MS5/Magpie Room

Hyperbolicity in Skew-Product Flows

Hyperbolicity with respect to a general compact invariant set in a dynamical system can be effectively studied by introducing a skew product flow. In this way an autonomous vector field becomes non-autonomous, but the skew-product structure alleviates the main difficulty associated with non-autonomous systems, namely the breakdown of the flow property. The speakers in this minisymposium will survey applications of the skew-product construction to various problems having hyperbolic structure. Homoclinic phenomena and bifurcation problems will be discussed.

Organizer: Russell A. Johnson
Università di Firenze, Italy and University of Southern California

2:30 Shadowing Orbits of Chaotic Differential Euqations
Kenneth J. Palmer and Huseyin Kocak, University of Miami

3:00 Smooth Invariant Foliations in Certain Dynamical Systems
Yingfei Yi, Georgia Institute of Technology

3:30 Homoclinic Twisting Bifurcations and Cusp Horsehoe Maps
Bo Deng, University of Nebraska, Lincoln

4:00 Breakdown of Stability of 2-tori
Russell Johnson, Organizer and Yingfei Yi, Georgia Institute of Technology

MS6/Wasatch Room

Turbulence and Wavelets

The speakers in this minisymposium will present an overview of some recent work on the applications of wavelets (and their relatives) to the problem of fluid turbulence. The presentations will cover the following aspects: an examination of the wavelet transform as a link between physical and Fourier space descriptions of turbulence, the physical-space description and modeling of turbulent fields by the use of wavelets, the analysis of the Navier-Stokes equations in the orthonormal wavelet representation and the theoretical and experimental work on the probability density function of wavelet coefficients for passive admixtures in fully developed turbulence.

Organizer: Katepalli R. Sreenivasan
Yale University

2:30 The Multiscale Structure of the Passive Scalar Field in Turbulent Water Jets
R.M. Everson, Brown University and K.R. Sreenivasan, Organizer

3:00 Analysis of Turbulence in the Orthonormal Wavelet Representation
Charles Meneveau, Johns Hopkins University

3:30 The Wavelet Transform as a Link between Physical Space and Fourier Space
James G. Brasseur and Qunzhen Wang, Pennsylvania State University

4:00 Wavelet Coefficient Probability Distribution Functions for Turbulent Flows
Philippe L. Similon, Yale University

2:30 PM - 4:30 PM

CONCURRENT SESSIONS

MS7 Maybird Room

Coupled Oscillators

Nonlinear oscillators are among the oldest and best understood types of dynamical systems, but very little is known about their collective behavior. In other words, what can happen when an enormous number of oscillators are coupled together? This minisymposium will focus on the dynamics of large systems of nonlinear oscillators, with applications to condensed-matter physics, chemical reaction-diffusion systems, and populations of biological oscillators.

Organizer: Steven H. Strogatz
Massachusetts Institute of Technology

2:30 Fireflies and Coupled Oscillators
Steven H. Strogatz, Organizer

3:00 Dynamics of Josephson Junction Arrays
Kurt Wiesenfeld, Georgia Institute of Technology

3:30 Nonlinear Oscillators, Biological Rhythms, and Landau Damping
Renato E. Mirollo, Boston College

4:00 Boundaries of Locking in Weakly Diffusive Chemical Systems
G. Bard Ermentrout, University of Pittsburgh

MS8 Ballroom 1&2

Infinite Dimensional KAM Theory

Ideas which first arose in the study of finite dimensional dynamical systems have recently begun to find increasing numbers of applications in the study of partial differential equations. In particular, the Kolmogorov-Arnold-Moser theory has been used to construct regular solutions for a number of equations of importance in mathematical physics. What is more, numerous other possible applications present themselves in areas such as scattering theory of non-integrable equations, stability of solitary waves, and the formation of shocks in dispersive equations. The speakers in this minisymposium will present a review of known results and explore possible future avenues of investigation.

Organizer: Clarence E. Wayne
Pennsylvania State University

2:30 Invariant Tori for Nonlinear Wave Equations
Walter L. Craig, Brown University

3:00 Approximation of Measure Preserving Transformations
Peter D. Lax, Courant Institute of Mathematical Sciences, New York University

3:30 The Forced Toda Problem
Stephanos Venakides, Duke University

4:00 Solitary Waves, Asymptotic Stability, and Hamiltonian Systems
Michael I. Weinstein, University of Michigan, Ann Arbor

CP3 Superior B Room

Spatial Structures

Chair: Xiao-Biao Lin, North Carolina State University

2:30 Dynamical Metastability in Cahn-Hilliard-Morral Systems
Christopher P. Grant, Georgia Institute of Technology

2:50 A New Passage to Generate Diffusive Patterns
Xiao-Biao Lin, North Carolina State University

3:10 Self-Trapping of Traveling-Wave Pulses
Hermann Riecke, Northwestern University

3:30 Domain Walls in Superstructures, Sources, Sinks and their Stability
David Raitt and Hermann Riecke, Northwestern University

3:50 Stability of Steady States of the Ginzburg-Landau Equation in Higher Space Dimensions
Shuichi Jimbo, Okayama University, Japan and *Yoshihisa Morita*, Ryukoku University, Japan

4:10 Interaction and Stochastic Dynamics of Localized States of Multidimensional Nonlinear Fields
A.S. Lomov and M.I. Rabinovich, Russian Academy of Sciences, Russia

CP4 Superior A Room

Stability and Approximation

Chair: Natalia Sternberg, Clark University

2:30 Systems with Intermittent Switching of the Activity—Distinguishing Random and Chaotic Processes
Nathan Platt, Naval Surface Warfare Center, Silver Spring, MD; Charles Tresser, IBM Thomas J. Watson Research Center; and Edward Spiegel, Columbia University

2:50 A Hartman-Grobman Theorem for Maps
Natalia Sternberg, Clark University

3:10 Closeness of the Solutions of Approximately Decoupled Damped Linear Systems to Their Exact Solutions
S.M. Shahruz, Berkeley Engineering Research Institute and G. Langari, Texas A&M University, College Station

3:30 On a Problem of Nirenberg Concerning Expanding Maps in Hilbert Space
Janusz Szczepanski, Polish Academy of Sciences, Poland

3:50 Structurally Stable Singularities of Line Element Fields on the Plane
I.U. Bronstein and *I.V. Nikolaev*, Academy of Sciences of Moldora, Russia

4:10 On Stability in Nonlinear Dynamical Systems with Perturbations
Oleg V. Anashkin, Simferopol State University, Ukraine

4:30/Golden Cliff Room

Coffee

5:00/Ballroom 1&2

IP3/Chair: Sheldon E. Newhouse, University of North Carolina, Chapel Hill

Complex Polynomial Dynamics

The speaker will present a survey of research in the dynamics of iterated polynomial maps in one complex variable. He will describe some classical results and emphasize recent developments.

John Milnor
Department of Mathematics
State University of New York, Stony Brook

6:00 PM - 7:00 PM

CONCURRENT SESSIONS

CP5 Magpie Room

Dynamics of Motion

Chair: Michael Rose, Technical University of Denmark, Denmark

6:00 Investigations of Chaos in a Train Wheelset with Adiabatically Varying Parameters
Michael Rose, Technical University of Denmark, Denmark

6:20 Transient Chaos in Wheel Dynamics
Gabor Stepan, Technical University of Budapest, Hungary

6:40 Dynamic Modeling of Vehicles Traveling on Bridges
E. Esmailzadeh and M. Ghorashi, Sharif University of Technology, Iran

CP6/Wasatch Room

Resonances

Chair: Timothy J. Burns, National Institute of Standards and Technology

6:00 Orbits Homoclinic to Resonances: The Hamiltonian Case
Gyorgy Haller and Stephen Wiggins, California Institute of Technology

6:20 Transfer of Capture During Passage Through Resonance
Timothy J. Burns, National Institute of Standards and Technology and Christopher K.R.T. Jones, Brown University

6:40 Second Order Averaging and Resonant Amplitude Dynamics of a Nonlinear Two Degree of Freedom System
Bappaditya Banerjee, Anil K. Bajaj and Patricia Davies, Purdue University, West Lafayette

CP7/Maybird Room

Chaotic Motion

Chair: Troy Shinbrot, University of Maryland, College Park

6:00 Piano-like Dynamics and Strange Nonchaotic Attractors
M.S. El Naschie, Cornell University

6:20 Transition to Hyperchaos in Coupled Generalized Van Der Pol Oscillators
Willi-Hans Steeb, Rand Afrikaans University, South Africa

6:40 Chaotic Model of Dry Friction Force
Tomasz Kapitaniak, Technical University of Lodz, Poland

FRIDAY MORNING, OCTOBER 16

7:30/Ballroom Foyer
Registration Opens

8:30/Ballroom 1&2
IP4/Chair: Christopher K.R.T. Jones, Brown University
Chaos in Near-Integrable Systems

This presentation is an overview of numerical and theoretical studies of chaotic behavior in near integrable soliton systems, specifically for perturbations of the nonlinear Schrödinger equation. (The work has been done in various collaborations with A. Bishop, N. Ercolani, G. Forest, Y. Li, E. Overman, S. Wiggins, and C. Xiong.)

The speaker will begin with a brief summary of typical phenomena which have been observed numerically; and then focus upon the use of the spectral transform to display instabilities and hyperbolic structure in the integrable system. This hyperbolic structure is responsible for the system's sensitivity to perturbations. In particular, he will identify invariant critical tori and analytically represent their stable and unstable manifolds — whiskered tori —for this integrable soliton system. The spectral transform is used to monitor numerically the presence of this hyperbolic structure in the perturbed numerical experiments. Finally, the status of the geometric perturbation studies of the system will be reviewed.

David W. McLaughlin
Department of Mathematics and
Program in Applied and
Computational Mathematics
Princeton University

9:30/Golden Cliff Room
Coffee

10:00 AM - 12:00 PM
CONCURRENT SESSIONS

MS9/Ballroom 1&2
Defects and Singularities

The notion of defect, together with other singularities, plays a prominent role in many physical theories. These notions often have mathematical counterparts in the form of inherent singular behavior of nonlinear partial differential equations serving as models for the physical phenomena. Various approaches to understanding the nature of such mathematical models, in several physical contexts, will be given.

Organizers: Paul Fife
University of Utah, and
Peter Sternberg,
Indiana University, Bloomington

10:00 **On the Dynamics of Defect Structures in Liquid Crystal Materials**
M. Carme Calderer, Pennsylvania State University, University Park

10:30 **Motion of Defects**
J. Rubinstein, Technion - Israel Institute of Technology, Israel

11:00 **Regularization of the Coulomb Singularity**
John Neu, University of California, Berkeley

11:30 **A Topological Defect Model of Superfluid**
Neil Carlson, Purdue University, West Lafayette

MS10/Magpie Room
(This session will run until 12:30 PM)
Controlling Chaos

Many interesting and difficult theoretical and practical problems in control system design involve complicated nonlinear dynamical phenomena in fundamental ways. The growing body of descriptive work on chaotic systems has a relevance and applicability to such problems that control theorists have only recently begun to appreciate. Concurrently, the dynamic systems community has started to recognize how the control theorists' prescriptive attitude not only casts a fresh light on old problems but engenders important new questions about practical situations that dynamical systems theory is well-equipped to answer. Each speaker in this minisymposium considers a class of nonlinear control systems whose dynamics exhibit chaos in one form or another. The first three speakers address the problem of suppressing an open-loop system's chaotic behavior using feedback control; while the first two speakers approach their problems from a purely deterministic standpoint, the third speaker models his system's complicated open-loop dynamics probabilistically. The fourth speaker considers a situation in which chaos results from controlling a nominally well-behaved system; the asymptotic statistical properties of the closed-loop system's chaotic dynamics depend upon the control scheme, and are therefore subject to the designer's influence.

Organizer: David F. Delchamps
Cornell University

10:00 **Control of Systems with Homoclinic and Heteroclinic Structures**
Anthony M. Bloch, Ohio State University, Columbus and Jerrold E. Marsden, University of California, Berkeley

10:30 **Bifurcation Control of Chaotic Dynamical Systems**
Hua Wang and *Eyad H. Abed*, University of Maryland, College Park

11:00 **Analysis and Control of Nonlinear Systems with Complicated Behavior**
Kenneth A. Loparo and Xiangbo Feng, Case Western Reserve University

11:30 **Invariant Densities and the Macroscopic Asymptotic Behavior of Digitally Controlled Continuous-Time Systems**
David F. Delchamps, Organizer

12:00 **Destabilizing Limit-Cycles in Delta-Sigma Modulators with Chaos**
Richard Schreier, Oregon State University

MS11/Wasatch Room
Saddle Orbits

Saddle periodic orbits provide an important characterization of dynamical systems. The speakers in this session describe both theoretical results and applications to experiments. They will discuss how saddle orbits can be extracted from experimental data to construct a geometric model of the dynamics of the experiment; the characterization of knots produced by flows in three-dimensional systems such as the Lorenz equations; the creation and destruction of hyperbolic and nonhyperbolic fixed points as a parameter is varied; and symmetry, fixed points, and what they imply about the structure of attractors.

Organizer: Eric Kostelich
Arizona State University

10:00 **Geometry from Saddle Cycles**
Robert Gilmore, Drexel University

10:30 **Structure of Attractors for Continuous Mappings**
Ian Melbourne, University of Houston

11:00 **Composite Knots in the Figure-8 Knot Complement can have any Number of Prime Factors**
Michael Sullivan, University of Texas, Austin,

11:30 **The Measure of Nonhyperbolicity in Chaotic Dynamical Systems**
Ying-Cheng, *Celso Grebogi* and James A. Yorke, University of Maryland, College Park

CP8/Superior A Room
Phase Space Reconstruction and Time Series 1

Chair: James Theiler, Los Alamos National Laboratory

10:00 **Mixed State Markov Models for Nonlinear Time Series**
Andrew M. Fraser, Portland State University

10:20 **Bleaching and Noise Amplification in Time Series Analysis**
James Theiler, Los Alamos National Laboratory

10:40 **Analyzing Chaotic Time Series Using Empirical Global Equations of Motion**
Jeffrey S. Brush, RTA Corporation, Springfield, VA and *James B. Kadtke*, University of California, San Diego

11:00 **Computing the Inferable Number of Dynamical Variables**
Joseph L. Breeden and Norman H. Packard, University of Illinois, Urbana

11:20 **Recursive Analysis of Chaotic Time Series**
Jaroslav Stark, GEC Hirst Research Centre, United Kingdom

11:40 **Dynamical Nonlinear Equations Obtained from Time Series**
Hans-Ruedi Moser and Peter F. Meier, University of Zurich, Switzerland

CP9/Superior B Room
Oscillation and Invariance 2

Chair: Carmen Chicone, University of Missouri, Columbia

10:00 **Numerical and Experimental Studies of Self-Synchronization and Synchronized Chaos**
Maria de Sousa Vieira, P. Khoury, A.J. Lichtenberg, M.A. Lieberman, and W. Wonchoba, University of California, Berkeley; J. Gullicksen, J.Y. Huang, R. Sherman and M. Steinberg, Loral Aerospace, San Jose, CA

10:20 **Invariants from Lengths of Caustics**
Edoh Y. Amiran, Western Washington University

10:40 **Collective Behavior in Limit-Cycle Oscillator Arrays**
Jeffrey L. Rogers and Luc T. Wille, Florida Atlantic University

11:00 **Lyapunov-Schmidt Reduction for Bifurcation of Periodic Solutions in Coupled Oscillators**
Carmen Chicone, University of Missouri, Columbia

11:20 **Chaotic Behavior in a Two-Frequency Perturbation of Duffing's Equation**
Kazuyuki Yagasaki, Tamagawa University, Japan

11:40 **Attractors of a Driven Oscillator with a Limit Cycle**
Ibere Luiz Caldas and Kai Ullmann, University of Sao Paulo, Brasil

CP10/Maybird Room
Symmetry in Dynamical Systems

Chair: Mary Silber, California Institute of Technology

10:00 Bifurcations with Local Gauge Symmetries: Patterns in Superconductors
Ernest Barany and Martin Golubitsky, University of Houston, University Park and Jacek Turski, University of Houston, Downtown

10:20 Hidden Symmetries in Bifurcations of Surface Waves: Occurence and Detection
John David Crawford, University of Pittsburgh

10:40 Synchrony and Symmetry--Breaking in Laser Arrays
Mary Silber, California Institute of Technology

11:00 Mechanism of Symmetry Creation in a Plane
Wai Chin and Celso Grebogi, University of Maryland, College Park and Ittai Kan, George Mason University

11:20 G-mode Solutions of Classical Dynamical Systems
Serge Prishepionok, Portland State University

11:40 Dynamical Systems with Cosymmetry and Bifurcation Theory
Victor I. Yudovich, Rostov State University, Russia

FRIDAY AFTERNOON, OCTOBER 16

12:00
Lunch

1:30/Ballroom I&2
IP5/Chair: Sheldon E. Newhouse, University of North Carolina, Chapel Hill
Computational Complexity and Chaos

The theory of computation originated in the 1930's with the work of logicians who were interested in questions of decidability. This work was refined and further developed in the 1960's by computer scientists who were interested in the intrinsic difficulty of solving discrete problems.

The speaker will discuss her joint work with Shub and Smale on a new theory of computation and complexity that integrates key ideas from the classical theory in a setting more amenable to problems over continuous domains. This new theory yields results in the continuous setting analogous to the pivotal classical results of undecidability and NP-completeness over the integers. For example, over the reals, the Mandelbrot set, as well as most Julia sets, are undecidable.

Lenore Blum
International Computer Science Institute
Berkeley, CA

2:30 PM - 4:30 PM
CONCURRENT SESSIONS

MS12/Magpie Room
Dynamical Problems in Theoretical Chemistry

Dynamical systems theory is concerned with the global, geometrical aspects of the dynamics of nonlinear systems. There has recently been much interest in applying this approach to the formulation and study of a variety of problems of central importance in theoretical chemistry. For example, the phenomenon of intramolecular energy flow and its manifestations in chemical kinetics and spectroscopy is very naturally studied as a problem of phase space transport. The speakers in this minisymposium are chemists who will speak on different problems with the common theme of how insight from nonlinear dynamics can be fruitfully brought to bear on problems in chemistry.

Organizers: Gregory Ezra, Cornell University and Stephen Wiggins, California Institute of Technology

2:30 Hierarchical Analysis of Molecular Spectra
Michael J. Davis, Argonne National Laboratory

3:00 Control over Molecular Motion: Issues and Paradigms
Herschel A. Rabitz, Princeton University

3:30 Local Random Matrix Models of Quantum Chaos in Many-Dimensional Systems
P.G. Wolynes, University of Illinois, Urbana-Champaign

4:00 Bifurcation Analysis of Highly Excited Molecular Spectra
Michael E. Kellman, University of Oregon, Eugene

MS13/Ballroom I&2
Stochastic Resonance

The term stochastic resonance refers to a peculiar physical phenomenon in which an increase in random noise can give rise to an improved signal-to-noise ratio. Originally put forward as an explanation for the approximate periodicity of Earth's Ice Ages, stochastic resonance involves the fundamental interplay between combined periodic and stochastic forcing of a nonlinear system. Stochastic resonance has been observed in a variety of controlled experiments, including those on optical, electrical, and mechanical systems. The speakers in this minisymposium will describe the current mathematical status of the subject, and discuss frontier issues in two areas of potential application.

Organizer: Kurt Wiesenfeld, Georgia Institute of Technology

2:30 The Theory of Stochasic Resonance
Peter Jung, University of Augsberg, Germany

3:10 Stochastic Resonance in Optical Systems
Rajarshi Roy, Georgia Institute of Technology

3:50 Stochastic Resonance. A Potential Application in Neuroscience
Frank Moss, University of Missouri, St. Louis

MS14/Wasatch Room
Recent Developments in Differential Delay Equations

This minisymposium will focus upon recent developments in the qualitative theory of time delay differential equations. Such equations arise in models in a number of scientific fields (biology, optics, electrical circuit theory, economics), and are studied using the ideas and tools of infinite dimensional dynamical systems. Methods are drawn from funtional analysis (semigroup theory), algebraic topology (degree theory, Conley index), and general techniques of dissipative systems (attractors, omega limit sets).

Organizers: John Mallet-Paret, Brown University and Roger Nussbaum, Rutgers University

2:30 Functional Differential Equations Arising from Structured Population Models
Hal L. Smith, Arizona State University

3:00 Completeness of the System of Floquet Solutions
Sjoerd Verduyn Lunel, Georgia Insitute of Technology, and Vrije Universiteit Amsterdam, The Netherlands

3:30 Discrete Waves in Systems of Delay Differential Equations
Jianhong Wu, York University, Canada

4:00 Structure of the Attractor for Delay-Differential Equations with Negative Feedback
Konstantin Mischaikow, Georgia Institute of Technology

CP11/Maybird Room
Taylor-Couette Flow

Chair: Rita Meyer-Spasche, Max Planck Institute für Plasmaphysik, Germany

2:30 Double Eigenvalues and the Formation of Flow Patterns
Rita Meyer-Spasche, Max Planck Institute fur Plasmaphysik, Germany

2:50 Connecting Double Points in Taylor Vortex Flows
John H. Bolstad, Lawrence Livermore National Laboratory

3:10 Numerical Lyapunov-Schmidt Decomposition near Mode Interactions in the Taylor-Couette Flow
John H. Bolstad, Lawrence Livermore National Laboratory and *Michael E. Henderson*, IBM Thomas J. Watson Research Center

3:30 Low Dimensional Models of Taylor-Couette Flow
Katie Coughlin and Philip S. Marcus, University of California, Berkeley

3:50 Confinement Effects in Flow between Counter-Rotating Cylinders
Randall P. Tagg, University of Colorado, Denver

4:10 Spiral Vortices in Finite Cylinders
Edgar Knobloch, University of California, Berkeley

12/Superior B Room

iase Space Reconstruction and Time Series 2

iair: Gottfried Mayer-Kress, Santa Fe Institute

30 **Chaotic System Identification Using Linked Periodic Orbits**
Stephen Hammel and James Heagy, Naval Surface Warfare Center, Silver Spring, MD

50 **Wavelet Reconstruction of Spatio-Temporal Chaos**
Gottfried Mayer-Kress, Santa Fe Institute and Ulrich Parlitz, Universität Darmstadt, Germany

10 **Nonlinear Prediction as a Way of Distinguishing Chaos from Random Fractal Sequences**
A.A. Tsonis, University of Wisconsin, Milwaukee and J.B. Elsner, Florida State University

30 **System Identification with Aperiodic and Chaotic Driving Forces**
Alfred Hubler, University of Illinois, Urbana

50 **Quantification of Recurrence Plots for Analysis of Physiologic Systems**
Joseph P. Zbilut, Rush Medical College, Chicago and VA Edward Hines, Jr. Hospital, Hines, IL and Charles L. Webber, Jr., Loyola University Medical Center, Maywood, IL

10 **On the Transferring of Chaotic, Periodic and Ergodic Properties from Subsystem to Extended Dynamical System**
Janusz Szczepanski and Eligiusz Wajnryb, Polish Academy of Sciences, Poland

30/Golden Cliff Room

offee

00/Ballroom 1&2

6/Chair: Peter W. Bates, Brigham Young niversity

plitting Separatrices and Arnol'd Diffusion

-paratrices, which are ubiquitous in Hamiltonian sys-ms, bound regions of contrasting dynamical behav-r. The separatrices generally split apart under pertur-ations of the Hamiltonian system. If the perturbation small, interesting dynamics associated with the cor-sponding homoclinic and heteroclinic intersections -velop. For instance, phase space points can travel ng distances, no matter how small the perturbation, as ng as it is non-zero (Arnol'd diffusion).

iovanni Gallavotti
epartment of Physics
niversity of Rome I, Italy

6:00 PM - 7:_ PM

CONCURRENT SESSIONS

CP13/Wasatch Room

Delay Equations

Chair: Jacques Belair, Université de Montréal, Canada

6:00 **Periodic Solutions of Differential Delay Systems**
Anatoli Fedorovich Ivanov, Ukrainian Academy of Sciences, Ukraine, and Universität Munchen, Germany

6:20 **Stability in a Delay-Differential Equation Modeling a System of Two Negative Feedback Loops**
Jacques Bélair, Université de Montréal, Canada and McGill University, Canada

6:40 **Non-Existence of Small Solutions for Scalar Differential Delay Equations**
Yulin Cao, University of Georgia

CP14/Superior B Room

Fractals and Invariant Measures

Chair: John C. Sommerer, The Johns Hopkins University

6:00 **A Fast $O(N)$ and Memory Efficient Algorithm for Box Counting**
Gerald R. Chachere, Howard University

6:20 **A Physical Fractal with a Pedigree**
John C. Sommerer, The Johns Hopkins University and Edward Ott, University of Maryland, College Park

6:40 **Approximating the Invariant Measures of Finite Dimensional Maps**
Fern Hunt, National Institute of Standards and Technology

7:00 **The Singularity Spectrum of Self--Affine Fractals with a Bernoulli Measure**
Jorg Schmeling and Rainer Siegmund-Schultze, Institute for Applied Analysis and Stochastics, Germany

CP15/Maybird Room

Homoclinic Orbits and Chaos 1

Chair: Sue Ann Campbell, Université de Montréal, Canada

6:00 **Application of Melnikov's Method to an Aeroelastic Oscillator**
Oded Gottlieb, Massachusetts Institute of Technology and Ronald B. Guenther, Oregon State University

6:20 **A Structurally Stable Double Pulse Heteroclinic Orbit**
Sue Ann Campbell, Université de Montréal, Canada

6:40 **Mel'nikov Analysis of Some Homoclinic-Heteroclinic Bifurcations of a Nonlinear Oscillator**
Mark Francis Dabbs and Peter Smith, Keele University, United Kingdom

7:00 **The Existence of Homoclinic Solutions for Autonomous Dynamical Systems in Arbitrary Dimension**
Joseph R. Gruendler, North Carolina A&T State University

8:00/Ballroom 1&2

Business Meeting

SIAM Activity Group on Dynamical Systems

SATURDAY MORNING, OCTOBER 17

7:30/Ballroom Foyer

Registration opens

8:30/Ballroom 1&2

IP7/Chair: William L. Kath, Northwestern University

Dynamical Systems Problems for the Superconducting Super Collider

Beam dynamics at the super-collider presents a challenging class of theoretical problems in dynamical systems. The central issue to understand is particle stability for roughly 10^8 revolutions around the 87 Km machine. A basic model is the single particle dynamics governed by a one-revolution 6D symplectic map composed of the 10,000 magnetic elements, or one of several Hamiltonian flow approximations to this map. Other effects are included perturbatively. Thus mathematically it is important to understand the stability of this map, the stability of its approximate flows and the effect of perturbations.

The speaker will review the status of stability investigations and the associated slow particle loss problem, discuss ensemble evolution and perturbative effects such as synchroton radiation (based on the Lorentz-Dirac Equation) and noise in the RF cavity. The latter involves a stochastic theory of adiabatic invariants and weak convergence techniques.

James A. Ellison
Department of Mathematics and Statistics
University of New Mexico, Albuquerque and SSCL, Waxahachie, TX

9:30/Golden Cliff Room

Coffee

10:00 AM - 12:00 PM

CONCURRENT SESSIONS

MS15/Magpie Room

Invariant Manifolds

In the study of dynamical systems, the theory of invariant manifolds has proven to be a fundamental and useful idea. In this minisymposium, the speakers will discuss center manifolds for reaction-diffusion equations with time delays, the existence of invariant tori for Hamiltonian systems and applications of invariant manifolds in mathematical physics.

Organizer: Kening Lu
Brigham Young University

10:00 **Stable Manifolds and Nonlinear PDEs**
Russell Johnson, Università di Firenze, Italy and University of Southern California, Yingfei Yi, Georgia Institute of Technology and Xing-Bin Pan, Zhenjiang University, People's Republic of China

10:30 **Centre Manifolds for Reaction Diffusion Equations with Time Delays**
Joseph W.-H. So, University of Alberta, Canada

11:00 **The Existence of Invariant Tori for a Class of Hamiltonian System**
Zhihong Xia, Georgia Institute of Technology

11:30 **Invariant Helical Subspaces for the 3-D Navier-Stokes Equations**
Sidney Leibovich, Cornell University; Alex Mahalov, Arizona State University; and *Edriss Titi*, University of California, Irvine and Cornell University

MS16/Ballroom 1&2

Nonlinear Optics and Hamiltonian Systems

Hamiltonian and conservative systems arise frequently in nonlinear optics, due to the low intrinsic loss rates which can be achieved in optical systems (e.g., in optical fibers). The use of dynamical systems techniques has led to new insights into the behavior occurring in such applications. This minisymposium will be comprised of presentations that illustrate how these techniques (including Hamiltonian and integrable systems methods, stability and bifurcation theory, and stochastic processes) are currently being utilized to study the dynamics of light in nonlinear optical systems.

Organizer: William L. Kath
Northwestern University

10:00 Class B Laser Oscillations
Thomas Erneux, Northwestern University

10:30 Soliton Robustness and Hamiltonian Deformations in Optical Fibers
Curtis Menyuk, University of Maryland, Baltimore County

11:00 An Unstable Modulation Theory and Optical Oscillations
David Muraki, Princeton University

11:30 Polarization Decorrelation in Randomly Birefringent Nonlinear Optical Fibers
Tetsuji Ueda, Los Alamos National Laboratory

MS17/Wasatch Room

The Dynamics for Patterns in Excitable Media

The speakers in this minisymposium will present recent results in the analytical, numerical, and experimental investigation of waves in two and three dimensional excitable media.

Organizer: James P. Keener
University of Utah

10:00 Defects, Spirals and Fibrillation
E. Meron, University of Arizona

10:30 Scroll Waves in Excitable Media
John J. Tyson, Virginia Polytechnic Institute and State University

11:00 Behavior of Vortex Filaments in Three-Dimensional Excitable Media: Results of Some Numerical Simulations
Chris Henze, University of Arizona

11:30 Dynamics of Organizing Centers in Excitable Chemical and Biological Media
Arkady M. Pertsov and Jose Jalife, State University of New York Health Sciences Center, and Michael Vinson, Syracuse University

MS18/Maybird Room
(This session will run until 12:30 PM.)

Dynamics of Mechanical Systems

The speakers in the minisymposium will concentrate on various aspects of geometrical methods in mechanics. *(Note: The following talk titles are tentative).*

Organizer: Mark Levi
Rensselaer Polytechnic Institute

10:00 Some Homoclinic Phenomena in Slowly Varying Hamiltonian Systems
Tasso Kaper, Brown University

10:30 The Resonance Phenomena in Hamiltonian Systems
Gregor Kovacic, Rensselaer Polytechnic Institute

11:00 An Overview of Random Behavior in Celestial Mechanics
Richard Moeckel, University of Minnesota

11:30 Ergodic Behavior in Mechanics of Colliding Particles
Maciej Wojtkowski, University of Arizona, Tuscon

12:00 Geometrical Ideas in Mechanics of Flexible Space Structures
Mark Levi, Organizer

CP16/Superior A Room

Control of Dynamical Systems

Chair: Bijoy Kumar Ghosh, Washington University

10:00 Analysis of a Method for Tracking Unstable Orbits in Experiments
Ira B. Schwartz, and *Ioana Triandaf*, Naval Research Laboratory, Washington, DC

10:20 A Perspective Systems Approach to Problems in Computer Vision
Bijoy Kumar Ghosh, Washington University

10:40 Using the Butterfly Effect to Direct Orbits to Targets in Chaotic Systems
Troy Shinbrot, University of Maryland, College Park

11:00 Model-based Control of Nonlinear Systems
Joseph L. Breeden and Norman H. Packard, University of Illinois, Urbana

11:20 PD High-Gain Natural Tracking Control of Time-Invariant Systems Described by IO Vector Differential Equations
William Pratt Mounfield, Louisiana State University, Baton Rouge and Ljubomir T. Grujic, University of Belgrade, Yugoslavia

11:40 Dynamics and Control of a Flexible Beam
Eric H.K. Fung, Hong Kong Polytechnic, Hong Kong

CP17/Superior B Room

Fluids 1

Chair: David Wollkind, Washington State University

10:00 Bifurcation Analysis of Turbulent Mixing Effects in the Chlorite-Iodide Reaction
Rodney O. Fox and Gholam Erjaee, Kansas State University

10:20 Roads to Turbulence in Dissipative Dynamical Systems: Amplitude Modulation as a New Road
Slobodan R. Sipcic and Alan Russo, Boston University

10:40 A Nonlinear Stability Analysis of a Unified Aerosol Model for Thin Layer Rayleigh-Benard Convection
David J. Wollkind, Washington State University

11:00 Flow-induced Liquid Crystallization and Pattern Formation in Suspensions
Andrew J. Szeri, University of California, Irvine

11:20 Navier-Stokes Equations
G. Adomian, Athens, GA

11:40 Chaotic Behavior of Convective Motions in the Solar Atmosphere
A. Hanslmeier, Universität Graz, Austria and A. Nesis, Kiepenheuer Institüt für Sonnenphysik, Germany

SATURDAY AFTERNOON, OCTOBER 17

12:00
Lunch

1:30/Ballroom 1&2
IP8/Chair: Paul Fife, University of Utah

Bifurcations and Traveling Waves in a Delayed Partial Differential Equation

The speaker will discuss cell population dynamics which there is simultaneous proliferation and maturation. The mathematical model is a nonlinear first order partial differential equation for the cell density which there is retardation in both temporal and maturation variables, and depends on three parameters. For strictly positive initial functions, there are three homogeneous solutions of biological importance: a trivial solution, a positive stationary solution, and a time periodic solution. For zero initial conditions, there are a number of different solution types depending on the theory parameters: the trivial solution, a spatially inhomogeneous stationary solution, a spatially homogeneous singular solution, a traveling wave solution, slow traveling waves and slow traveling chaotic waves. The speaker will delineate the regions of parameter space in which these solutions exist and are locally stable, and present some numerical results.

Michael C. Mackey
Departments of Physiology, Physics and Mathematics and Centre for Nonlinear Dynamics in Physiology and Medicine
McGill University, Canada

2:30 PM - 4:30 PM

CONCURRENT SESSIONS

MS19/Ballrom 1&2

Dynamics of Infinite-Dimensional Problems

The speakers in this minisymposium will discuss existence of global attractors for locally damped wave equations, connections with stabilization and complete controllability and applications in thin domains. They will also discuss lower and upper semicontinuity of attractors for continuous and discrete flows, structural stability of flows, effects of shape of domain on dynamics in PDEs, existence of rotating waves on a thin annulus, and convergence to equilibrium solutions.

Organizer: Shui-Nee Chow
Georgia Institute of Technology

2:30 Limits of Semigroups Depending on Parameters
Jack K. Hale, Georgia Institute of Technology

3:30 Attractors for Locally Damped Hyperbolic Equations
Genevieve Raugel, Université Paris-Sud, France

MS20 Magpie Room

Nonlinear Optics

Nonlinear optics is a highly diversified research field, strongly driven by the needs of modern technology. It offers the applied mathematician a marvelously rich and varied set of mathematical challenges. Perhaps best known are the problems of soliton propagation in optical fibers and the chaotic dynamics of a single-mode homogeneously broadened ring laser. However, optics offer much more to the applied mathematician.

The theme of this minisymposium is localized nonlinear structures and spontaneous pattern formation in passive and active nonlinear optical systems. Where appropriate, analogies will be made with other physical systems such as convection of fluids. The goal is to introduce problems of great current interest which are just entering the nonlinear optics mainstream. Emphasis will be placed on nonlinear pde's which arise either as initial or initial/boundary value problems. The role of imposed or nonlinearly induced spatial gratings on an optical wavelength scale, when optical waves counterpropagate in a nonlinear medium will be highlighted.

Organizer: Jerome V. Moloney
University of Arizona

2:30 **Instabilities of Counterpropagating Light Waves in Kerr and Brillouin Media**
Colin J. McKinstrie, University of Rochester

3:00 **Dynamics of Light Pulses in Periodic Structures**
Alejandro Ace[illegible]rsity of New Mexico

3:30 **Spontaneous Pa[illegible]ormation in Wide Gain Section Lase[illegible]**
Jerome V. Moloney, Organizer

4:00 **Localized States in Fluid Convection and Multi-Photon Lasers**
James A Powell, Utah State University

MS21 Wasatch Room

Neural Networks

Many scientists are now studying how the brain works and how ideas about biological intelligence can be used to solve difficult technological problems, notably problems concerning autonomous adaptive behavior in response to a nonstationary world. Neural network models are typically defined by nonlinear dynamical systems of high dimension which include multiple spatial and temporal scales. They embody many new computational ideas for solving problems in image processing, speech and language understanding, pattern recognition, nonstationary prediction, adaptive control, statistical estimation, and hypothesis testing.

The speakers in this minisymposium will describe recent results about models of learning, pattern recognition, prediction, and control.

Organizer: Stephen Grossberg
Boston University

2:30 **Saturation of Outputs for Positive Feedback Networks at High Gain**
Morris W. Hirsch, University of California, Berkeley

3:10 **Learning, Pattern Recognition, and Prediction by Self-Organizing Neural Networks**
Gail A. Carpenter, Boston University and *Stephen Grossberg*, Organizer

3:50 **Neural Networks in Control Systems**
Kumpati S. Narendra, Yale University

CP18 Maybird Room

Computational Dynamical Systems 1

Chair: Debra Lewis, University of California, [illegible]a Cruz

2:30 **Bifurcations from Symmetric Relative Equilibria**
Debra Lewis, University of California, Santa Cruz

2:50 **Conley Decomposition for Fixed Bounds on Pseudo-Orbit Deviations from True Orbits**
Douglas E. Norton, Villanova University

3:10 **An Extended System with Determined Auxiliary Vectors for Locating Simple Bifurcation Points**
Yun-Qiu Shen, Western Washington University

3:30 **Computer Generation of Symmetric Patterns**
David Kwok-wai Chung, City Polytechnic of Hong Kong, Hong Kong

CP19 Superior A Room

Physical Applications 1

Chair: Celso Grebogi, University of Maryland, College Park

2:30 **Algebraic Decay and Phase-Space Metamorphoses in Microwave Ionization of Hydrogen Rydberg Atoms**
Ying-Cheng Lai and Celso Grebogi, University of Maryland, College Park; Reinhold Blumel, University of Delaware; and Mingzhou Ding, Florida Atlantic University

2:50 **Hamiltonian Dynamical Analysis of A Basic Two-Wave Interaction in Plasma Physics**
Mark Buchanan and John J. Dorning, University of Virginia

3:10 **Tori and Chaos in a Nonlinear Dynamo Model for Solar Activity**
Ulrike Feudel, Max-Planck-Gesellschaft an der Universität Potsdam, Germany

3:30 **Thermodynamics of Dissipative Systems**
Victor Berdichevsky, Georgia Institute of Technology

3:50 **Permanence of Stochasticity Thresholds in KAM Systems**
A. Scotti and F. Zanzucchi, Università di Parma, Italy

4:10 **Control of Turbulence and Transport in the Small Tokamak TBR--1**
Ibere Luiz Caldas, Maria Vittoria A.P. Heller, Raul M. Castro, Ruy P. da Silva, Zoezer A. Brasilio, University of Sao Paulo, Brasil

CP20 Superior B Room

Fluids 2

Chair: To be announced

2:30 **Pattern Selection in Rotating Raleigh-Benard Convection in a Finite Cylinder**
H.F. Goldstein and E. Knobloch, University of California, Berkeley; I. Mercader and M. Net, Universidad Politecnica de Catalunya, Spain

2:50 **Three-Dimensional Oscillations of a Fluid Conveying Tube with Discrete Symmetries**
Alois Steindl and Hans Troger, Technical University Vienna, Austria

3:10 **Solitons on a Vortex Filament with Axial Flow**
Kimiaki Konno, Nihon University, Japan and Yoshi H. Ichikawa, National Institute for Fusion Science, Japan

3:30 **A Package for Determining Pattern Selection in Convecting Systems**
Thomas Clune, University of California, Berkeley

3:50 **Lyapunov Exponents for Hydromagnetic Convection**
Jurgen Kurths, Max-Planck-Gesellschaft an der Universität Potsdam, Germany

4:10 **Atmosphere-Ocean Models with Quasiperiodic or Stochastic Forcing**
John Brindley, University of Leeds, United Kingdom and Albert Barcilon, Florida State University

4:30 Golden Cliff Room

Coffee

5:00 Ballroom 1&2

IP9/Chair: James Keener, University of Utah

Chaos and Fractals in Physiology and Medicine

Healthy systems in physiology and medicine are remarkable for their structural and dynamical complexity. The concept of fractal growth and form offers novel approaches to understanding morphogenesis from the level of the gene to the organism. Scale-invariance and long-range power law correlations, markers of phenomena having a self-similar or fractal origin, are also features of healthy physiological processes, such as regulation of the heartbeat. The complex variability exhibited by such systems and its relation to deterministic chaos is under active investigation. Perturbation of healthy systems by diseases, drug toxicity or aging most often leads to a loss of complexity or shorter-range correlations. Nonlinear dynamics provides new ways of quantifying both healthy variability and the pathologic loss of complexity, and is providing new methods of bedside monitoring, including the prevention of sudden cardiac death.

Ary L. Goldberger
Harvard Medical School and
Beth Israel Hospital, Boston

SATURDAY EVENING, OCTOBER 17

7:30-9:30/Golden Cliff Room and Ballroom Foyer
Poster Session

Complimentary Beer/Soda/Chips

Simulation of Sustained Reaction-Diffusion Oscillations on a Massively Parallel Computer
William A. Hogan, MasPar Computer Corporation, Sunnyvale, CA and Robert F. Stetson, Florida Atlantic University

Amplitude Expansions for Instabilities in Populations of Globally-Coupled Oscillators
John David Crawford, University of Pittsburgh and Steven Strogatz, Massachusetts Institute of Technology

A Fractal Model of Diffusion in Extracellular Space (ECS) of the CNS
Thomas A. Sipes and Martin P. Paulus, University of California, San Diego

Assessing Complexity in Biological Data Sets
Martin P. Paulus, University of California, San Diego

A Slightly Nonlinear Stability Model for Driven, Dissipative Magnetohydrodynamic Systems
Wilbur F. Pierce IV, University of Washington

Bifurcation Structures of Minimal ODEs from Weighted Sobolev Projections of PDEs
Emily Stone and Michael Kirby, Colorado State University

Effect of Actuator Positions on the Performance of Ground Vehicle Systems
Faleh Al-Sulaiman and *Sadaruz Zaman*, King Fahd University of Petroleum and Minerals, Saudi Arabia

On the Characterization of Turbulence as Spatio-Temporal Chaos
Jerry F. Magnan and P.K. Jay Kumar, Florida State University

On the Fractal Nature of Human Heart Rate Variability and the Effect of Sympathetic Blockade
Yoshiharu Yamamoto and Richard L. Hughson, University of Waterloo, Canada

Parasympathetic Blockade Reduces Dynamic Complexity of Heart Rate Variability
Yoshio Nakamura, Waseda University, Japan; Yoshiharu Yamamoto, University of Waterloo, Canada; Hiroshi Sato, Machiko Yamamoto and Kazuzo Kato, The Cardiovascular Institute, Japan

Silnikov-Hopf Birfucation
Philip Hirschberg and E. Knobloch, University of California, Berkeley

Scaling in an Electroencephalogram
John E. Erdei and Elaine M. Brunsman, University of Dayton and Albert F. Badeau, Armstrong Laboratory, Wright Patterson Air Force Base

A Lax Pair for the Three-Wave Interaction of Four Waves
Filipe J. Romeiras, Instituto Superior Tecnico, Portugal

Hemapoietic Models with Delays
Joseph M. Mahaffy, San Diego State University

On Nonlinear Normal Modes: Geometrical Concepts and Computational Techniques
Jose Manoel Balthazar, Universidade Estadual Paulista, Brasil and Mario Francisco Mucheroni, Universidade Sao Paulo, Brasil

An Investigation of Transverse Effects in the Dynamics of Solid State Laser Systems
Lila F. Roberts, Georgia Southern University

Evolution of 2-D Instabilities in Circular Shear Layers
Keith Bergeron and E.A. Coutsias, University of New Mexico, Albuquerque and J.P. Lynov, Riso National Laboratory, Denmark

Arnold Sausages for the Sawtooth Circle Map
David J. Uherka, University of North Dakota, Grand Forks and David K. Campbell, Los Alamos National Laboratory

A Study of an Algorithm Using a Posteriori Error for Adaptive IIR Filters
Guoliang Zeng, Arizona State University

Lie Symmetries for Three-Dimensional Models
Ildeu de Castro Moreira and Maria Antonieta de Almeida, Universidade Federal do Rio de Janeiro, Brasil

Numerical Study of Separatrix Breaking of Adiabatic Invariants
A.R. Champneys, University of Bath, United Kingdom and P.G. Hjorth, The Technical University of Denmark, Denmark

Helicity in Hamiltonian Dynamical Systems
P.G. Hjorth, The Technical University of Denmark, Denmark; and M.E. Glinsky, Lawrence Livermore National Laboratory, Livermore CA

Bifurcations and Stability of Motions of One Mechanical System
Tatiana A. Dobrinskaya, North-Western Polytechnical Institute of St. Petersburg, Russia

Fractal Structures on the Viscous Fluid Surface
Sergei A. Chivilikhin, "Quarz" Corporation, St. Petersburg, Russia

Classification of Heteroclinic Ω-Explosion
Kazuyuki Aihara, and *Shin Kiriki*, Tokyo Denki University, Japan

On the Dynamics of Some Endomorphisms of the Plane
Indur Mandhyan, Philips Laboratories, Briarcliff Manor, NY

Nonlinear Oscillation and Chaos in Backward Four Wave Mixing
J. Li and C.J. McKinstrie, Laboratory for Laser Energetics, Rochester, NY

Invariant Manifolds in Homogeneous Chemical Kinetics
Simon J. Fraser,and Marc R. Roussel, University of Toronto, Canada

Chaotic Behavior in a "Prey-Predator" Model
Gregori Markman, Rostov State University, Russia

Motion of Energy Eigenvalue Levels
W.-H. Steeb, Rand Afrikaans University, South Africa

Minimum Energy Optimal Control for Linear Time-invariant Discrete-time Systems
Ala Al-Humadi, Embry-Riddle Aeronautical University

SUNDAY MORNING, OCTOBER 18

7:30
Buses leave for Salt Lake City tour and Mormon Temple

Cliff Lodge

SUNDAY AFTERNOON, OCTOBER

12:00
Buses return from tour

12:00/Ballroom Foyer
Registration opens

12:30-3:00
MS22/Ballroom 1&2
Inertial Manifolds and Low Dimensional Dynamics of PDEs (Part 1 of 2)

The spatiotemporal complexity of the dynamic behavior of nonlinear PDEs (and the physical systems they model) is often found to be low-dimensional, and can thus, in principle, be described by "small" sets of ODEs. Large classes of physical systems, ranging from combustion to transitional flows to nonlinear optics, fall under this category in realistic parameter regimes. Theory and computation have come together in an attempt to establish and then exploit the low-dimensional nature of the dynamics for modeling, simulation and control purposes.

The speakers in this minisymposium will present methods, algorithms and examples of this model reduction approach to spatiotemporal dynamics. They will discuss rigorous and "experimental" approaches: the theory of Inertial Manifolds, implementations of Approximate Inertial Manifolds, the Karhunen-Loeve expansion, and their interplay with modern scientific computing. The speakers will stress applications and illustrations using relevant physical models.

Organizers: Yannis Kevrekidis, Princeton University, and Edriss S. Titi, University of California, Irvine

12:30 Title to be announced
George Sell, University of Minnesota

1:00 The Meaning of Different Length Scales in Turbulent Flows
John D. Gibbon, Imperial College, United Kingdom

1:30 On Wavelet Projections of an Evolution Equation
Philip Holmes, Cornell University

2:00 Dynamical Systems Reduction Approaches
Nadine Aubry and Wenyu Lian, Levich Institute, City College of the City University of New York

2:30 Low and Not so Low Dynamical Models
Lawrence Sirovich, Brown University

1:00 PM - 3:00 PM

CONCURRENT SESSIONS

MS23/Magpie Room

Application of Dynamical Systems to Information Theory

Ideas originating in Shannon's work in information theory have arisen somewhat independently in a mathematical discipline called topological dynamics. On one hand, Shannon devised notions of entropy and channel capacity to determine the amount of information that can be transmitted through a channel. However, the question remains as how to actually do it. On the other hand, the notion of topological entropy, which turns out to be a generalization of noiseless channel capacity, was introduced to topological dynamics as an isomorphism invariant. The resulting isomorphism theory can be applied to construct finite state automata which can essentially achieve maximum channel capacity. In this mini-symposium we discuss these developments.

Organizer: Roy L. Adler
IBM Thomas J. Watson Research Center

1:00 **Application of Symbolic Dynamics to Data Storage and Transmission**
Roy L. Adler, Organizer

2:00 **Overview of the Isomorphism Theory of Symbolic Dynamics**
Jonathon Ashley, IBM Almaden Research Center

MS24/Wasatch Room

Computer Techniques for the Numerical Study of Dynamical Systems

Numerical studies are fundamental to advancement in dynamics. The speakers will address three main current research areas in which computer experiments play a major role.

Organizer: Celso Grebogi
University of Maryland, College Park

1:00 **Higher Dimensional Targeting**
Eric Kostelich, Arizona State University

1:40 **Noise Reduction for Signals from Nonlinear Systems**
Timothy Sauer, George Mason University

2:20 **When Trajectories of Higher Dimensional Systems Cannot be Shadowed**
James A. Yorke, University of Maryland, College Park

MS25/Maybird Room

Bursting Oscillations in Biological Systems

Bursting oscillations arise in a variety of biological systems including models for electrical activity in pancreatic β cells. These oscillations consist of slow alternations between a silent phase of near steady state behavior and an active phase of rapid spike-like oscillations. Numerous models have been developed to test different hypotheses for the biophysical mechanisms that underlie the bursting behavior. Methods currently being used to analyze these models include recent geometric methods from the theory of dynamical systems and singular perturbation techniques. The speakers in this minisymposium will discuss models for several bursting systems and their analysis.

Organizer: David H. Terman
Ohio State University, Columbus, and
John Rinzel,
National Institutes of Health

1:00 **Bursting Oscillations and Slow Passage Through Bifurcation Points**
Thomas Erneux, Northwestern University and Lisa Holden, Kalamazoo College

1:30 **Plateau Fractions for Models of Pancreatic β Cells**
Robert Miura, University of British Columbia, Canada

2:00 **Complex Oscillations in Insulin-Secreting Cells: On Beyond Bursting**
Arthur Sherman, National Institutes of Health

2:30 **Bursting Oscillations and Homoclinic Orbits to a Chaotic Saddle**
Xing-Jing Wang, University of Chicago

CP21/Superior A Room

Physical Applications 2

Chair: Stephen B. Margolis, Sandia National Laboratories, Livermore, CA

1:00 **A Dynamical Systems Approach to the Stability of Geophysical Features**
Sue Ellen Haupt, University of Colorado, Boulder

1:20 **Nonlinear Dynamics of Complex Two-Phase-Flow Systems: Heat Exchangers and Nuclear Reactors**
Rizwan-uddin and John J. Dorning, University of Virginia

1:40 **Some Connections Between Localization in Plasticity and in Combustion**
T.J. Burns, National Institute of Standards and Technology

2:00 **Quasiperiodicity and Chaos in a Dynamical System of Amplitude Equations Describing Gasless Combustion**
Stephen B. Margolis, Sandia National Laboratories, Livermore, CA

2:20 **Multi-Dimensional Acoustic Analysis of A Solid Propellant Rocket Motor**
Mohammad Farshchi and Mehdi Golafshani, Sharif University of Technology, Iran

2:40 **One-Dimensional Flow Analysis of a Solid Propellant Rocket Motor**
Mehdi Golafshani and Mohammad Farshchi, Sharif University of Technology, Iran

CP22/Superior B Room

Homoclinic Orbits and Chaos 2

Chair: Edgar Knobloch, University of California, Berkeley

1:00 **Horseshoe Maps with Sinks Near Homoclinic Tangencies**
Thomas L. Richards, University of North Dakota, Grand Forks

1:20 **An Analogue to the Birkhoff-Smale Homoclinic Theorem for Snapback Repellers of Entire Mappings**
Franz Rothe, University of North Carolina, Charlotte

1:40 **Transition to Chaotic Travelling Waves via a New Type of Global Bifurcation**
Edgar Knobloch, University of California, Berkeley and D.R. Moore, Imperial College, United Kingdom

2:00 **A Novel Homoclinic Bifurcation in a Hamiltonian System**
Alan R. Champneys, Alastair Spence and John F. Toland, University of Bath, United Kingdom

2:20 **Infinitely Many Sinks for a Singular Map**
David T. Closky, College of Mount St. Joseph

2:40 **Dynamical Behaviors in Kolmogrov Models**
Fude Cheng, Hubei Normal Institute, People's Republic of China

3:00/Golden Cliff Room

Coffee

3:30/Ballroom I&2

IP10/Chair: James Yorke, University of Maryland, College Park

Stationary and Turbulent Patterns in a Reaction-Diffusion System

Experiments have been conducted on a quasi-two-dimensional open chemical reactor that can be maintained indefinitely in well-defined nonequilibrium states by feeding fresh chemicals from reservoirs. Bifurcations from a uniform (nonpatterned) state to different patterns (hexagons, stripes, and a mixed state) were observed as a function of different control parameters. A further change in bifurcation parameter led to a supercritical transition from a hexagonal pattern to "chemical turbulence", which is marked by a continuous motion of the pattern within a domain and of the grain boundaries between domains. The transition from hexagons to turbulence was accompanied by a large increase in the defects in the pattern, which suggests that this is an example of defect-mediated turbulence. The speaker will discuss these results and their implications

Harry L. Swinney
Center for Nonlinear Dynamics
University of Texas, Austin

4:30/Ballroom I&2

IP11/Chair: E. Norman Dancer, Brigham Young University

Symmetric Chaos

Typically, dynamical systems with symmetry exhibit kinds of bifurcation that are different from those observed in systems without symmetry. For example, bifurcation of steady states and periodic solutions often leads to high multiplicity of such states and the breaking of symmetry. From this perspective, one expects the complexity of dynamics to increase and the amount of symmetry of an asymptotic state to decrease as parameters are varied. What is less well known is that once the dynamics of symmetric systems is chaotic, there is a trend towards the increase in symmetry of asymptotic states through collisions of conjugate attractors. This increased symmetry can be observed in systems of differential equations using time averages.

The speaker will present an overview of recent joint work with Michael Dellnitz, Mike Field and Ian Melbourne on symmetry increasing bifurcations and will discuss a number of examples from the iteration of symmetric maps to the dynamics of reaction diffusion equations.

Martin Golubitsky
Department of Mathematics
University of Houston

SUNDAY EVENING, OCTOBER 18

7:30 PM - 9:30 PM

CONCURRENT SESSIONS

MS26/Ballroom 1&2

Inertial Manifolds and Low Dimensional Dynamics of PDEs (Part 2 of 2)

(For Description, See MS 22, page 14)

Organizers: Yannis Kevrekidis, Princeton University, and Edriss S. Titi, University of California, Irvine

7:30 Numerical Schemes Based on the Algebraic Approximation of the Attractors
Ciprian Foias, Indiana University, Bloomington

8:00 Inertial Sets and Exponential Attractors for Navier-Stokes Flows
Basil Nicolaenko and Alp Eden, Arizona State University; Ciprian Foias, and Roger Temam, Indiana University, Bloomington

8:30 Spatiotemporal Behavior of Approximate Inertial Forms for the 2-D Navier-Stokes Equation
Michael S. Jolly, Indiana University, Bloomington

9:00 Numerical Study of Dynamics and Symmetry Breaking in the Wake of a Circular Cylinder
Dwight Barkley, Princeton University

MS27/Magpie Room

Signal Processing and Chaos (Part 1 of 2)

Nonlinear dynamics research has introduced several new data processing techniques as well as techniques for the study of novel behavior in dynamical systems (e.g. chaos). Several of these techniques have been developed to the point that they have application to signal processing, especially as applied to chaotic signals. The speakers will present a full spectrum of applications from software techniques for signal processing to full hardware implementation of dynamical behaviors that would be useful in communications and control.

Organizer: Louis M. Pecora, Naval Research Laboratory, Washington, DC

7:30 Processing Filtered Chaotic Signals
Steve Isabelle, Massachusetts Institute of Technology

8:00 Modeling Chaotic Systems with Hidden Markov Models
Cory Meyers, Lockheed/Sanders, Nashua, NH

8:30 Determining Robust Dynamical Maps From Observed Time Series
Reginald Brown, University of California, San Diego

9:00 Determining Minimum Embedding Dimension and Local Dimension
Matthew Kennell, University of California, San Diego

MS28/Wasatch Room

Qualitative Results for Partial Differential Equations

This minisymposium focuses on qualitative results on solutions of nonlinear partial differential equations relevant in applications. On the one side there are detailed results concerning particular solutions of the Cahn-Hilliard equation. On the other side, assertions of a general character on the asymptotics for continuous-time and discrete-time infinite-dimensional dynamical systems stemming from parabolic and elliptic equations are given. Of particular interest is the fact that in all these considerations a wide range of mathematical tools, from a-priori estimates to general principles in functional analysis, are used.

Organizers: E. Norman Dancer and Peter Hess, Brigham Young University

7:30 Nucleating Solutions for the Cahn-Hilliard Equation in Higher Space Dimension
Giorgio Fusco, University of Rome II, Italy

8:00 Equilibrium and Dynamics of Bubbles for the Cahn-Hilliard Equation
Nicholas D. Alikakos, University of Tennessee and University of Crete, Greece

8:30 Large-Time Behavior of Monotone Discrete-Time Dynamical Systems
Peter Takac, Vanderbilt University

9:00 Structural Stability of Global Attractors for Partial Differential Equations of Dissipative Type
XuYan Chen, Georgia Institute of Technology

MS29/Maybird Room

The Numerical Treatment of PDEs with Symmetry

Partial differential equations frequently possess symmetry which is related to the geometry of the spatial domain, the type of boundary conditions or the algebraic structure of the equation itself. Also they may show spatio-temporally complex processes, for instance a chaotic behavior. Recently Galerkin approximations based on proper orthogonal decompositions (PODs) of solutions have successfully been used in PDEs with symmetry in order to analyze this type of behavior numerically. We will essentially focus on two aspects: Modifications of the POD itself and how to make use of it in the numerical investigation concerning the interaction of dynamics and symmetry.

Organizer: Michael Dellnitz, Universität Hamburg, Germany

7:30 From Partial Differential Equations to Minimal Dynamical Systems
Michael Kirby, Colorado State University, Fort Collins

8:00 Detecting Symmetry Creation in PDEs
Ernest Barany, University of Houston, *Michael Dellnitz*, Organizer, and Martin Golubitsky, University of Houston

8:30 The Use of Symmetries in Dynamical Systems
Nadine Aubry and Zhen-Su Cao, City College of the City University of New York and Ricardo Lima, City College of the City University of New York and Centre National de la Recherche Scientifique, France

9:00 Non-Linear Extensions to the POD and Systems with Symmetry
Gal Berkooz, Cornell University

CP23/Superior B Room

Biological Applications 1

Chair: John Dorning, University of Virginia

7:30 Physical Modelling of the Human Circulatory System for Cardiovascular Device Testing
M. Keith Sharp, University of Utah

7:50 Dynamics of the Calcium Subsystem in Cardiac Cells
Anthony Varghese, University of Minnesota, Minneapolis; Raimond L. Winslow, Johns Hopkins University; and James E. Holte, University of Minnesota, Minneapolis

8:10 A Simple ODE Model for the Nonlinear Dynamics of the Heart Sinus Node
John J. Dorning and *Rizwan-uddin*, University of Virginia

8:30 A Transplanted Human Heart as a Deterministic Nonlinear Dynamical System
David F. Scollan, John J. Dorning, Rizwan-uddin and J. Randall Moorman, University of Virginia

8:50 A Coupled Oscillator Model for the Dynamics of a Transplanted Human Heart
John J. Dorning, Rizwan-uddin, David F. Scollan and J. Randall Moorman, University of Virginia

9:10 Investigations on a Model of Neuronal Bursting
T.I. Toth, University of Wales College of Cardiff, United Kingdom

CP24/Superior A Room

Physical Applications 3

Chair: M.S. El Naschie, Cornell University

7:30 Some Applications of Peano Dynamics in Classical and Quantum Mechanics
M.S. El Naschie, Cornell University

7:50 Dealing with Multiple Objectives in an Econometric Model
H.A. Eiselt, University of New Brunswick, Canada and C.-L. Sandblom, Technical University of Nova Scotia, Canada

8:10 Chaotic Phenomena in Communication Networks
Ashok Erramilli and Leonard Forys, Bell Communications Research, Red Bank, NJ

8:30 Physically Realizable Polynomial Systems
Anatoly P. Torokhty, St. Petersburg Institute of Transportation Engineering, Russia

8:50 Stable and Unstable Quasiperiodic Oscillations in Robot Dynamics with Delay
Gabor Stepan, Technical University of Budapest, Hungary and G. Haller, California Institute of Technology

9:10 Dynamics of Flexible Manipulators
Ali Meghdari and Mani Ghassempouri, Sharif University of Technology, Iran

MONDAY MORNING, OCTOBER 19

00/Ballroom Foyer

?egistration opens

30/Ballroom 1&2

P12/Chair: Darryl D. Holm, Los Alamos National .aboratory

.tability, Instability and Bifurcation by the nergy-Momentum Method

he energy momentum method and especially its block iagonalization properties has proven very effective or stability analysis of mechanical systems, including uids and plasmas. However, when a bifurcation and ymmetry change occurs, the method requires modifiation. The speaker will present a blowing up, or gularization procedure for such cases. He will illusate the procedure with the double spherical pendulum ı which one sees non-generic eigenvalue movement nd discuss the role of small dissipation, which can be abilizing or destabilizing.

errold E. Marsden
)epartment of Mathema ics
Iniversity of California, Berkeley

30/Golden Cliff Room

:offee

0·00/Ballroom Foyer

egistration desk closes

0:00 AM - 12:00 PM

CONCURRENT SESSIONS

'S30/Magpie Room

ew Methods of Embedding and Analysis for oisy Chaotic Data

ime series produced in an experiment where an under-ing low-dimensional dynamical system governs the utput will be contaminated with noise. Moreover, omplex systems sometimes can be described approxiiately by low-dimensional models. Indeed it may be iat some very irregular data seen in field observations in biological systems, are reasonably represented as w-dimensional, but noisy chaos.

The speakers in this minisymposium will present ome new mathematical methods of scalar time series nbedding, geometric noise reduction, and chaotic ata analysis being developed to uncover and analyze .perimental and field data produced by such systems.

'rganizer: Robert Cawley
Naval Surface Warfare Center,
Silver Spring, MD

):00 Attractor Reconstruction
James A. Yorke, University of Maryland, College Park

):30 System Reconstruction Using Embedding Techniques
Timothy D. Sauer, George Mason University

:00 Geometric Noise Reduction
Guan-Hsong Hsu, University of Missouri, Columbia

.:30 Analysis of Experimental Data
Robert Cawley, Organizer, Guan-Hsong Hsu, University of Missouri, Columbia, and Liming W. Salvino, Naval Surface Warfare Center, Silver Spring, MD

MS31/Wasatch Room

Applications of Dynamical Systems Methods in Nonlinear Optics

Comprehensive numerical simulations and theoretical investigations have recently been progressing toward better understanding of laser-matter interaction in optical fibers and resonant cavities. Laser-matter interaction dynamics involves very short time scales at which a Hamilton description is often applicable. The speakers in this minisymposium will discuss some of the mathematical and computatioinal approaches for treating coherent optical pulses at such short time scales in dynamical systems models of nonlinear optics. The minisymposium will acquaint the audience with some of the ideas and methods being employed for understanding laser-matter interaction in optical fibers and resonant cavities, by using dynamical systems models. The minisymposium is intended to complement the other dynamical systems discussions.

Mathematical and theoretical issues in laser-matter interaction will be addressed from a strongly physical motivation. The expected role of Hamiltonian dynamics, and its computability and measurability in this application will be discussed from a dynamical systems viewpoint.

Organizer: Darryl D. Holm
Los Alamos National Laboratory

10:00 Enhancement of Optical Bistability by Periodic Layering
Roberto Camassa, Los Alamos National Laboratory

10:30 Mode Dynamics in Nonlinear Optical Fibers
Alejandro Aceves, University of New Mexico, Albuquerque

11:00 Perturbation Effects on the Dynamics of a Mode and Two Sidebands in an Optical Fiber
Gregor Kovacic, Rensselaer Polytechnic Institute

11:30 Homoclinic Chaos due to Competition among Degenerate Modes in a Ring-Cavity Laser
Darryl D. Holm, Organizer

MS32/Maybird Room

Chaotic Transport for Hamiltonian Systems

Understanding the statistical properties of maps arising from Hamiltonian flows is of importance in many applications, e.g. particle confinement in accelerators and plasma devices, chemical reaction rates, and fluid mixing. Recent advances have led to a new picture of transport processes in two dimensions. Successes of the theory include results on universality of onset of transport, long time correlation decay and a-priori estimates of transport rates.

Application to higher dimensions has proved more difficult. Some progress has made for the nearly separable case but the general theory remains to be constructed. The speakers will discuss some of the successes and the work that remains to be done.

Organizer: James D. Meiss
University of Colorado, Boulder

10:00 Chaotic Transport in Symplectic Maps
James D. Meiss, Organizer

10:30 Transport in Two and Four Dimensions
Robert W. Easton, University of Colorado, Boulder

11:00 The Birkhoff Signature: Identification and Applications
Vered Rom-Kedar, University of Chicago and The Weizmann Institute of Science, Israel

11:30 Phase Space Structure Near Resonant Equilibria of 3 Degree-of-freedom Hamiltonian Systems
Stephen R. Wiggins, California Institute of Technology

MS33/Ballroom 1&2

Signal Processing and Chaos (Part 2 of 2)

(For Description see MS 27, page 16)

Organizer: Louis M. Pecora
Naval Research Laboratory,
Washington, DC

10:00 Attractor Reconstruction, Data Filtering, and Ill-Posed Problems
Louis M. Pecora, Organizer

10:30 Building Synchronizing Chaotic Circuits
Thomas Carroll, Naval Research Laboratory, Washington, DC

11:00 Using Strange Attractors
Hal Fredericksen, Naval Postgraduate School

11:30 Tracking Unstable Periodic Orbits in Experiments: A New Continuation Method
Ira B. Schwartz, Naval Research Laboratory, Washington, DC

CP25/Superior A Room

Computational Dynamical Systems 2

Chair: Donald L. Hitzl, Lockheed Research Laboratory, Palo Alto, CA

10:00 Transient Perturbations Prior to Instability in Periodically Excited Oscillators
Lawrence Virgin, Phil Bayly and Kevin Murphy, Duke University

10:20 Numerical Experiments in Noise Reduction and Attractor Restoration
Donald L. Hitzl and Legesse Senbetu, Lockheed Research Laboratory, Palo Alto, CA

10:40 Thermodynamics of Duffing's Oscillator
Akif Ozbek and Victor Berdichevsky, Georgia Institute of Technology

11:00 General Theory of Higher-order Decomposition of Symplectic Integrators
Masuo Suzuki, University of Tokyo, Japan

CP26/Superior B Room

Biological Applications 2

Chair: Jack Dockery, Montana State University

10:00 Modifications to a Model of Chaotic Dopamine Neurodynamics
E. Jeffrey Sale, A. Douglas Will, Jeffrey M. Tosk and Stephen H. Price, Loma Linda University Medical Center

10:20 Block Copolymers and the Visual Cortex: the Striped Pattern
Monica Bahiana, Federal University of Rio de Janeiro, Brasil

10:40 Analysis of a Double Porosity Bioreactor Model
Jack Dockery and Curt Vogel, Montana State University

11:00 Some New Observations on the Classical Logistic Equation with Heredity
S. Roy Choudhury, University of Central Florida and Jay I. Frankel, Florida Institute of Technology

11:20 Planting and Harvesting for Pioneer-Climax Models
James F. Selgrade, North Carolina State University

11:40 On the Bifurcation of Positive Solutions Arising in Population Genetics
Nickolaos Stavrakakis, National Technical University, Greece

12:00 Conference Adjourns

BY CAR

From the Airport

Snowbird is located 29 miles (40 minutes) from Salt Lake City International Airport.

Take Inter tate 80 east to Interstate 215 south. Interstate 215 swings east toward the Wasatch Mountains. Exit at 6200 South Street making a right turn at the light. Follow this road up the hill to Wasatch Blvd. and on toward Little Cottonwood Canyon, following the signs to Snowbird and Alta.

From Downtown Salt Lake City

Snowbird is 25 miles (30 minutes) from downtown Salt Lake City

Take Interstate 15 south to Interstate 215 east and exit at 6200 South Street. Make a right turn at the light. Follow this road up the hill to Wasatch Blvd. and on toward Little Cottonwood Canyon, following the signs to Snowbird and Alta.

PUBLIC TRANSPORTATION FROM THE AIRPORT

Canyon Transportation Inc. is a shuttle service that transports passengers between the airport and Snowbird. YOU MUST MAKE RESERVATIONS IN ADVANCE. You can do this by either filling out the transportation form in the back of this brochure, calling Canyon direct at 1-800-255-1841 or making your transportation reservations with Snowbird's Central Reservations Office when making your lodging reservations. If you are making a reservation by phone, please be sure to include the date of arrival, your last name, the airline you are using, the flight number, time of arrival and the lodge that you are staying in at Snowbird. If you are using the registration card, mail to: Canyon Transportation, P.O. Box 1762, Sandy, Utah 84091.

Once you arrive at the airport, proceed to the ground transportation desk (Canyon Transportation Inc.) located in the baggage claim area of the airport. The cost of the shuttle service is $14.00 per person each way with a minimum of 2 people in a van. If you are arriving late or leaving early, and there are no other passengers, the cost to you would be $28.00 because you must pay the minimum of 2 passenger ($14 x 2 min.). You do not have to pay in advance when making your reservation. All payments are made at the time you confirm your reservation at the Ground Transportation Desk at the airport. Canyon Transportation accepts American Express, VISA and Mastercard as forms of payment for services. Snowbird is approximately 29 miles (40 minutes) from the airport. Canyon Transportation Inc. hours of operation are as follows:

Salt Lake City Airport to Snowbird	9:00 AM - 9:00 PM daily
Snowbird to Salt Lake City	7:00 AM - 7:00 PM daily

You must confirm your reservation for departure from Snowbird to the airport with Canyon Transportation 24 hours prior to your scheduled departure.

The average one way cost of a cab to or from Snowbird is approximately $50.00.

CAR RENTAL

Dollar Rent A Car has been selected as the official car rental agency for the SIAM Conference on Dynamical System. The following rates will apply to cars rented at the airport:

Type of Car	Daily Rate	Weekly Rate
Compact	$32.00	$160.00
Intermediate	$33.00	$165.00
Standard	$33.00	$165.00
Luxury	$41.00	$225.00

CAR RENTAL RESERVATIONS

You can make a reservation for car rental by calling (toll free):

800-800-4000
from points in the United States and
800-421-6868
from points in Canada

From points outside the United States and Canada, send your reservation by fax to:

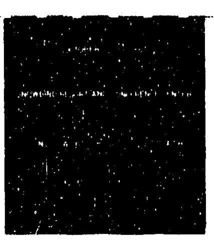
213-641-1111
Attn: Karen Bell
c/o Dollar Rent A Car

Make sure to give the SIAM account code **CCSIA1**, and mention that you are attending the SIAM Conference on Dynamical Systems, October 15-22, 1992, at Snowbird, Utah.

Please make your car rental reservations in advance as on-site availability cannot be guaranteed.

CONDITIONS FOR CAR RENTAL

1. Rates are valid from October 8 - 22, 1992, inclusive. Cars are available at the airport location and should be picked up and dropped off at the same location.
2. You must be 21 years of age and have a valid U.S. or International Driver's License.
3. You must have one of the following credit cards to rent a car: American Express, MasterCard, VISA or Diner's Club.
4. The prices quoted do not include refueling service, tax optional collision and loss damage waiver (LDW and CDW), and optional personal accident insurance.
5. Dollar Rent A Car offers free unlimited mileage with every rental.
6. Daily rates apply to 1-4 day rentals, weekly rate apply to 5-7 day rentals.



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Sandy, Utah 84091

I am attending the SIAM Conference on Dynamical Systems at Snowbird Resort and Conference Center and am requesting a reservation for shuttle pick up based on the following information:

Name ______ FIRST ______ MIDDLE ______ LAST

Address ______

City ______ State ______ Zip ______

Phone ______ Fax ______

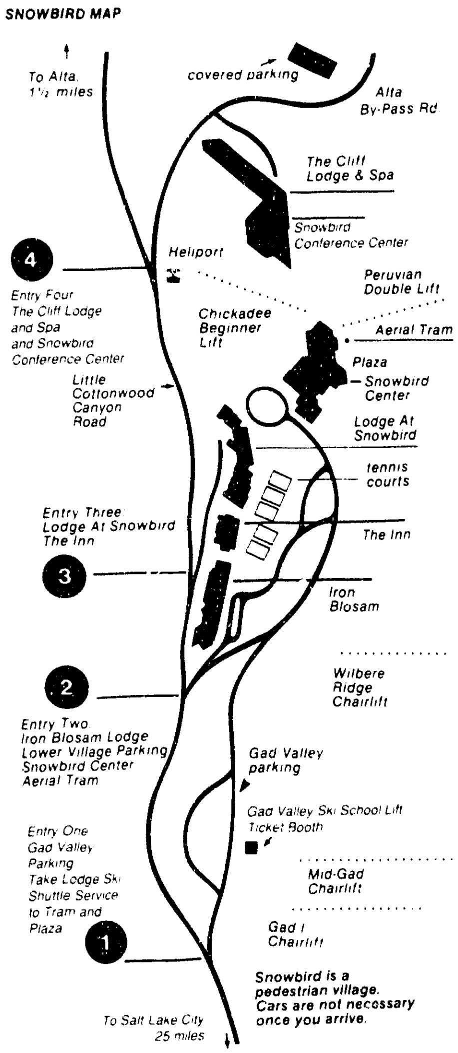
The airline I will be using is ______ Flight # ______

Arrival Date ______ Arrival Time ______ Departure Date ______ Departure Time ______ Departure Flight # ______

I will be staying at the ❑ Cliff Lodge ❑ Lodge/Inn

I will pay for my reservation at the time that I check in at the Canyon Transportation Desk located in the baggage claim area of the airport. I understand the fa to be a maximum of $28.00 if there is only one person in the van and $14.00 if there is more than one person.

Detach form and mail to: CANYON TRANSPORTATION, Reservations, P.O. Box 1762, Sandy, Utah 84091



HOTEL INFORMATION

Snowbird Resort and Conference Center
Snowbird, Utah 84092-6019
Telephone: (801)742-2222
Fax: (801)742-3204

SIAM is holding a block of rooms at Snowbird on a first come first served basis at the following discounted rates until September 21, 1992:

Cliff Lodge	\$60.00 Single or Double
Lodge/Inn	\$63.00 Studio Efficiency
Dormitory rooms	\$21.00 per person (4 in a room)

There is a 9.25% occupancy tax that will be added to your room rate.

These rooms are being held for our exclusive use until September 21, 1992, after this date reservations will depend on availability and the above rates may not be in effect. We urge you to make your reservations as soon as possible. You may do so by telephoning (800)453-3000, or filling out and returning the attached Hotel Reservation Form found on the inside back page of this brochure. You must mention that you are attending the SIAM Conference on Dynamical Systems in order to receive the discounted room rates. A deposit in the amount of one night's room rate is required when making a reservation.

Cliff Lodge Rooms: Set up like a full service modern hotel with outdoor swimming pool, hot tubs, health spa and two queen beds.

Lodge/Inn Studio/Efficiencies: Rustic living room with kitchen facilities, fireplace (in most) and walkout balconies. These rooms do not have separate bedroom.

Sofa beds are located in the living room of the studios and wall beds in the efficiencies. There is a limited number of these rooms available.

Dormitory Rooms: DUE TO THE LIMITED NUMBER OF ROOMS AVAILABLE, YOU MUST BE A STUDENT IN ORDER TO RESERVE THESE ROOMS. Rooms are located in the Cliff Lodge and there are 5 rooms available with 4 people per room. These are non-smoking rooms. There is a private bathroom in each room. Common areas located at end of the hall are equipped with televisions and pool tables. When registering for a room please be sure to mention your gender. You will be asked to show your student I.D. before checking into rooms.

If your first choice in rooms is not available, a reservation will then be made for you in the Cliff Lodge.

Cancellations: To obtain a refund of a deposit, reservations must be cancelled before 4:00 PM and at least 48 hours prior to scheduled arrival date.

Arrivals and Departures: To check in at Snowbird you should report to either the Cliff Lodge or the Lodge/Inn depending on the room you have reserved. The technical sessions will be held in the Cliff Lodge. Check-in at either location is 4:00 PM and check out is 11:00 AM.

Facilities: Each lodge is equipped with saunas and at least one all-season swimming pool. The Cliff Spa occupies the 9th and 10th floors of the Cliff Lodge and offers numerous services: massages, aerobics and weight room. Spa facilities are available to guests 16 years of age and older. A children's pool is available on Level B. A wide variety of shops and boutiques are available in the Snowbird Center and the Cliff Lodge. There are five tennis courts at Snowbird. Court time is \$8.00 per hour. Hotel guests receive their first hour of court time per day at \$4.00. For those who enjoy hiking, maps of the Snowbird area are available at the Activities Center. Guides are available by appointment. Mountain bikes are available for rental. Bring a lunch and pedal along at 8,000 feet. Helmets and water bottles are included with your rental.

Parking: There is complimentary valet parking available at the Cliff Lodge.

Restaurants: The Mexican Keyhole serves breakfast, lunch and traditional Mexican dinners and drinks. Elegant dining can be found in the Aerie, a glass enclosed rooftop restaurant with views of the mountains on all sides. There are also a variety of other restaurants and lounges located in the Snowbird Village.

Weather: The average temperature at Snowbird for October ranges between 30 and 50 degrees.

SIAM Conferences, Meetings, Symposia, Tutorials, and Workshops

Sponsored by the Society for Industrial and Applied Mathematics

1992

September 17-19 1992
SIAM Conference on Control and Its Applications
Radisson Hotel Metrodome, University of Minnesota, Minneapolis, MN

Sponsored by SIAM Activity Group on Control and Systems Theory

Organizers: Kevin Grasse, University of Oklahoma, Norman; Andre Manitius, George Mason University; and Eduardo Sontag, Rutgers University

September 21-23 1992
SIAM Workshop on Evolution of Phase Boundaries and Microstructure
Xerox Training Center
Leesburg, VA

Organizer: Robert V. Kohn, Courant Institute of Mathematical Science, NYU

October 15-19, 1992
SIAM Conference on Applications of Dynamical Systems
Snowbird Conference Center
Snowbird, UT

Sponsored by SIAM Activity Group on Dynamical Systems

Organizers: Peter W. Bates, Brigham Young University, and Christopher K.R.T. Jones, Brown University

1993

January 25-27, 1993
Fourth ACM-SIAM Symposium on Discrete Algorithms (SODA)
Omni Austin Hotel, Austin, TX

Abstract deadline: 7/14/92

Organizer: Vijaya Ramachandran, University of Texas, Austin

March 21-24, 1993
Sixth SIAM Conference on Parallel Processing for Scientific Computing
Marriott Hotel, Norfolk, VA

Sponsored by SIAM Activity Group on Supercomputing

Abstract deadline: 9/14/92

Organizer: Richard F. Sincovec, Oak Ridge National Laboratory

April 19-21, 1993
SIAM Conference on Mathematical and Computational Issues in the Geosciences
Hyatt Regency Hotel, Houston, TX
Sponsored by SIAM Activity Group on Geosciences

Abstract deadline: 10/5/92

Organizer: James Glimm, State University of New York at Stony Brook

June 7-10, 1993
SIAM Conference on Mathematical and Numerical Aspects of Wave Propagation Phenomena
University of Delaware, Newark, DE

Abstract deadline: 11/13/92

Organizer: Ralph Kleinman, University of Delaware

July 12-16, 1993
SIAM Annual Meeting
Wyndham Franklin Plaza Hotel
Philadelphia, PA

Abstract deadline: 1/15/93

August 4-6, 1993
SIAM Conference on Simulation and Computational Probability
Cathedral Hill Hotel
San Francisco, CA

Abstract deadline: 1/22/93

Organizer: Peter W. Glynn, Stanford University

August 16-19, 1993
Third SIAM Conference on Linear Algebra in Signals, Systems and Control
University of Washington, Seattle, WA

Abstract deadline: 1/29/93

Organizers: Biswa N. Datta, Northern Illinois University and John G. Lewis, Boeing Computer Services, Inc.

October 25-29, 1993
Third SIAM Conference on Geometric Design
Seattle, WA (tentative)

Sponsored by SIAM Activity Group on Geometric Design

Abstract deadline: 3/22/93

Organizers: Robert E. Barnhill, Arizona State University, and Rosemary E. Chang, Silicon Graphics Computer Systems

July 25 - 29, 1994
SIAM Annual Meeting
Sheraton Harbor Island, San Diego, Ca

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FOR MORE INFORMATION, PLEASE CONTACT:
SIAM Conference Coordinator
3600 University City Science Center
Philadelphia, PA 19104-2688
Phone: (215)382-9800 / Fax: (215)386-7999 / E-mail: meetings@siam.org

05/92

REGISTRATION INFORMATION

The registration desk will be located in the Cliff Lodge lobby in front of Ballroom 1&2. The registration desk will be open as listed below:

Wednesday, October 14	6:00 PM - 8:00 PM
Thursday, October 15	7:45 AM - 4:30 PM
Friday, October 16	7:30 AM - 4:30 PM
Saturday, October 17	7:30 AM - 4:30 PM
Sunday, October 18	12:00 PM - 4:30 PM
Monday, October 19	8:00 AM -10:00 AM

Please complete the Advance Registration Form on the inside back cover and return it with your payment to SIAM in the enclosed envelope. We urge attendees to register in advance as the registration fees are lower for advance registrants. Your advance registration form and payment must arrive at the SIAM office by October 2nd. Attendees whose registration is received at SIAM after October 2nd will be required to pay the difference between Advance and On-site registration fees at the conference.

Registration Fees:

	SIAG/DS	SIAM Member	Non Member	Student
Advance	$120	$125	$155	$25
On-site	$150	$155	$185	$25

Non-SIAM Members

Non-member registrants are encouraged to join SIAM in order to obtain the member rate for conference registration and enjoy all the other benefits of SIAM membership.

There will be no prorated fees. *No refunds will be issued once the meeting has started.*

Advance fee expires on October 2, 1992. Payments postmarked after October 2 will be on-site fee.

On-site registration starts October 14. If your payment has not reached the SIAM office by October 14, you will be asked to register and remit the on-site fee. Should your payment arrive in the SIAM office after October 14, that payment will not be processed; checks will be returned and credit card information destroyed.

Telephone Messages

The telephone number of the Snowbird Resort and Conference Center is 801-742-2222. Snowbird will either connect you with the SIAM registration desk or with the attendees guest room where you can leave a message.

Credit Cards

SIAM accepts VISA, MasterCard and American Express for the payment of registration fees, special events, membership and book orders. When you complete the Advance Registration Form, please be certain to indicate the type of credit card, the account number and the expiration date.

SIAM Corporate Members

Non-member attendees who are employed by the following institutions are entitled to the SIAM member rate.

Amoco Production Company
AT&T Bell Laboratories
Bell Communications Research
Boeing Company
BP America
Cray Research
E.I. du Pont de Nemours & Company
Eastman Kodak Company
Exxon Research and Engineering Company
General Motors Corporation
GTE Laboratories, Inc.
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IBM Corporation
ICASE
IDA Center for Communications Research
IMSL, Inc.
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MacNeal-Schwendler Corporation
Martin Marietta Energy Systems
Mathematical Sciences Research Institute
NEC Research Institute
Supercomputing Research Center,
a division of Institute for Defense Analysis
Texaco, Inc.
United Technologies Corporation

GET-TOGETHERS

SIAM Welcoming Reception
Wednesday, October 14, 1992
6:30 PM - 8:30 PM
Golden Cliff Room
(Level B of Cliff Lodge)
Cash Bar and mini hors d'oeuvres.

Business Meeting
SIAM Activity Group on Dynamical Systems
Friday, October 16, 1992
8:00 PM - 9:00 PM
Ballroom 1&2
Anyone interested in the activity group is welcome to attend.

Poster Session
Saturday, October 17, 1992
7:30 PM - 9:30 PM
Golden Cliff Room
(Level B of Cliff Lodge)
Come and talk with your colleagues and enjoy complimentary beer, sodas and chips.

Trip to Salt Lake City and Mormon Temple (Tabernacle Choir)
Sunday, October 18, 1992
7:30 AM - 12:00 Noon
Board buses in front of Cliff Lodge at 7:45 AM. You will enjoy a continental breakfast while a guide offers a description of Little Cottonwood Canyon. This canyon played a significant part in the settling of the Salt Lake Valley. Today, the canyon is home to a gigantic genealogical records vault which is carved in the granite walls that line the canyon. Little Cottonwood is also home to two major ski resorts. Once in Salt Lake, which is an hour's drive from Snowbird, you will stop at Historic Temple Square for the live radio broadcast of the Mormon Tabernacle Choir. Following the broadcast, you will visit the Capitol and Beehive House, city founder Brigham Young's home. You will be served refreshments on your trip back to Snowbird. Cost $25.00

CONF-921037--Absts.

SIAM Conference on APPLICATIONS OF DYNAMICAL SYSTEMS

Sponsored by SIAM Activity Group on Dynamical Systems

OCTOBER 15 - 19, 1992
SNOWBIRD RESORT AND CONFERENCE CENTER
SNOWBIRD, UTAH

ABSTRACTS AND AUTHOR INDEX

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ABSTRACTS: MINISYMPOSIA AND CONTRIBUTED PRESENTATIONS *(in session order)*

MS 1

The Painlevé Transcendents in Nonlinear Mathematical Physics

It is becoming increasingly evident, that the classical Painlevé transcendents play in nonlinear physics the same role that the usual special functions (such as Airy function, Bessel function etc.) play in linear problems. Moreover as for the usual special functions it is possible to derive explicit connection formulae for the Painlevé transcendents. An idea about the relevant method -- the isomonodromy method -- will be presented together with the review of the recent applications of the Painlevé transcendents in quantum field theory.

Alexander R. Its, Department of Mathematics and Computer Science, Clarkson University, Potsdam, New York 13699-5815

Steepest descent method for oscillatory Riemann-Hilbert problems with applications to dynamical systems.

We describe a new and general approach to analyzing the asymptotics of oscillatory Riemann-Hilbert problems, of the kind that arise in the theory of integrable nonlinear wave equations. We illustrate our method by describing the long-time asymptotics of the modified Korteweg-deVries equation, the nonlinear Schrodinger equation, and the autocorrelation function of the transverse Ising chain at the critical magnetic field.

P. Deift, Courant Institute, New York University
251 Mercer Street
New York, N.Y. 10012

X. Zhou, Yale University
Box 2155, Yale Station
New Haven, CT 06520

Statistical Critical Phenomena in a Near-Integrable Discrete Sine-Gordon Lattice

This lecture concerns many degree-of-freedom, near-integrable Hamiltonian Systems that exhibit non-recurrent behavior. We combine integrable theory and diagnostics with statistical measures (Lyapunov exponents, spectral entropy) to study transitions from recurrence to stochasticity in a discrete sine-Gordon system. First we show that various statistical transitions coincide with resonance of integrable instabilities and associated homoclinic-orbits. Then we focus on observable energy transport due to resonance of these integrable "whiskered tori", returning full circle to the original Fermi-Pasta-Ulam intention: to measure finite rates of nonlinear diffusion toward equipartition of energy.

M. Gregory Forest, Christopher G. Goedde, Amarendra Sinha, Department of Mathematics, Ohio State University, Columbus, Ohio 43210

Recent Progress on a Long-Distance and High-Bit-Rate Optical Soliton Communication System

The mathematical background of the modeling of long-distance and high-bit-rate optical soliton communication will be discussed. The objective is to develop methods of controlling some of the optical soliton properties under the presence of perturbations. Historical developments and recent progress will also be covered, including especially a system using periodic amplification and properly designed band-pass filters. A recent experiment at AT&T Bell Labs by the Mollenauer group has achieved an error-free transmission at 2.5 Gbit/s over 14,000 Km.

Yuji Kodama, Department of Mathematics, Ohio State Univeristy, Columbus, Ohio 43210

MS 2

Rotation Intervals for Diffeomorphisms of the Plane

Chaotic invariant sets for planar maps typically contain periodic orbits whose stable and unstable manifolds cross in grid-like fashion. Consider the rotation of orbits around a central fixed point. The intersections of the invariant manifolds of two periodic points with distinct rotation numbers can imply complicated rotational behavior. We discuss, in particular, situations in which all rotation numbers between those of the two given orbits are represented.

Kathleen T. Alligood
Department of Mathematical Sciences
George Mason University
Fairfax, VA 22030

Periodic Orbits Created by Rigid Rotation

Glen R. Hall, Boston University

No abstract submitted at press time.

Fixed Points in the Plane and Rotation Numbers

Rotation behavior, as measured by rotation numbers and rotation vectors, provides a wealth of qualitative information for dynamics in one and two dimensions. We will examine why moving from two to three dimensions (three to four for flows) precludes the usefulness of rotation vectors. In low dimensions rotation numbers force the existence of periodic orbits and even of horseshoes. Besides rotation number theory, the main tools are the Brouwer Translation Lemma and the Thurston-Nielsen classification of surface maps. We will discuss applications to nonlinear oscillators, computations of global entropy, closed geodesics, and "toroidal chaos".

Richard Swanson
Department of Mathematical Sciences
Montana State University
Bozeman, MT 59717

A Poincaré-Birkhoff Theorem for Dissipative Maps of the Plane

The classical Poincaré-Birkhoff Theorem asserts the existence of two periodic orbits of each rational rotation number strictly between the boundary rotation numbers for an area preserving homeomorphism of the annulus. We will discuss an analogous theorem that holds in certain types of one-dimensional invariant sets, including the closure of an unstable manifold of a hyperbolic saddle and the plane separating attractors that arise in periodically forced oscillators. The methods employed in this investigation include index theory and topological techniques on irreducible continua. These ideas apply to a wide range of dissipative systems in the plane.

Marcy Barge
Department of Mathematics
Montana State University
Bozeman, MT 59717

MS 3

Global Solutions and Shock Waves for the Riccati Partial Differential Equations of Nonlinear Optimal Control

The derivation and analysis of the Riccati partial differential equation for optimal control has been recently developed in a series of papers and announcements. In addition to finite escape time, which already is an issue for linear quadratic problems, the existence of shock waves for solutions of these Riccati partial differential equations is the principle object of the nonlinear analysis and is known to be the only obstruction to the "off-line" characterization of optimal feedback laws. The purpose of this talk is to illustrate, in a simple optimal control problem, the use of Riccati partial differential equations which, in this case, reduces to the inviscid Burgers' equation. One rather interesting aspect of this analysis is the development of a variational interpretation of the Burgers' equation, quite similar to the variational interpretation of the Riccati ordinary differential equation in linear quadratic theory; viz., that the existence of unique optimal control laws, the existence of global solutions of the Riccati partial differential equation and convexity of the constraint on the terminal state are mutually equivalent. Also illustrating these concepts and the existence of shock waves for a nonconvex terminal constraint.

Christopher I. Byrnes
School of Engineering and Applied Science
Washington University
1 Brookings Drive
Campus Box 1163
St. Louis, MO 63130

On the Nonlinear Dynamics of Kalman Filtering

In this talk we report on some work (joint with C. I. Byrnes and Y. Zhou) which addresses a fundamental open problem in linear filtering and estimation, viz. what is the steady-state or asymptotic behavior of the Kalman filter, or the Kalman gain, when the observed stationary stochastic process is not generated by a finite-dimensional stochastic system, or when it is generated by a stochastic system having linear dimensional unmodelled dynamics. For example, some time ago Kalman pointed out that the usual positivity conditions assumed in the classical situation are not in fact necessary for the Kalman filter to converge. Using a "fast filtering" algorithm, which incorporate the statistics of the observation process as initial conditions, (rather than coefficient parameters) for a dynamical system, this question is analyzed in terms of the phase portrait of a "universal" nonlinear dynamical system. This point of view has additional advantages as well, since it enables one to use the theory of dynamical systems to study the sensitivity of the Kalman filter to (small) changes in initial conditions; e.g. to change in the statistics of the underlying process. This is especially important since these statistics are often either approximated or estimated. In our work, for a scalar observation process we derive necessary and sufficient condition for the Kalman filter to converge, using methods from stochastic systems and from nonlinear dynamics - especially the use of stable, unstable and center manifolds. We also show that, in nonconvergent cases, there exist periodic points of every period $p, p \geq 3$ which are arbitrarily close to initial conditions having unbounded orbits - rigorously demonstrating that the Kalman filter can also be "sensitive to initial Conditions".

Anders Lindquist
Department of Optimization & Systems Theory
Royal Institute of Technology
Lindstedtsvagen 30
Stockholm 10044, Sweden

Nonholonomic Systems and Control

In this talk we describe some joint work with Peter Crouch on the dynamics and control of nonholonomic mechanical systems on Riemannian manifolds. We describe a general formulation for such systems which incorporates the controls, the constraints and constants of motion, thus naturally incorporating symmetries in the problem. We discuss the notions of kinematic and dynamics nonholonomic control system and the role of forces in the dynamic case. We also present a reduction scheme and discuss optimal control.

Anthony M. Bloch
Department of Mathematics
Ohio State University
Columbus, OH 43210

&

Peter E. Crouch
Department of Systems Science & Engineering
Arizona State University
Tempe, AZ 85287

Universal Observability of Dynamic Systems

An observed dynamical systems is a dynamical system paired with a real valued function defined on its state space, $\dot{x} = f(x)$, $x(t) = x_0$ and $y(t) = h(x(t))$. The basic question is whether or not x_0 can be recovered from knowledge of $y(t)$. This question is often replaced by the question of whether or not $y(t)$ distinguishes orbits of the dynamic system. Most systems are observed by some class of functions $h(x)$ and it was assumed that given any dynamical systems there would be some function that would fail to distinguish the orbits of the system. It was a great surprise when the late Douglas McMahon produced a dynamical system on a three dimensional manifold that was observable by every non-constant continuous real valued function. Considerable work has gone into the problem of determining if any other such systems exist. It was shown by Byrnes, Dayawansa and Martin that if such a system exists in two dimensions then the domain of the system must be the two torus and at this point it remains an open question of whether or not there exists a universally observable dynamical system on the torus. McMahon's example is special to three dimensions and to this point all other examples have been constructed using McMahon's example. This talk will outline the state of the research on this problem.

W. P. Dayawansa
Systems Research Center
University of Maryland
College Park, Maryland
Alisa DeStefano
Department of Mathematics
Dartmouth College
Dartmouth, New Hampshire
Clyde Martin
Department of Mathematics
Texas Tech University
Lubbock, Texas

MS 4

Comparison of Deterministic and Stochastic SI Models

Deterministic differential equation models for the spread of HIV have had to account for stages of infection, variable infectivity, long incubation periods, death from the disease (and therefore, variable population sizes), and complex population mixing patterns. We have begun studying stochastic analogues of such models, beginning with models which include disease related deaths and variable population size. Comparisons of models will be made.

Carl Simon
Department of Mathematics and Economics
412 Lorch Hall
University of Michigan
Ann Arbor, MI 48109

John Jacquez
Department of Physiology
University of Michigan
Ann Arbor, MI 48109-0622

The Importance of Interregional Mobility for Infectious Disease Spread in Bounded Geographic Areas

The mobility of humans in the course of their daily activities is an important factor influencing patterns of disease spread. This paper presents a model for the transmission of measles in a bounded geographic region. The model represents patterns of human mobility by a mobility matrix. An actual mobility matrix is estimated using data from the Caribbean island of Dominica. This matrix is used in a simulation of measles transmission on the island. Results from the model are compared to prevalence data from a 1984 epidemic of the disease to evaluate the adequacy of mathematical models in describing disease transmission patterns in a geographic region.

Lisa Sattenspiel
Department of Anthropology
200 Swallow Hall
University of Missouri
Columbia, MO 65211

Implication of Network Structure for Epidemic Dynamics

Computer simulations were used to examine the effect on the dynamics of an HIV epidemic of the transmission network's structure. The goals were to measure inter-population and intra-population variability in the time from the initial introduction of the disease into the population to infection, and to then predict this with static network analysis. Stochastic fluctuations account for 25 percent of the variability in time to infection. The extent of clustering in a network had a significant effect on disease spread; a three fold difference was found between the average infection time in a random network and in a network with realistic clustering. Several static analysis methods were considered for predicting individuals' infection time. The best method, an averaging method based on the shortest path algorithm, predicted over 60 percent of the variability in every network and over 80 percent within clustered networks. By contrast, the total contact rate for an individual was a poor predictor of infection time. The results indicate that epidemic projections and parameter estimatiom must take network structure into account and that averaging methods may be used to predict the dynamics of the infection process.

Michael Altmann
University of Minnesota
Box 511 UMHC
420 Delware St. SE
Minneapolis, MN 55455

Social Mixing Patterns and the Spread of AIDS

Heterosexual sexual contacts are the primary reason for the spread of AIDS worldwide, and heterosexual spread is of growing concern in the United States. As models have demonstrated for homosexual populations, the pattern of sexual contacts created by social structures is one of the primary factors determining the pattern of heterosexual spread. Sexual behavior surveys indicate that men and women are distributed differently by sexual contact rates, and the amount of contact across risk groups may be different as well for the two sexes. For example, in populations where most high-risk women are prostitutes, male partners of high-risk women may themselves primarily come from fairly low partner-acquisition rate groups, while female partners of the high-risk men may primariliy be high-risk women. Age-structures of contacts are equally as important as risk-structures in determining the spread rate of the epidemic, and play a key role in determining the number of infected children born.
This talk will present a mixing formulation for two sexes, and describe some of the contact patterns which can occur between differently distributed male and female populations across both age and risk. It will highlight differences between homosexual and heterosexual spread of AIDS when mixing is highly biased, using asymptotic expansions to examine the behavior of transmission models in these two populations as the mixing width narrows.

E. Ann Stanley
Department of Mathematics
Iowa State University
Ames, IA 50011

CP 1

Numerical Computation of Homoclinic Orbits

For $\dot{x} = f(x, \lambda)$, $x \in \mathbb{R}^n$, $\lambda \in \mathbb{R}$, having a hyperbolic equilibrium $p(\lambda)$, we study the numerical computation of parameter values λ^* at which there is a homoclinic orbit. We approximate λ^* by solving a finite-interval BVP on $[-T, T]$, with boundary conditions that say $x(-T)$ and $x(T)$ are in appropriate linearized invariant manifolds of $p(\lambda)$. If the solution of this BVP is $(x_T(t), \lambda_T)$, and if the eigenvalues of the linearized vector field at $p(\lambda^*)$ are contained in $(-\infty, -\alpha) \cup (\beta, \infty)$, then we show that $|\lambda_T - \lambda^*|$ is $\mathcal{O}(e^{-KT})$, $K = \min(2\alpha + \beta, \alpha + 2\beta)$. This improves a result of Beyn, and leads to an exponential convergence result for analogous problems in which an eigenvalue at $p(\lambda^*)$ is 0. The latter improves earlier results of Friedman and the speaker.

Stephen Schecter
Mathematics Department
North Carolina State University
Box 8205
Raleigh, NC 27695-8205

Computation of Heteroclinic Connections in Gradient PDEs Part I

The numerical computation of heteroclinic connections in dissipative PDEs with a gradient structure, such as those arising in the modeling of phase transitions, is considered. As a result of the gradient structure it is known that, if all equilibria are hyperbolic, the global attractor comprises the set of equilibria and heteroclinic orbits connecting equilibria to one another. The PDE is approximated by a Galerkin spectral discretization to produce a system of ODEs. Analogous results to those holding for the PDE are proved for the ODEs—in particular the existence and structure of the global attractor.

Heteroclinic connections in the system of ODEs are computed using numerical continuation on the attractor. The methods employed allow the calculation of connecting orbits which are *unstable* as solutions of the initial value problem. Some basic numerical results are given validating the numerical methods for the Chafee Infante problem. Further numerical results are given for the Cahn-Hilliard equation, and for the phase field model of phase transitions; these illustrate the previously unknown structure of their global attractors and the nature of the heteroclinic connections.

Fengshan Bai[a,c] *Alastair Spence*[a] *Andrew M Stuart*[a,b]
[a] School of Mathematical Sciences, University of Bath, Bath BA2 7AY, United Kingdom
[b] Address from April 1992 Program in Scientific Computation and Computational Mathematics, Department of Computer Science, Stanford University, CA 94305, USA
[c] On leave from Applied Mathematics Department, Tsinghua University, Beijing 100084, P.R.China

Computation of Heteroclinic Connections in Gradient PDEs Part II

The numerical computation of heteroclinic connections in dissipative PDEs with a gradient structure, such as those arising in the modeling of phase transitions, is considered. As a result of the gradient structure it is known that, if all equilibria are hyperbolic, the global attractor comprises the set of equilibria and heteroclinic orbits connecting equilibria to one another. The PDE is approximated by a Galerkin spectral discretization to produce a system of ODEs. Analogous results to those holding for the PDE are proved for the ODEs—in particular the existence and structure of the global attractor.

Heteroclinic connections in the system of ODEs are computed using numerical continuation on the attractor. The methods employed allow the calculation of connecting orbits which are *unstable* as solutions of the initial value problem. Some basic numerical results are given validating the numerical methods for the Chafee Infante problem. Further numerical results are given for the Cahn Hilliard equation, and for the phase field model of phase transitions; these illustrate the previously unknown structure of their global attractors and the nature of the heteroclinic connections.

Fengshan Bai[a,c] *Alastair Spence*[a] *Andrew M Stuart*[a,b]
[a] School of Mathematical Sciences, University of Bath, Bath BA2 7AY, United Kingdom
[b] Address from April 1992 Program in Scientific Computation and Computational Mathematics, Department of Computer Science, Stanford University, CA 94305, USA
[c] On leave from Applied Mathematics Department, Tsinghua University, Beijing 100084, P.R.China

Numerical Methods for Dissipative and Gradient Dynamical Systems

For a general class of dissipative systems, which includes the Lorenz equations, it is shown that a class of Runge-Kutta methods preserve the absorbing set of the underlying system, and hence possess a *global* attractor. Using [Hale, Lin & Raugel, Maths Comp 1988] it can then be shown that the numerical attractor converges to the attractor of the continuous system, in some sense, as the step-size tends to zero.

The numerical solution of gradient systems, such as those arising from models of phase transistions, is also considered. For such systems all the ω-limit points are equilibria and RK methods which preserve this property are identified.

Mr Antony R Humphries, University of Bath, UK, and Stanford University.
Dr Andrew M Stuart, Stanford University.
Adresses for both authors:
Until March 15th 1992; School of Mathematical Sciences, University of Bath, Avon, BA2 7AY, UK.
From March 30th 1992; Program in Scientific Computation, Division of Applied Mechanics, Department of Mechanical Engineering, Stanford University, California 94305.

The Complex Ginzburg–Landau Equation: Numerical Schemes and Absorbing Sets.

Although it is well known that the complex Ginzburg–Landau equation defines a dynamical system, and that absorbing sets exist in both L^2 and H^1 which yields the existence of a global attractor, little or no attention has been paid to how the equation should be discretized in this context.

Our aim in constructing numerical methods is to obtain a discrete dynamical system which has absorbing sets in the discrete L^2 and H^1 spaces which are bounded independently of initial data.

The method of analysis will be indicated and results presented for both fixed step schemes and variable time step methods using a local error contiol.

Gabriel James Lord,	Dr Andrew Stuart,
Dept of Mathematics,	Program in Scientific Computation and
University of Bath,	Computational Mathematics,
Claverton Down,	Dept of Comput Science,
Bath, Avon,	Stanford University,
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Accurate Computation and Continuation of Heteroclinic Orbits

We first summarize some results by Doedel and Friedman on efficient computation of branches of heteroclinic orbits for systems of autonomous ordinary differential equations. Essentially, our numerical method is to reduce a boundary value problem on a real line to a boundary value problem on a finite interval, using a closed form local approximation of the unstable and stable manifolds.

We next consider refinements of our algorithm to be able to obtain starting orbits on the continuation branch in a more systematic way as well as making the continuation algorithm more flexible. In applications we use the continuation software package AUTO in combination with some initial value software.

The examples considered, include computation of homoclinic orbits in a singular perturbation problem and in a problem of two coupled oscillators.

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CP 2

Breakdown of Stability of 2-tori

We discuss the problem of loss of stability of an invariant 2-torus in a one-parameter system of finite- dimensional ordinary differential equations. The flows on the 2-torus are of quite general type. Our theory does not require smoothness of the torus. We point out three distinct ways in which stability can be lost, and indicate what can happen in each of these three cases.

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Recurring Anti-Phase Behavior in Coupled Nonlinear Oscillators: Random Noise or Deterministic Chaos?

We discovered the existence of a new type of high-dimensional attractor in coupled nonlinear oscillator systems. Due to the presence of neutrally stable directions on the attractor, there can be noise driven phase space drift. Recurring anti-phase states are observed as coherent portions of the time series. The observed time series looks coherent for an interval, then incoherent, and then coherent again. Although the time series "looks" chaotic, the Lyapunov exponents are not positive. Both analysis and simulations will be presented. Analysis of this new phenomenon will be used to explain experimental data for a symmetrically coupled oscillator system.

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A Singularly Perturbed Nonlinear Oscillator with Applications to Structural Dynamics

Many multi-degree-of-freedom structural and mechanical systems are assembled from subsystems or components with widely spaced stiffnesses or natural frequencies. The nonlinear dynamical behavior of such systems may be studied by utilizing techniques from singular perturbation theory and invariant manifold theory. These methods allow for the dynamical behavior of the full order system to be closely approximated by a reduced order system with much lower dimensionality on the slow manifold. An example of a buckled beam mounted on stiff linear supports subject to harmonic base excitation is studied, and the conditions on system parameters under which the various approximations of the reduced order system adequately represent the full order long term dynamics, including homoclinic orbits and chaos, are investigated.

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Bifurcations and Chaos in a Bilinear Hysteretic Oscillator

A simply supported elastoplastic beam is modelled as a single degree of freedom oscillator with bilinear hysteresis. The kinematic hardening parameter, η^2 is used as a problem parameter for free vibrations. An explicit map is obtained for plastic cycles and a bifurcation of η^2 is discussed. A unique elastoplastic limit cycle is shown to exist for $\eta^2 \in [.5, 1)$ whereas infinite elastic orbits exist as final states for $\eta^2 \in [0, .5)$. Counter intuitive phenomena are exhibited in the latter case. Response of the system under perodic kicking is analysed next using semi-analytical and numerical techniques. Stable limit cycles are shown to exist for constant amplitude kicks. But the system goes through a series of complex bifurcations leading to chaos if the kick amplitudes are linear functions of the displacement.

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Mode-locking Structure in Billiards with Spin

We have studied a modified problem of Sinai's billiards in the square table, where an angle kick is added to the elastically reflected angel due to the spin effect. In the space of the aspect ratio and a kick, we have found that a phase diagram is complex with infinite mode-locked tongues, and periodic orbits in the main tongues are characterized by odd harmonic sequences. We have shown that at the boundary of the tongues a periodic orbit breaks down into chaos due to the change in the scattering sequence, different from saddle-node bifurcations into quasiperiodicity in typical quasiperiodic problems.

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On the Dynamics of Aeroelastic Oscillators With One Degree of Freedom

We consider two aeroelastic oscillators in cross flow with one degree of freedom. The first oscillator is a special mass-spring system which is able to oscillate in cross-flow, that is perpendicular to the direction of a uniform flowing medium. The second oscillator is a pendulum-type oscillator in crossflow. The interesting difference between the two oscillators is that the motion of the first oscillator is pure translatory whereas the motion of the second oscillator has a rotational character. By using a quasi-steady theory as model equations a Lienard and generalized Lienard equation are obtained. For the first equation a global and for the second equation a local analysis is presented resulting in conditions for the existence and uniqueness of limitcycles.

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MS 5

Shadowing Orbits of Chaotic Differential Equations

The orbits of a chaotic differential equation exhibit sensitive dependence on initial conditions. Hence a numerically computed orbit will diverge very quickly from the true orbit with the same initial conditions. In work now in progress we exploit the (possibly non-uniform) hyperbolicity of the variational equation along the computed orbit to find a true orbit which shadows it. Note that the methods developed for shadowing orbits of chaotic maps cannot be directly applied because of the lack of hyperbolicity in the direction of the vectorfield. Nevertheless we have found a way to "quotient out" this non-hyperbolic direction.

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Smooth Invariant Foliations in Certain Dynamical Systems

We study existence and smoothness of invariant foliations to invariant manifolds of certain dynamical systems with skew-product structure. Gap conditions are introduced, and an uniform contraction mapping principal on scale of Banach spaces is provided. Applications to quasi-periodical motion and to singular perturbations are also discussed.

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Homoclinic Orientation and Chaos

Chaotic dynamics arises when the unstable manifold of a hyperbolic equilibrium point changes its twist type along a homoclinic orbit as some generic parameter is varied. Such bifurcation points occur naturally in singularly perturbed systems. Some quotient symbolic systems induced from the Bernoulli symbolic system on two symbols are prove to be characteristic for this new mechanism of chaos generation. Combination of geometrical and analytical methods is proved be to more fruitful.

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Cantor Spectrum for the Quasi-periodic Schrödinger Operator

We consider the one-dimensional Schrödinger operator H with quasi-periodic potential q. We prove that there is a generic set *q* of such potentials (in the sense of Baire category) for which the spectrum of H is a Cantor set.

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MS 6

Analysis of Turbulence in the Orthonormal Wavelet Representation

The wavelet-transformed Navier-Stokes equations are used to define quantities such as the transfer and flux of kinetic energy through position (x,y,z) and scale r. Analysis of pseudospectral direct numerical simulations of turbulent flows reveals that although the mean spatial values of these quantities agree with their traditional counterparts in Fourier space, their spatial variability is very large, exhibiting non-Gaussian statistics. The local flux of energy involving scales smaller than some r also exhibits large spatial intermittency and it is negative quite often, indicative of local inverse cascades.

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The Multiscale Structure of the Passive Scalar Field in Turbulent Water Jets

The wavelet transform is applied to two-dimensional dye concentration data in turbulent jets at moderate Reynolds numbers. The transform permits an examination, at different scales, of the geometry of turbulent structures. Information about the number of structures at a given scale, their area and aspect ratio is obtained; long, stringy structures are observed at small scales.

The wavelet transform is also applied to temporally resolved sequences of LIF images, which allows analysis of the evolution of structures at different scales, their interactions and speeds. A significant part of the dynamics involves the merging of scales besides the usual splitting traditionally associated with cascading. A comparison with the vorticity field is made.

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Wavelet Coefficient Probability Distribution Functions for Turbulent Flows

A new diagnostics method is being developed to study some aspects of intermittency in turbulent flows. It consists in measuring systematically the probability distribution function of the wavelet transform of the turbulent fields. This measurement avoids the problems due to finite instrumental resolution which arise in the formation of the probability distribution functions for scalar or dissipation fields from experimental data, or due to discretization in numerical simulations. The theory of wavelet coefficient probability distribution functions is developed and a simple analytical closure is presented. Solutions of these equations are compared with numerical and experimental data. Improved closure schemes will be discussed.

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The Wavelet Transform as a Link between Physical Space and Fourier Space

Turbulence dynamics centers on complex nonlinear interactions among a wide range of spatial scales. Interscale interactions in fully developed turbulence may be studied to advantage with three-dimensional orthogonal expansions of Fourier modes in which each Fourier mode describes a single well-defined spatial scale. A difficulty, however, has been in relating interscale dynamics in Fourier-spectral space to structural evolution and dynamics in physical space. We focus here on the n-dimensional wavelet transform as a tool for relating structural evolution in n-dimensional physical space to modal evolution in n-dimensional Fourier-spectral space. To this end the wavelet transform is developed as a class of spectral filters which in physical space extract scale-dependent regions of concentrated activity, but in Fourier-spectral space extract Fourier modes within scale-dependent regions of n-dimensional spectral space. The use of isotropic vs. nonisotropic wavelets and wavelet transforms and their application to the analysis of turbulence data concurrently in physical space and Fourier-spectral space will be discussed using 3D computer graphics as a visual aid.

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MS 7

Fireflies and Coupled Oscillators

In some parts of Southeast Asia, thousands of fireflies gather in trees at night and flash on and off in unison. We discuss a simple model for this remarkable example of spontaneous synchronization. The model consists of coupled relaxation oscillators that communicate by sudden impulses, rather than by continuous feedback. We prove that, for almost all initial conditions, the system evolves to a state where all the oscillators are firing synchronously. A videotape of synchronous Malaysian fireflies will be shown.

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Dynamics of Josephson Junction Arrays

The Josephson junction array has for years been an important system in the study of low temperature physics. More recently, it has become an archetype in the study of dynamical systems having many degrees of freedom. Methods from dynamical systems theory have proven useful in uncovering certain novel behavior relevant to a far larger class of physical systems. This talk touches on three such phenomena: attractor crowding, coherent destructive amplification, and dynamical reversibility.

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Nonlinear Oscillators, Biological Rhythms, and Landau Damping

We analyze a model of coupled nonlinear oscillators with randomly distributed frequencies. Twenty-five years ago it was conjectured that, for coupling strengths below a certain threshold, this system would always relax to an incoherent state. We prove that this conjecture holds for the system linearized about the incoherent state, for frequency distributions with compact support. The relaxation is exponentially fast at intermediate times but slower than exponential at long times. The decay mechanism is remarkably similar to Landau damping in plasmas, even though the model was originally inspired by biological rhythms.

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Boundaries of Locking in Weakly Diffusive Chemical Systems

An oscillatory reaction-diffusion system with weak diffusion and a gradient in intrinsic properties is considered. It is shown that such a system can support O(1) gradients in local frequency. This contrasts with the discrete analogue which only supports gradients of the same order of magnitude as the coupling. This work is motivated by some recent experiments by Swinney et al. and as a continuation of previous work by the author and W.C. Troy.

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MS 8

Invariant tori for nonlinear wave equations

Some of the principal results of the KAM theorem are extended to infinite dimensional Hamiltonian Systems. This allows us to describe some of the important structures of the phase space on which they are posed. The main applications are to the nonlinear wave equation, and to other nonlinear evolution equations of mathematical physics. There is a surprising relation between the techniques used in the proofs and the Frohlich-Spencer theory of localization for random operators.

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Dispersive Initial Value Problems and Their Limiting Behavior

In this talk, based on a review article by David Levermore, Stefanos Venakides and the speaker, we look at variety of equations describing physical systems in which dissipative or diffusive mechanisms are absent, but which undergo dispersive processes. We shall investigate the limiting behavior of such a system when the parameter in the dispersive term tends to zero. The limit exists in the weak, i.e. average sense, and can be described with great precision. We present several cases where the limiting behavior has been analyzed and understood. All these cases are completely integrable, which makes them explicitly solvable. We study these explicit solutions and trace within their structure the passage to zero of the small parameter. In this way, not only the weak limit, but the microstructure of the oscillations can be understood.

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Forced Oscillations of the Toda Lattice

We study the behavior of a semi-infinite chain of particles with nonlinear nearest neighboor interactions when the zeroth particle is forced with a given velocity function $v_0(t)$. The object is to analyze the structure of the oscillations which arise. We perform our calculations on the Toda chain (exponential force law) and address periodic forcings $v_0(t)$ with a positive mean (shock problem). This makes the problem nonintegrable. We derive a closed system of differential equations for the eigenvalues of the associated Lax operator of the problem. We make a long-time analysis of this system to detect the main features of the oscillatory structure in the chain.

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Solitary Waves, Asymptotic Stability and Hamiltonian Systems

I will discuss results on orbital *asymptotic* stability of solitary waves of nonlinear dispersive partial differential equations. Examples include the Korteweg - de Vries equation and a class of nonlinear Schrodinger equations, both infinite dimensional Hamiltonian systems. I will also discuss the onset of instabilities in such systems. For example, in KdV-type equations, transitions to instability are unlike typical transitions to instability in finite dimensional Hamiltonian systems. Such transitions can be understood in terms of the motion of poles (*resonance poles*) of a resolvent formula extended to a multi-sheeted Riemann surface.

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CP 3

Dynamical Metastability in Cahn-Hilliard-Morral Systems

Cahn-Hilliard-Morral systems are multicomponent analogues of the Cahn-Hilliard equation for phase separation in binary mixtures. Numerical and empirical evidence suggests that after rapid fine-grained decomposition extremely slow coarsening may occur. Until recently this phenomenon had only received rigorous verification in the two-component case, and fairly complicated methods were necessary in order to obtain the best estimate on the slowness of motion.

The speaker will describe how a very simple method based on energy arguments can be modified to give equally good estimates; furthermore, it can be generalized to an arbitrary number of components.

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A New Passage to Generate Diffusive Patterns

I discuss a diffusively perturbed predator-prey system. For the corresponding ODE, there is a homoclinic (heteroclinic) loop which breaks into stable periodic solution after varying a parameter. For large diffusion, this solution represents a stable spatially homogeneous time periodic solution for the PDE. I show when the diffusion becomes small, the spatially homogeneous solution loses stability and bifurcates into spatially nonhomogeneous solutions.

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Self-Trapping of Traveling-Wave Pulses

A puzzling feature of experimentally observed traveling-wave pulses (i.e. of (envelope) *solitary* waves) in binary-mixture convection is their exceedingly slow drift; it is up to a factor of 30 slower than expected from conventional complex Ginzburg-Landau equations. I show that the expansion leading to these equations ceases to be well ordered in the limit of slow mass diffusion which is relevant to this system. For simplified boundary conditions, I derive new, extended complex Ginzburg-Landau equations for the convective amplitude A, coupled to a new concentration mode C. Numerical simulations of these equations show that localized pulses of traveling waves can become *trapped in their own concentration field*, i.e. they propagate with a speed which is considerably smaller than the group velocity over a wide range of parameters. With the concentration mode C included and for non-zero group velocity, localized traveling waves can be stable even when all the coefficients are real, i.e. without any dispersion, and even if the bifurcation to extended waves is *supercritical*.

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Domain Walls in Superstructures, Sources, Sinks and their Stability

Domain walls separating static spatially periodic structures with different wave numbers have been observed in chemical systems (Turing structures) as well as in convection. We investigate them within the framework of a Ginzburg-Landau equation which is fourth order in space. We determine their stability and compare the results to those obtained in the corresponding phase equation. Particular emphasis is put on the fact that the phase equation becomes invalid when the wave-number gradients become too steep. We clarify the connection between the domain walls and the universal Eckhaus instability. In the case of a complex Ginzburg-Landau equation the domain walls correspond to sources (or sinks).

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Stability of Steady States of the Ginzburg-Landau Equation in Higher Space Dimensions

We consider the Ginzburg-Landau equation in a bounded domain of $\mathbf{R}^n$ subject to the homogeneous Neumann boundary conditions; it is written in the form $u_t=\Delta u+(1-|u|^2)u$, $u=u_1+iu_2$. This equation has a Lyapunov function, from which it follows that every solution converges to a steady state as $t\to\infty$. In this presentation we will show that the stability of non-constant steady states is closely related to the shape of the domain.

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Interaction and Stochastic Dynamics of Localized States of Multidimensional Nonlinear Fields

The analysis of collisions of two localized states of a classical nonlinear field reveals chaotic scattering that consists in a complicated unpredictable behavior of "particles" in the region of interaction, with the "scattered" (outgoing) particle trajectories strongly dependent on initial conditions (i.e. on incoming trajectories). The dynamics of the interaction of such localized states in a bounded space gives birth to deterministic spatio-temporal chaos like that observed in Sinai billiards. Direct computer simulations and analytical estimations show that localized states may exist in the fields given by generalized Klein-Gordon and Ginzburg-Landau equations. Newtonian equations of motion for the localized structure are obtained. Numerical experiments show that there are oscillations in forms of localized states corresponding to internal degrees of freedom. When examining the simple problem of the interaction of a pair of two-dimensional localized states, it has been found that the interaction gets more complicated as the internal degrees of freedom of the localized solutions are excited. i.e. a "nonelastic shock" occurs.

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CP 4

Systems with Intermittent Switching of the Activity — Distinguishing Random and Chaotic Processes

There is a large number of physical phenomena exhibiting a peculiar behavior: the system is quiescent for long periods followed by a burst of activity. This behavior is persistent, and can be characterized by intermittent switching of system variables. Examples include sunspot activity in astrophysics and intermittent turbulent bursts occurring in otherwise laminar pipe flow in fluid dynamics. A general model describing intermittent behavior has been found. Our model consists of a simple dynamical system near a bifurcation point. Introducing a time dependent bifurcation parameter we are able to switch between different states of the system creating a time trace as described. At the present time we can vary time dependent bifurcation parameter either randomly or chaotically and, yet we can produce signals which are almost identical. In the future we would like to provide tests on the output signal which would distinguish the type of forcing being used.

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A Hartman-Grobman Theorem for Maps.

A local stability theorem, an analog of the Hartman-Grobman Theorem for maps is formulated and proved. The discussion is illustrated on simple examples which clarify why the previous attempts to formulate the Hartman-Grobman Theorem have failed. The obtained result is directly applicable to a class of retarded funtional differential equations.

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Closeness of the Solutions of Approximately Decoupled Damped Linear Systems to Their Exact Solutions

The simplest technique of decoupling the normalized equations of motion of a linear nonclassically damped second-order system is to neglect the off-diagonal elements of the normalized damping matrix. In this paper, the error introduced in the system response due to this decoupling technique is studied. It is shown rigorously that if the off-diagonal elements of the normalized damping matrix are sufficiently small and if the approximately decoupled systems are reasonably damped, then the approximation error and its derivative are small – an intuitively obvious result.

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On a Problem of Nirenberg
Concerning Expanding Maps in Hilbert Space[a]

Let H be a Hilbert space and $f : H \to H$ a continuous expanding map (i.e. $\|f(x) - f(y)\| \geq \|x - y\|$ $\wedge x, y \in H$) and $f(H)$ has nonempty interior. L.Nirenberg asked if these conditions are sufficient to ensure that f is onto: Topics in Nonlinear Functional Analysis, Lecture Notes, New York, 1974. We give a partially negative answer to this problem by constructing a continuous map $F : H \to H$ which is not onto, $F(H)$ has nonempty interior, $\|F(x)\| = c\|x\| \wedge x \in H$, $c > 2$ and the trajectories of dynamical system defined by F diverge in an exponential way (i.e. sensitive dependence property occurs). We show that no map with the above properties exists in the finite dimensional case.

[a] to be published in Proceedings of the American Mathematical Society

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On Stability in Nonlinear Dynamical Systems with Perturbations

General nonlinear ordinary differential equations system of Carateodory type with small parameter are considered. It is supposed that unperturbed system (if small parameter E equals to zero) is a nonlinear system in the critical case. The common definitions of E - stability, E - attractivity and asymptotic stability are introduced. Sufficient conditions of stability and instability by means of generalized Lyapunov's functions are given. The Method is based on the recent development of Lyapunov's direct method modified for systems with small parameter. The partial stability are discussed as well. The results are illustrated by some applications.

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CP 5

Investigations of Chaos in a Train Wheelset with Adiabatically Varying Parameters

We consider a train wheelset as a nonlinear dynamical system consisting of coupled linear oscillators subject to nonlinear friction and flange forces. Determination of the parameters for which chaotic behavior occurs in this system is important both for railway design and for understanding the dynamics of complex mechanical systems under the influence of impact forces. This is accomplished by calculating the Lyapunov exponents for the system while the parameters are varied adiabatically. This procedure has two benefits over the usual calculation of Lyapunov exponents at fixed parameter values: it allows for a more efficient investigation of parameter space as well as providing insight into the behavior of accelerating systems. Using this procedure we investigate the onset of chaos in a train wheelset as a function of velocity, spring constants, and flange forces.

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Transient Chaos in Wheel Dynamics

The so-called shimmy of towed wheels is a classical dynamical problem. Design considerations of aeroplane nose gears and steered wheels of cars are still underlining the importance of nonlinear analysis. Anybody can experience the chaotic motion of these wheels on trolleys in supermarkets. It can also be detected that the chaotic dance sometimes disappears quite unexpectedly.

A low-dimensional model and the analysis of its phase space explains this peculiar phenomenon which has rarely been observed in classical mechanical systems. An analytical method is presented to estimate the life-expectancy of chaos in these systems.

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Dynamic Modeling of Vehicles Traveling on Bridges

Engineers designing highway and railroad bridges have renewed the investigation of the travelling mass problem. Suspension bridges on which vehicles travel could be dynamically modelled as a moving mass on a simply supported beam. A thorough investigation into the analysis of beams with different boundary conditions,carrying either moving masses or loads is performed. Analytical and numerical techniques for determination of the dynamic behavior of beams due to a concentrated travelling load and mass are presented. The transformation of the Euler-Bernoulli thin beam equation into a new solvable series of ordinary differential equations is fully demonstrated. The response of this resulting,*somewhat more realistic*,modeled system is determined using analytical and numerical techniques. A detailed comparison between the results for the case of moving mass with those corresponding to the travelling load is carried out.Furthermore,the inertial effect of the moving mass has been proved to be an important factor in the dynamic behavior of such structures.

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CP 6

Orbits Homoclinic to Resonances: The Hamiltonian Case

We consider perturbations of completely integrable two degree of freedom hamiltonian systems with an S^1 symmetry. We assume that the unperturbed system has a hyperbolic one-parameter family of closed orbits with coincident stable and unstable manifolds, and one such orbit or a subset of the family is resonant, i.e. degenerates into a set of fixed points. Systems of this kind arise e.g. in the study of the hamiltonian Sine-Gordon equation or in the analysis of the hamiltonian 1:2:2 resonance. In these cases global perturbation methods for the detection of homoclinic tangles do not work by the very presence of the resonance.

Using singular and regular perturbation theory, we present a simple-to-use *energy-phase criterion* for the existence of transverse homoclinic and heteroclinic orbits in a neighborhood of the resonance. These orbits are doubly asymptotic to different kinds of fixed points, periodic solutions or combinations of these, which are *created by the perturbation*. The criterion involves the analysis of a one degree of freedom potential problem, usually called the *pendulum equation*. We also consider chaos and bursting associated with some of the possible predictions of the theory.

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Transfer of Capture During Passage Through Resonance

We present a mechanism for transfer of capture in perturbed two-frequency Hamiltonian systems. When the totally averaged system has an isolated attractor which passes through a strong resonance, on a time scale which is asymptotically slower than that on which the damping works, then it transfers its domain of attraction to the resonance. Application of this work to spin-orbit resonance capture in the Solar System will also be discussed.

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Second Order Averaging and Resonant Amplitude Dynamics of a Nonlinear Two Degree of Freedom System

Many weakly nonlinear, multi degree of freedom mechanical systems have been found to exhibit complex dynamic behaviour and amplitude modulated chaos under resonant forcing conditions. One example of such systems is the autoparametric pendulum vibration absorber consisting of a primary spring-mass-damper system attached to a damped simple pendulum. Using the amplitude of forcing as a small parameter a second order averaging analysis is performed and the resulting averaged equations are investigated for their steady state solutions. Bifurcation sets of the system are developed and regions of chaotic behaviour are studied using the software packages AUTO and CHAOS.

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CP 7

Piano-like Dynamics and Strange Nonchaotic Attractors

Smale horse shoe map is commonly accepted as an arch type for strange chaotic behaviour. Similarly we are proposing for nonchaotic strange behaviour a discrete map and an analogous geometrical picture based on cantor set-like objects. The immediate consequence of the suggested discrete piano dynamics is that the Kolomogorov capacity d_c of the Poincare map of a system displaying nonchaotic strange fractal behaviour will tend toward an integer $d_c = 2$. An analogy to a quasi-periodically forced oscillator is made.

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Transition to Hyperchaos in Coupled Generalized van der Pol Oscillators

It has been shown that two forced coupled generalized van der Pol equations can show hyperchaotic behavior, i.e. the first two one-dimensional Lyapunov exponents are positive. The scaling law for transition from chaos to hyperchaos based on the properties of Poincare map has been found. For fixed parameters values different behaviours of the system, such as limit cycles, chaos, hyperchaos coexist.

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Chaotic Model of Dry Friction Force

A mathematical experiment is described in which dry friction provides a nonlinear coupling between two quasiperiodically forced linear oscillators. Interpretation of the aperiodic behaviour of the system suggest that the frictional force is a chaotic function of the relative velocity; the chaotic behaviour may be understood in terms of a degree of freedom of motion normal to the surfaces in friction contact. A new chaotic model of dry friction force is presented.

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MS 9

On the dynamics of defect structures in liquid crystal materials

I discuss the process of formation and evolution of singularities and domain structures in liquid crystal materials in the presence of flow, electroma genetic fields or in relaxation regimes associated with such phenomena. Specifically, I consider the following topics: Formation and evolution of domains, walls and phaseboundaries in the material. Defects and patterns in the presence of flow. Formation of disclinations. The governing system consists of nonlinear equations of parabolic type for the velocity field, the hydrostatic pressure as well as the optic variables of the model. Such equations exhibit reaction-diffusion mechanisms together with those that cause singularities to form. Properties of the solutions corresponding to the previously described phenomena result from the outcome of such competing nonlinear mechanisms. In some cases, the problem turns out to be analogous to that of the Hele-Shaw cells.

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Motion of defects

Defects are singularities that appear when long scale approximations break down because of topological constraints. They play a major role in both statics and dynamics of liquid crystals, superfluids, superconductors, nonequilibrium patterns etc. We shall review recent results about the interaction of codimension two defects in various setups.

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Regularization of the Coulomb singularity

In Dirac's theory of a point electron, the equation of electron motion is a balance between finite parts of an infinite energy-momentum. This equation admits nonphysical runaway solutions in which an electron accelerates to the speed of light in the absence of an external field. Here, a nonlinear field theory is introduced, which supports singularities along time-like world lines with finite energy. The equation of singularity motion follows from a finite energy-momentum balance, and the operator which represents radiation reaction is an integro-differential operator which does not permit the runaway solutions of Dirac's theory.

Prof. John Neu
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A topological defect model of Superfluid

We consider a complex scalar field evolving according to a nonlinear Schroedinger equation. This equation has an interpretation as a model of Superfluid, where the topological defects of the field play the role of Superfluid vortex filaments. In a certain limit, one obtains a reduced equation for the motion of the defects which agrees with the well-known phenomenological Hall and Vinen equation. We will describe the matched asymptotic analysis which yields this equation and discuss some aspects of the defect motion such as stability. We will also discuss a feature of the full field equation which leads to the spontaneous nucleation of defects.

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MS 10

Control of Systems with Homoclinic and Heteroclinic Structures.

The existence of complex or chaotic behavior in dynamical systems can often be explained by the presence of homoclinic or heteroclinic orbits. In a system with controls one can use these structures to control the behavior of the system, either by driving the system to appropriate neighborhoods of the orbits or by altering the orbit parameters. In this talk we explain how this technique may be used to regularize a system with complex behavior and show how it may applied to controlled ODE's with symmetry and to the control of turbulence in a finite-dimensional model of the near-wall region of a turbulent boundary layer.

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Bifurcation Control of Chaotic Dynamical Systems

The stabilizing control of a deterministic chaotic system is investigated. The system under study is a thermal convection loop with a set of Lorenz-like system equations. The control law, which employs so-called washout filters, does not require accurate knowledge of the system equilibrium points and preserves all the equilibrium points of the original system. Both the chaotic motion and the transient chaotic motion are successfully suppressed. The control is designed in two stages. In the first stage, the parameter value at which the primary bifurcation (a Hopf bifurcation) occurs is delayed to an acceptable value. In the second stage, a bifurcation control law is employed to stabilize the bifurcated periodic solutions resulting from the Hopf bifurcation.

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Analysis and Control of Nonlinear Systems with Complicated Behavior

In this paper we study the control of a family of piecewise linear systems which can be approximated using a relaxation technique by a two dimensional system with a hysteresis nonlinearity. We prove that the relaxed system exhibits complicated behavior (chaos) and a probabilistic model for the evolution of this system on the attractor is obtained. The problem of controlling the original piecewise linear system is then examined. The objective of the control problem is to determine a feedback control strategy which eliminates the complicated motion of the relaxed system on the attractor.

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Invariant Densities and the Macroscopic Asymptotic Behavior of Digitally Controlled Continuous-Time Systems

Recent work has demonstrated that controlling an unstable continuous-time system with a digital feedback controller gives rise to a closed-loop system whose state dynamics are chaotic. The chaos arises from the locally expansive dynamics of the open-loop system along with the presence of quantizers and finite-precision arithmetic devices in the feedback loop. Complicating the analysis is the fact that the flow governing the closed-loop state evolution is not only nonlinear but also non-differentiable. Nonetheless, in certain cases one can characterize the closed-loop chaos macroscopically in terms of a probability measure on the state space invariant under the mapping that describes the state evolution between sampling instants. The properties of this measure depend on the control scheme and are therefore subject to the designer's influence.

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Destabilizing Limit-Cycles in Delta-Sigma Modulators with Chaos

Delta-sigma modulators are electronic circuits which are used to make high precision analog-to-digital and digital-to-analog converters. These systems contain a single nonlinear element (a quantizer) embedded in an otherwise linear system, and so can exhibit such nonlinear behavior as limit-cycles, subharmonics, phase-locking and even chaos. Limit-cycles are particularly distressing. Randomizing the quantizer by adding a dither signal has been suggested as a solution, but this adds extra noise to the system. The alternative explored here destabilizes limit-cycles, thereby creating a chaotic modulator. The effectiveness of the technique will be illustrated with an audio demonstration.

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MS 11

Geometry from Saddle Cycles

The key to understanding complicated dynamical behavior lies in understanding the unstable periodic orbits embedded in this behavior. We extract unstable periodic orbits from chaotic signals produced by dynamical systems of low dimension using the method of close returns. Topological invariants (linking numbers, relative rotation rates) of pairs of orbits and of individual orbits are computed in order to identify a template, or knot-holder, which supports the invariant set. The template provides a geometric model for the underlying dynamics. Comparison of topological invariants computed for a proposed template with those determined from the unstable periodic orbits allows us to confirm or reject the proposed template. Topological analyses of this type have been carried out on a number of experimental data sets.

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Structure of Attractors for Continuous Mappings

We show that there are interesting theorems about attractors for continuous mappings, under the assumption that the basin of attraction is open. (For example, if such an attractor contains a fixed point, then the attractor is connected.) Such results rely on a single topological lemma. On specialization to one-dimensional mappings, this lemma can be used to prove density of periodic orbits and sensitive dependence under very general hypotheses. When there is symmetry present, our methods give restrictions on the possible symmetries of attractors and of their connected components. (Joint work with Michael Dellnitz and Marty Golubitsky)

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Composite Knots in the Figure-8 Knot Complement can have any Number of Prime Factors

The periodic orbits of a flow on a 3-manifold may be knotted. Birman and Williams initiated the study of the knots in a flow in the figure-8 knot complement. (To get a rough picture imagine the magnetic field induced by a current in a knotted wire.) They conjectured that the knots in this flow could have at most two prime factors and that in any such flow the number of prime factors would be bounded. (Knots can be factored into *prime* knots.) However, we can now show that this is not true.

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The Measure of Nonhyperbolicity in Chaotic Dynamical Systems

We numerically investigate the measure of nonhyperbolicity of chaotic dynamical systems in the parameter range where there is no attractor. For dynamical processes given by $x_{n+1} = T(x_n, \mu)$, where x is in the plane and μ is the parameter to be varied, Newhouse and Robinson proved that if at $\mu = \mu_0$ there exist tangencies between stable and unstable manifolds for T, then there exists an interval (Newhouse interval) of nearby μ values for which there are tangencies. Hence the tangency parameter values have positive measure. We numerically compute the measure of the set of nonhyperbolic parameter values for the Henon map. Similar two-dimensional diffeomorphisms may arise in the study of Poincare return map for physical systems. Our results suggest that the Newhouse interval can be quite large in the parameter space.

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3. Department of Mathematics
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CP 8

Mixed State Markov Models for Nonlinear Time Series

A new method of modeling time series is applied to chaotic data. Models are at the heart of applications such as filtering, compression, detection, and estimation. Linear ARMA models are often used for time series but they are inadequate for chaotic autoregressive processes (a generic class of time series). Hidden Markov models (HMMs) are often used for nonlinear phenomenea. Their weakness lies in the discretization of state space. I have extended HMMs to use mixed states $\psi(t)$ instead of discrete states $s(t)$, where $\psi(t)$ consists of a discrete part $s(t) \in \{s_1, s_2, \ldots, s_{\max}\}$ and a continuous part $x(t) \in \mathbf{R}^n$.

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Bleaching and Noise Amplification in Time Series Analysis

I will address the problem of characterizing dynamics from a time series of data. Linear pre-processing (bleaching) a data set to produce a residual time series which is spectrally white does not formally alter the characteristics of the time series (*e.g.*, dimension and Lyapunov exponent), but it can make their *estimation* more difficult. Further, residual-based tests for nonlinearity are not as powerful as direct tests when applied to chaotic data. This phenomenon is investigated by interpreting the linear filtering as another embedding of the time series, and then measuring the noise amplification associated with that embedding [Casdagli, *et al. Physica D* **51** (1991) 52–98].

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Analyzing Chaotic Time Series Using Empirical Global Equations of Motion

We present several new techniques for the analysis of chaotic time series using empirical global equations of motion (EGEOM). EGEOMs have previously been shown to have excellent noise averaging characteristics, good predictive ability, and provide a compact description of the modelled dynamics. We show results of new noise reduction algorithms utilizing EGEOMs, as well as techniques for estimating dynamical invariants such as dimension and Lyapunov spectra from time series. Results are shown for known chaotic dynamical systems as well as time series from real-world systems.

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Computing the Inferable Number of Dynamical Variables

We have developed a technique for computing the inferable dimension of a time series, d_i, using a dynamical approach to distinguish dynamical variables from random variables. This indicates the minimum number of dynamical variables necessary in the original system to produce the observed data. This is different from calculations of the embedding dimension which use only topological considerations and thus compute higher dimensions for higher noise levels.

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Recursive Analysis of Chaotic Time Series

Considerable progress has been made in recent years in the analysis of time series arising from chaotic systems. Applications include prediction, noise reduction and diagnostic monitoring in a variety of systems, such as vibrating machinery. However, hitherto all algorithms in this area have used batch processing. This severely limits their usefulness in real time signal processing applications. In this talk we present a continuous update prediction scheme for chaotic time series which overcomes this difficulty. It is based on radial basis function interpolation combined with recursive least squares estimation.

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Dynamical Nonlinear Equations Obtained from Time Series

We present a method to extract a set of dynamical equations from observed time series. The reconstruction procedure is based on an ansatz of variable generality. Using simulated time series, it is shown that the resulting system in the embedding space is correct in the sense of preserving metric properties. In particular, for the generalized, driven Van der Pol oscillator we reconstruct the full Lyapunov spectrum (without spurious exponents). Moreover, we investigate the use of time series with more than one component and examine the influence of superimposed noise.

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CP 9

Numerical and Experimental Studies of Self-Synchronization and Synchronized Chaos

We study numerically and experimentally self-synchronization of digital phase-locked loops (DPLL's) and the chaotic synchronization of DPLL's in a communication system which consists of three or more coupled DPLL's. The transmitter in the communication system consists of two or more self-synchronized DPLL's, where one of the loops is stable and the other is unstable. The receiver consists of a stable loop. We verified that the receiver synchronizes with the transmitter if the stable loop in the transmitter and receiver are nearly identical. Numerical and experimental results are in good agreement. Modulation techniques for the transmission of informations are currently under investigation.

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Invariants from Lengths of Caustics

Every time reversible Hamiltonian system with two degrees of freedom can be reduced to a planar billiard table. Caustics are invariant curves for the resulting motion, and their lengths define invariants which contain information about the shape of the billiard table.

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Collective Behavior in Limit-Cycle Oscillator Arrays

Mutual entrainment and synchronization in ensembles of non-linear oscillators are relevant to many biological systems ranging from the heartbeat to flashing fireflies. In most studies the natural frequencies of the oscillators are randomly chosen from some distribution. Depending on coupling strength and frequency spread, different types of behavior ranging over modelocking, amplitude death, periodicity, and chaos are possible. This paper analyzes the response in a one-dimensional system with nearest-neighbor coupling in which all oscillators except one have identical frequencies. Analytical and numerical results are presented and the resulting phase diagram is discussed.

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Lyapunov-Schmidt Reduction for Bifurcation of Periodic Solutions in Coupled Oscillators

We consider a system of ordinary differential equations depending on a small parameter where the unperturbed system has an invariant manifold of periodic solutions. The problem addressed is the determination of sufficient geometric conditions for some of the periodic solutions on this invariant manifold to survive after perturbation. The main idea is to use a Lyapunov-Schmidt reduction for a displacement function in order to obtain the bifurcation function as a generalization of the subharmonic Melnikov function. An important application is made when the unperturbed system is a system of coupled oscillators in resonance.

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Chaotic Behavior in a Two-Frequency Perturbation of Duffing's Equation

We consider a two-frequency perturbation of Duffing's equation in which the frequencies depend on the state variables. When the perturbation is small, this system has a normally hyperbolic invariant torus which may be subjected to phase locking. Using Melnikov's method, we predict the regions in parameter space where chaotic dynamics may occur. We also show that phase locking of the invariant torus can interrupt the occurrence of chaos resulting from transverse intersection between the stable and unstable manifolds of the invariant torus. Our method can be extended to a wide class of multi-frequency systems.

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Attractors of a Driven Oscillator with a Limit Cycle

Numerical studies were performed to characterize attractors of a one-dimensional circle mapping representing, in the fast relaxation limit, the dynamics of a driven nonlinear oscillator with a stable limit cycle. Dynamic regimes in the parameter space, bifurcation diagrams and routes to chaos were numerically determined.

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CP 10

Bifurcations with Local Gauge Symmetries: Patterns in Superconductors

An interesting class of physical systems are those that exhibit *local gauge symmetries*. Systems in which these symmetries are spontaneously broken exhibit remarkable properties such as superconductivity, and if such systems also possess spatial symmetry, pattern formation can accompany the gauge symmetry-breaking. We conduct a careful analysis of a well-known example of this phenomenon: the formation of the *Abrikosov vortex lattice* in Type-II superconductors. The study of this system has a long history and our principal contribution is to put the analysis rigorously into the context of steady-state equivariant bifurcation theory by the proper implementation of a gauge-fixing procedure.

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Jacek Turski
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Hidden Symmetries in Bifurcations of Surface Waves: Occurrence and Detection

I discuss a symmetric bifurcation problem arising in parametrically forced surface waves. Experiments in square containers reveal the actual symmetry is larger than the geometric symmetry. Physically the extra "hidden" symmetries arise from the translational and rotational symmetry of an infinite fluid layer. For a finite layer, these symmetries are broken by the container sidewalls, but their effects may persist. In square containers, one expects square symmetry, but additional rotational and translational symmetries also influence the waves as a consequence of weak viscous and capillary effects. Deforming the sidewalls to a non-square cross-section that retains square symmetry removes the hidden symmetry. Experiments by Lane and Gollub study such deformations.

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Synchrony and Symmetry-Breaking in Laser Arrays

A model for the dynamics of N linearly coupled solid state lasers is examined. Both global and nearest-neighbor coupling are considered. In both cases two distinct types of solutions exist for all values of N; these solutions are characterized by the phase relation, $\Delta\varphi$, between lasers. Their stabilities are determined in the coupling strength-pump current parameter space. The in-phase solutions ($\Delta\varphi = 0$) can be stable for both types of coupling. The splay-phase solutions ($\Delta\varphi = 2\pi/N$) are unstable in the nearest neighbor case and neutrally stable in the globally coupled case. The source of the neutral stability is discussed.

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Mechanism of Symmetry Creation in a Plane

For two dimensional maps with symmetry, there are separate conjugate attractors in the plane for some parameter ranges. As the parameter varies, the conjugate attractors merge to form one large attractor. For different types of symmetric attractors, we investigate the different routes by which merging occurs. In particular, for a large class of maps with D_n symmetry (where n is an integer greater than 2), we prove that the conjugate attractors merge on the lines of symmetry, and not through the origin.

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G-mode Solutions of Classical Dynamical Systems

We discuss properties of trajectories of dynamical systems that lays on the orbits of an action of a Lie Group G on the phase space of the system. Such solutions (G-modes) are natural generalizations of "relative equilibriums" of the system (in the case where G is a symmetry group of dynamical system). Examples from hydrodynamics and elasticity theory are given.

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Dynamical Systems with Cosymmetry and Bifurcation Theory

There exist different reasons for degenerating of fixed points of operators or equilibriums and stationary solutions of differential equations. The most usual one is symmetry but the other reasons are possible and cosymmetry is one of them. Cosymmetry pair is orthogonal pair of vector fields in Riemann or Hilbert space. Every member of this pair is called the cosymmetry of the other one. Some hydrodynamical systems (Euler equations, Darcy equations for convection in porous media) have nontrivial and nonholonomic cosymmetries.
The bifurcations in presence of cosymmetry represent some specific features, particularly the branching of continuum families of equilibriums through Euler bifurcation.

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MS 12

Hierarchical Analysis of Molecular Spectra.

A method to characterize and understand spectra of highly excited molecules is presented. The method relies on the construction of an ultrametric tree from a spectrum. The tree is generated by monitoring how the spectrum changes as the resolution is increased. As resolution is increased peaks tend to split off other peaks, defining a parent/child relationship between any two peaks, yielding a tree to describe the whole spectrum. The tree can be analyzed using various measures and information concerning energy transfer can also be extracted from it.

Work supported by the U. S. Department of Energy, Office of Basic Energy Sciences, Division of Chemical Sciences, under Contract W-31-109-Eng-38.

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Control Over Molecular Motion: Issues and Paradigms

A long sought-after goal in chemical dynamics has been control over molecular motion by means of externally imposed laser fields. Recently, there has been recognition that this objective falls into the category of optimal control of quantum dynamical events. Optimal control theory within quantum mechanics imposes a nonlinear problem. It may be shown that the ensuing inverse problem leads to a type of nonlinear Schroedinger equation. The existence of multiple solutions, and the nature of the solutions, to classes of control quantum dynamics objectives will be discussed. Illustrations will be drawn from the control of rotational, vibrational, and electronic degrees of freedom. The prospect of drawing together the theoretical tools with current laser pulse shaping techniques will also be discussed.

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Local Random Matrix Models of Quantum Chaos in Many-Dimensional Systems

Energy flow in molecules is one important realization of "quantum chaos." I argue that the quantum mechanics of energy flow in many-dimensional Fermi resonance systems can be mapped on to local matrix models. These models can be analyzed using ideas for the theory of Anderson localization. A simple mean field theory shows that these models exhibit a sharp but continuous transition from local to global energy flow characterized by critical exponents. I will also discuss the use of scaling theories to take into account the finite size of the phase space of molecules.

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Bifurcation Analysis of Highly Excited Molecular Spectra

Highly excited vibrational states of molecules are important in chemical reactions and molecular energy transfer processes. These states are now accessible to detailed study by laser spectroscopy. The recognition and understanding of patterns in their observed quantum spectra are hampered by the fact that the classical dynamics of these systems is highly nonlinear. Approaches using nonlinear classical Hamiltonian dynamics are useful for classifying the quantum spectra in terms of the structure of the classical phase space. Bifurcation analysis gives a classification of spectra of molecules of interest in atmospheric processes: water, ozone, carbon dioxide, and some substituted methane molecules.

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MS 13

The Theory of Stochastic Resonance

Stochastic resonance is a cooperative effect observed in noise induced switching in bi- or multistable systems modulated by a weak periodic perturbation. The result is an amplification of small noisy signals by pumping the necessary power from the noise to the signal. In contrast to a dynamical resonance, which occurs when two dynamical time scales are comparable, stochastic resonance can occur when a dynamical time scale agrees with a statistical time scale. We report on numerical and analytical studies of stochastic resonance, based on an idealized bistable model with white (and weakly colored) noise and periodic modulations.

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Stochastic Resonance in Optical Systems

The operation of bistable optical systems that display stochastic resonance will be described. Experimental results as well as theoretical models for these devices will be reviewed. Possible future developments and applications will be explored.

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Stochastic Resonance:
A Potential Application in Neuroscience

Sensory neurons demonstrate two striking similarities to known Stochastic Resonance(SR) systems: first, they behave like bistable systems (firing or not firing) exhibiting the characteristic noise induced switching; and second, a historgram of the time intervals between firings is virtually identical with the probablility density of residence times of physical bistable SR systems. Moreover, some processes familiar to neurophysiologists such as nonrenewal effects are also reproducible by physical SR systems. Several problems which might be challenging to applied mathematicians and/or mathematical biologists associated with statistical escapes in nonstationary potentials, nonrenewal effects, and the connection of the residence time probability density to information transmission processes will be outlined.

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MS 14

Functional Differential Equations Arising from Structured Population Models

We show that structured population models which model populations with several life stages can sometimes be reduced to functional differential equations. This reduction allows the application of the extensive theory which has been developed for these equations to be applied to the study of the asymptotic behavior of the original model equations. Questions of the existence of global attractors and persistence can be answered.

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Completeness of the System of Floquet Solutions

For a class of compact operators we state necessary and sufficient conditions in order to have a complete system of eigenfunctions and generalized eigenfunctions. As an illustration, we study the period map of a system of periodic retarded equations. In particular, if the delays are integer multiples of the period, we present necessary and sufficient conditions for completenes of the system of Floquet solutions.

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Discrete Waves in Systems of Delay Differential Equations

In this talk, we illustrate how to apply an equivariant topological degree to obtain bifurcations of periodic solutions of symmetric or time-reversible delay differential equations. The existence of discrete waves will be discussed of systems of delay differential equations arising from *Turing rings with delayed coupling and from* the growth of single-species population over a patchy environment.

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Structure of the Attractor for Delay-Differential Equations with Negative Feedback

Numerical experiments indicate that non-linear scalar delay differential equations can exhibit simple, complicated, and even possibly chaotic dynamics. Under the assumption of negative feedback J. Mallet-Paret has shown the existence of a discrete Lyapunov function and hence a Morse-decomposition of the global attractor. Based on this result C. McCord and I show that the dynamics on the attractor can be mapped via a *semi-conjugacy onto* an explicit Morse-Smale flow with the same number of Morse sets. One can interpret this result as providing a lower bound on the complexity of the dynamics of such delay equations.

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CP 11

Double Eigenvalues and the Formation of Flow Patterns

Numerically obtained solution diagrams for stationary flows between infinitely long rotating concentric cylinders look quite asymmetric when they show all bifurcating branches. In this review it is emphasized that these asymmetries are due to the broken symmetry of the Taylor apparatus itself. To get global results on the mathematical structure of the solution set, it seems advantageous to consider more symmetric model problems first.

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Connecting Double Points in Taylor Vortex Flows

We consider steady, axisymmetric, incompressible, viscous flow between infinite, rotating coaxial cylinders (Taylor-Couette flow). Using a two-parameter continuation algorithm, we numerically examine the structure of the bifurcation diagram in the neighborhood of the crossing of the two-cell and four-cell neutral curves in the (aspect ratio, Reynolds number) plane.

The intersection of these curves (a "double point") corresponds to a double zero eigenvalue (of the Frechet derivative of the incompressible Navier-Stokes equations). We show that this double point is connected to another such double point (the crossing of the four-cell neutral curve with the two-axial-cell two-radial-cell mode) by a path of subharmonic secondary symmetry-preserving bifurcations. This numerically verifies a recent conjecture of Meyer-Spasche and Wagner.

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Numerical Lyapunov-Schmidt Decomposition near Mode Interactions in the Taylor-Couette Flow

There are several different types of singular flows in the Taylor-Couette flow. The simplest is the bifurcation of axisymmetric Taylor cells from Couette flow, whi[illegible] on curves in the plane of aspect ratio and Reynolds number. [illegible] two of these curves cross a mode interaction occurs.

We will describe how to compute singular expansions about these mode interactions, compare the computed expansion to the predictions of an analysis of the symmetry of the bifurcations, and compare flows given by the computed expansion to flows computed using two dimensional, axisymmetric codes.

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Michael E. Henderson
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Low Dimensional Models of Taylor Couette Flow

It is well known that the *time* dependence of many equilibrium states in the Taylor Couette system is analogous to [illegible]viour of small systems of ordinary differential equations, how[illegible]s not yet known whether *one can* accurately represent the full spatial development of such flows with any low dimensional model. In this paper we discuss a method for developing such models, based on information about how coherent structures in the flow are associated with dynamical degrees of freedom. We present quantitative estimates of the error incurred in projecting the full flow onto a small set of basis functions, which encode the coherent structures, for a number of example flows. The examples are taken from full numerical simulation of the Navier Stokes equations for Taylor Couette flow, and include period doubling, intermittency, and mode competition.

Katie Coughlin
University of California, Berkeley, CA
Philip S. Marcus
University of California, Berkeley, CA

Confinement Effects in Flow Between Counter-rotating Cylinders

Spiral vortex flow between counter-rotating cylinders has long held promise for connecting ideas about interaction of a small number of modes, implications of symmetry, dynamics at multiple length and time scales, and transition to turbulence. We first review some of the unique possibilities arising from study of this flow, such as 1.) "tuning in" different types of azimuthal mode interaction problems; 2.) absolute versus convective instablities; 3.) traveling waves with zero or even negative group velocity and 4.) competition between two axial wavenumbers. Next we review some recent ideas and experiments on confinement effects, important even in cylinders of moderately large aspect ratio. These include the effect on the wave speed and the evidence for large length-scale dynamics that may be very sensitive to changes in the size of the system.

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Spiral Vortices in Finite Cylinders

In this talk we describe the effects of distant ends on the bifurcation from Couette flow to spiral vortices in the Taylor-Couette system with counter-rotating cylinders. Existing theory assumes that the cylinders are infinite with periodic boundary conditions in the axial direction. With the ends present the primary instability is always to spiral vortices that travel in opposite directions in the top and bottom halves of the cylinder. With increasing rotation rate the pattern loses stability to either a pattern of spiral vortices that travel up (or down) the whole length of the cylinder, or to a pattern of spiral vortices that periodically reverse their direction of propagation. These alternating spiral vortices subsequently disappear in a heteroclinic bifurcation and are replaced by nonreversing spirals. Which secondary bifurcation occurs first depends on the length of the cylinder *mod* axial wavelength.

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CP 12

Chaotic System Identification Using Linked Periodic Orbits

It is quite common to analyze the behavior of a chaotic dynamical system by means of a scalar time series. However, traditional techniques such as Fourier analysis do not reveal much of the structure and behavior of the system, thus making classification of the system difficult. The broadband nature of the signal also makes it hard to distinguish dynamics from noise. A phase space for the system can be reconstructed in several different ways. I will discuss a method to extract characteristic descriptors from a reconstructed system. These descriptors involve topological invariants based upon the organization of low-period saddle orbits with the system attractor. A noise reduction technique can be applied to facilitate the classification scheme. The goal is to provide a comparison with an analytical model, when such a thing is available; when no model is available, a change of state of the system can be recognized.

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Wavelet Reconstruction of Spatio-Temporal Chaos

We present the numerical analysis of several examples of spatio temporal, chaotic data from simulations and experiment. We compare different algorithms of discrete and continuous wavelet decompositions with respect to their performance in reconstructing essential coherent structures of the data. Specifically we present dynamical reconstructions with respect to the scales and locations of evolving structures. We can show that these methods do not only accurately reproduce the dynamics of these structures, but they can also be used for very specific filtering of isotropic and anisotropic structures. The temporal reconstruction of dynamical models from the wavelet decomposed data is compared with those from Karhunen-Loeve decomposition.

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NONLINEAR PREDICTION AS A WAY OF DISTINGUISHING CHAOS FROM RANDOM FRACTAL SEQUENCES

In two recent papers[1,2] it was shown that nonlinear forecasting can be used in order to distinguish deterministic chaos from additive noise and to estimate the largest Lyapunov exponent which provides a measure of how chaotic the system is. Here we show that, in addition to the above, nonlinear prediction can be used to distinguish between chaos and autocorrelated noise. This is particularly important since random fractal sequences, unlike additive noise, have been known to "fool" other procedures of identifying chaos in time series from the natural world.

1. Sugihara, G. and May, R.M. Nature 344, 734-741(1990)
2. Wales, D.J. Nature 350, 485-488(1991)

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J.B.Elsner (Department of Meteorology Florida State University, Tallahassaa, FL., USA, 32306)

System Identification with Aperiodic and Chaotic Driving Forces

We study the modeling of nonlinear dynamical systems with spectroscopy methods. We find that the accuracy of model can be significantly increased by using aperiodic and chaotic driving forces. We present the numerical analysis of several examples.

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Quantification of Recurrence Plots for Analysis of Physiologic Systems

Although numerous efforts have been made to characterize various experimental physiologic systems as chaotic, and extract from them dimensions, entropies, and Liapunov exponents; often, little attention is paid toward the requirement of time independence. Furthermore, the question of noise is rarely addressed. Eckmann, et al. (Europhysics Letters, 4:973-977) have suggested the use of recurrence plots to diagnose time series for the presence of necessary assumptions. We have extended their idea by quantifying certain features of such plots in order to be able to test experimental hypotheses: we have found that percent recurrence, percent determinism, and information entropy are useful in analyzing time-varying experimental data.

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On the Transferring of Chaotic, Periodic and Ergodic Properties from Subsystem to Extended Dynamical System

We investigate how chaotic behavior, ergodicity, and periodicity of the reflection law $x_{n+1} = f(x_n)$ transfer to the dynamical system $T : x_{n+1} = f(x_n)$, $y_{n+1} = g(x_n, y_n)$ describing a particle motion inside a bounded domain. Such systems appear in the theory of Brownian motion, turbulent flow ([1,2] and references there) and control theory. Two models are studied analytically and numerically. In the first model the properties of f transfer directly to T [3]. In the second one: ergodicity and chaotic behavior of f lead to asymptotically stable periodic motion of particle while periodicity of f transfers into ergodicity of T. The transferring is controlled by the shape of the domain.

[1] C.Beck, Commun.Math.Phys.130,(1990) 51
[2] T.Shimizu,Phys.Lett.140A,(1989) 343
[3] J.Szczepański, E.Wajnryb, Phys.Rev.A V.44,N.6, (1991) 3615

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CP 13

Periodic Solutions of Differential Delay Systems

Systems of nonlinear autonomous differential delay equations are considered. They find applications in biology, nonlinear optics, physiology, economics, etc.

Results on existence of periodic solutions of first and high order scalar differential delay equations are known. We consider the case of general dimension and when systems are not reducible to single equations.

Appropriate notions of an eventual negative feedback and a slow oscillation are introduced. Conditions for the existence of periodic solutions of slowly oscillating type are established.

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Stability in a Delay-Differential Equation Modeling a System of Two Negative Feedback Loops

The stability in a system of two delayed negative feedback loops is analysed. The modeling equation is nonlinear and contains two delays: it describes many physiological regulatory systems in general, and models a series of experiments on a simple motor control system in particular. The local asymptotic stability of the equilibria is determined; Hopf and more degenerate (codimension two) local bifurcations are completely analysed, by a Centre Manifold construction. These results are contrasted with systems involving a single feedback loop, and/or a single delay.

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Non-existence of Small Solutions for Scalar Differential Delay Equations

The method of majorants is generalized to estimate higher order total derivatives of solutions of differential delay equations. In the light of the connection between the oscillations and exponential decay rates of solutions of scalar differential delay equation, and in the light of the non-existence of small solution of linear autonomous differential delay equations, the non-existence of small solution for analytic scalar differential delay equation is proved. As an immediate application of the result above, any solution which decays to a hyperbolic equilibrium of the differential delay equation can have a first order estimation in terms of the solution of the linearized equation around the equilibrium.

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CP 14

A Fast O(N) and Memory Efficient Algorithm for Box Counting

Box counting is used to calculate the capacity dimension of a set, usually a fractal or an attractor of some chaotic dynamical system. The worst case time requirement for this algorithm is O(N) where N is the number of points used to approximate the set. The memory requirement is a constant plus the memory to store the N points. 1,000,000 points of the Henon attractor were processed in 270 seconds on a Sun Workstation. Probably the most efficient algorithm prior to this one has the same memory requirement, but its average time requirement is O(N log N).

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A Physical Fractal with a Pedigree

By now, the observation of fractals in physical systems is unsurprising. However, in most cases the connection between the observed fractal and the underlying physical process has been qualitative at best. Recent developments in the theory of random maps [L. Yu, E. Ott, and Q. Chen, Phys. Rev. Lett. 65 2935, (1991)] and ongoing experiments make this connection more quantitative in at least one physical context: the convection of passive tracers on the surface of a chaotically moving fluid. The theory states that the information dimension of the fractal concentration of the tracers is given by the dynamics of the surface flow. Results of the experiments will be presented.

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Approximating the Invariant Measures of Finite Dimensional Maps

We will discuss a method for estimating invariant measures arising from the it- eration of one and two dimensional maps. The method is based on a finite dimen- sional approximation of the Frobenius- Perron operator. Convergence theorems and convergence rates will be presented and applied to the problem of estimating Lyapunov exponents.

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The Singularity Spectrum of Self-Affine Fractals with a Bernoulli Measure

Since the eighties an important idea to understand the long-time behavior of orbits was that the characteristic invariant sets (for instance *attractors*) arising in dynamical systems should be regarded as the supports of some invariant measures and these measures should be characterized by certain singularities. Considering a compact set $F \subset \mathbf{R}^d$ equipped with a measure μ we are interested in the *Hausdorff dimension* $f(\alpha)$ of the subsets $K_\alpha \subseteq F$ where μ has *local dimension* α. Another characterization can be given by the *Renyi dimension spectrum* D_q. A heuristic approach suggests that α, $f(\alpha)$ and q, D_q should be related by the Legendre transform. We verify these heuristics in the case of a self-affine (*'multi'-) fractal*.

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CP 15

Application of Melnikov's Method to an Aeroelastic Oscillator

The Melnikov method is applied to a bluff body aeroelastic oscillator excited by a transverse two dimensional stream. The oscillator consists of a coupled dynamical system governed by a self-excited galloping mechanism. System model formulation allows for the derivation of intermittent chaotic limit cycle motion which have recently been recorded in physical and numerical experiments. Application of Melnikov's method is enabled by identification of an underlying quasi-steady homoclinicity that when perturbed, reveals existence of transverse intersections in the averaged system. The resulting stability criterion consists of an estimate of the exponentially small separatrix splitting.

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A Structurally Stable Double Pulse Heteroclinic Orbit

A double pulse (or period two) heteroclinic orbit is the heteroclinic orbit analogue of a period two limit cycle. Such solutions can lead to complex behaviour due to the twisting and looping of the manifolds associated with the connection. Further, it is possible for these solutions to undergo "period doubling" bifurcations leading to period four, eight etc. heteroclinic orbits. Glendinning (P. Glendinning [1988] Global Bifurcations in Flows *London Math. Soc. Lecture Note Ser.* 127) discussed the idea of cascades of homoclinic orbits leading to chaotic motions. We extend some of this work to the heteroclinic case, and, as our work involves structurally stable connections, we show numerical evidence of these solutions. To study the sequence of bifurcations leading to a structurally stable double pulse heteroclinic orbit we consider the heteroclinic analogue of the homoclinic bifurcation involving a period two limit cycle. We also consider an extension of the work of Silnikov (e.g. Guckenheimer J. and Holmes P. [1986] Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields, Section 6.5) to the heteroclinic case. We will also present numerical simulations of this bifurcation sequence illustrating the associated complex behaviour.

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Mel'nikov analysis of some homoclinic-heteroclinic bifurcations of a nonlinear oscillator.

We modify the global perturbation techniques originally due to Mel'nikov [1963] to study the bifurcation behaviour exhibited by a family of nonlinear oscillators in which the unperturbed Hamiltonian system simultaneously supports both heteroclinic and homoclinic orbits. In the unforced case we concentrate upon finding a critical parameter relationship which causes the heteroclinic and homoclinic orbits to unite, forming two stable separatrices. This is done both by the modified Mel'nikov analysis and by a novel perturbation series approach. Consequences of a possible physical system are then discussed. We then force this critical system and develop methods to search for any periodic solutions.

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The Existence of Homoclinic Solutions for Autonomous Dynamical Systems in Arbitrary Dimension

Dynamical systems of the form $\dot{x} = f(x, \mu)$ are considered with $f \in C^2$, $x \in \mathcal{R}^n$, and $\mu \in \mathcal{R}^2$. It is assumed that $x = 0$ is a hyperbolic equilibrium and that when $\mu = 0$ there exists a known homoclinic solution. By using the method of Lyapunov-Schmidt a function, H, is obtained between two finite-dimensional spaces where the zeros of H represent homoclinic solutions for nonzero values of μ. The implicit function theorem is applied to H in various cases. For $n = 2$ a single curve is obtained through the origin in the $\mu_1 - \mu_2$ plane along which there exists a homoclinic solution. This is a well known result. When $n > 2$ and the stable and unstable manifolds of the hyperbolic equilibrium have an intersection of dimension one, a result of Palmer is obtained which, again, yields a single curve. When this dimension of intersection is greater than one multiple curves can result. This is illustrated with examples.

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MS 15

Stable Manifolds and Nonlinear PDEs

We review applications of the classical theory of stable and unstable manifolds at a hyperbolic fixed point to some problems in the theory of nonlinear partial differential equations. These problems concern the existence/nonexistence of ground states and singular ground states for certain nonlinear PDEs. The work reviewed is joint with X.-B. Pan and Y.-F. Yi.

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Centre Manifolds for Reaction Diffusion Equations with Time Delays

We consider centre manifolds for equations for the form:

$$\dot{u}(t) = A\,u(t) + f(u_t)$$

where A is a Laplace operator.

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The Existence of Invariant Tori for a Class of Hamiltonian System

Zhihong Xia, Georgia Institute of Technology

No abstract received as of 8/31/92,press time.

Invariant Helical Subspaces for the 3-D Navier-Stokes Equations

In general, it is known that the 3D Navier-Stokes equations has a unique regular solution for a short interval of time. We will show that this regular solution exists globally in time in the presence of helical symmetry. Namely, we will show that the subspaces of helical functions are invariant under the solutions of the 3-D Navier-Stokes equations for all $t > 0$.

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MS 16

Class B Laser Oscillations

Class B lasers include many important lasers such as CO_2, YAG and semiconductor lasers and are known to exhibit pulsating oscillations. Because the dimensionless decay constant of the population inversion is typically small, it is possible to reformulate the laser equations as a weakly perturbed conservative system of equations. The new formulation eliminates part of the stiffness of the original equations and allows analytical studies of the periodic solutions. We consider both single mode and multimode lasers and formulate solvability conditions for the time-periodic solutions. We then analyze these conditions and determine the bifurcation diagrams.

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Soliton Robustness and Hamiltonian Deformations in Optical Fibers

Solitons in optical fibers are often viewed as arising from a balance between nonlinearity and dispersion. They can also be viewed intuitively as nonlinear modes of the optical fiber. This point of view is useful in understanding the robustness of solitons with respect to Hamiltonian deformations. If one uses the nonlinear Schrodinger equation to model the solitons, one finds that some of the effects which are not included in this equation but which exist in optical fibers, e.g., higher-order dispersion and birefringence, can be modeled by Hamiltonian deformations. Others, e.g., attenuation and the Raman effect, can be modeled by non-Hamiltonian deformations. Solitons are robust in the former case, persisting almost forever, but not in the latter case.

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An Unstable Modulation Theory & Optical Oscillations

The simplest periodic solutions to the nonlinear Schrödinger (NLS) equation are the exponential *plane waves*. It is well-known for the particular *case* of the defocussing NLS, that this basic wave is stable and thus permits the formulation of a well-posed modulation theory via a nonlinear WKB type of approach.

Certain *coupled NLS systems*, however, admit a cross-phase modulational instability for which even the defocussing modulation theory is invalid. This scenario is realized in nonlinear optical fibers where the axial waveguide geometry allows for the co-propagation of orthogonally-polarized fields and results in the coupling of two NLS modes. Here, the instability generates coherent oscillations at terahertz frequencies which are highly desirable for ultra-fast optical applications.

A dynamical perspective of this cross-phase instability is presented for an integrable coupling of NLS equations. Results obtained through the development of its higher-order, periodic inverse spectral theory provide a basis for the understanding of the nonlinear nature of these optical oscillations.

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Polarization Decorrelation in Randomly Birefringent Nonlinear Optical Fibers

A model for nonlinear pulse propagation in optical fibers is studied. For short length-scale randomness, the dominant effect is due to a phase-velocity difference (birefringence) and produces an increasing uncertainty with propagation distance in the pulse's polarization state. An approximate evolution equation for the probability distribution of the polarization state has been derived elsewhere; here, comparisons between this distribution and Monte-Carlo simulations are presented which demonstrate the validity of the analytical results. In particular, the polarization state fluctuations induced by the randomness are shown to significantly reduce the effects of pulse splitting and width broadening caused by group-velocity birefringence.

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MS 17

Domain Walls in Non-Equilibrium Systems and the Emergence of Persistent Patterns

Domain walls or fronts in equilibrium phase transitions propagate in a preferred direction so as to minimize the free energy (Liapunov functional) of the system. As a result, initial spatio-temporal patterns ultimately decay toward uniform states. The absence of a variational principle far from equilibrium allows the coexistence of domain walls propagating in any direction irrespective of the relative stability of the phases they separate. As a consequence, persistent patterns may emerge. We will study this aspect of pattern formation using coupled reaction diffusion equations that have extensively been studied in the context of chemical and biological patterns.

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Scroll Waves in Excitable Media

Excitable media are spatially distributed systems that propagate undamped traveling waves of excitation. Examples include nerve axons (waves of membrane depolarization), acellular tissues (waves of mitosis), and chemical reactors (waves of oxidation). The laws of motion of these waves have important consequences for intercellular communication, cardiac rhythm , and developing embryos. Excitable media are usually described by a pair of "reaction-diffusion" equations in one, two, or three spatial dimensions. Although much information about traveling waves has been derived from these equations by singular perturbation theory, there remain many challenging problems having to do with rotating scroll-shaped waves in three dimensions. I will discuss some properties of scroll waves derived from differential geometry, perturbation theory, numerical simulations, and cellular automaton modeling.

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Behavior of Vortex Filaments in Three-Dimensional Excitable Media: Results of Some Numerical Simulations

Vortex filaments are 1D phase singularities which can form stable "organizing centers", and thereby dominate the global periodic behavior of 3D excitable media. In an excitable medium such as heart tissue, this can catastrophically disrupt normal functioning. Organizing centers are also of interest from a purely mathematical viewpoint as stable solutions to the underlying reaction-diffusion PDE's. Analysis of these systems of equations in 3D is difficult for even the simplest reaction kinetics; analysis of the more realistic electrophysiological models is at present intractable. Presented here are some results from a systematic numerical exploration of a diversity of stable organizing centers, including simple rings, helices, and knotted filaments. Emphasis is placed on attempts to functionally relate the geometry and dynamics of these objects.

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Dynamics of Organizing Centers in Excitable Chemical and Biological Media

Excitable media support nonlinear waves that propagate as pulses, e.g. the action potential in nerve fibers and heart muscle, and the oxidation pulse in certain chemical reactions. In two and three dimensional media, these waves may self-organize into persistent vortex-like patterns of activity, described in terms of a singularity point (in 2D) or line (in 3D). Experimental studies have been limited by the absence of a direct method to observe the dynamics of the singularity point (line). Here we present a method of singularity localization based on a time-space plot analysis, and we apply it to the study of vortex dynamics in heart tissue and in a 3D BZ reaction.

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MS 18

Some New Homoclinic Orbits in Multi-dimensional Singularly Perturbed Hamiltonian Systems

Persistent homoclinic orbits have been found in many singularly perturbed systems, mainly via Melnikov's method and Fenichel's theory of fibers. In this talk, the existence of ***non-persistent*** homoclinic orbits is established for a class of multi-dimensional singularly-perturbed Hamiltonian systems. The main technical result is an extension of the exchange lemma due to Jones and Kopell. The lemma and its extension, which is of interest in its own right, allow one to follow invariant manifolds during long $\mathcal{O}(\frac{1}{\epsilon})$ passages through neighborhoods of slow manifolds. The existence of orbits which make multiple "fast" excursions away from slow manifolds is proven using the extension. One of the difficulties associated to perturbed Hamiltonian systems, which we overcome, is that the transversality of the underlying invariant manifolds is only $\mathcal{O}(\epsilon)$, whereas it is $\mathcal{O}(1)$ in earlier work on traveling waves. The theory will be illustrated on two examples. This talk is based on joint work with C. Jones and N. Kopell.

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Orbits Homoclinic to Resonance Bands

A new method for establishing the existence of homoclinic and heteroclinic orbits in near-integrable, two-degree-of-freedom dynamical systems is presented. This method is a combination of the usual multi-dimensional Melnikov method and geometric singular perturbation theory, and is used to show how a family of orbits homoclinic to a circle of equilibria breaks up under perturbation to produce various homoclinic or heteroclinic orbits. Both dissipative and conservative perturbations are discussed. The phase spaces of all the cases under investigation exhibit some form of chaotic dynamics.

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An Overview of Random Behavior in Celestial Mechanics

Richard Moeckel, University of Minnesota

No abstract received at press time, 8/31/92.

Mechanical Systems With Purely Hyperbolic Behavior

We consider a system of n point particles in the half line $q \geq 0$ with masses $m_1, ..., m_n$. They collide elastically with each other and the bottom particle collides with the floor $q = 0$. They are all under the influence of an external potential field with the potential $V(q)$ such that $V'(q) > 0$ (i.e., the particles fall down) and $V''(q) < 0$ (i.e., the acceleration decreases with the distance to the floor). If the masses of the particles decrease the farther they are from the floor, $m_1 > m_2 > \ldots m_n$, then the system has all Lyapunov exponents different from zero.

We will discuss the general theory allowing the detection of the hyperbolic behavior in all of the phase space.

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Geometrical Ideas in Mechanics of Flexible Space Structures

In this talk we describe some applications of variational methods to finding periodic motions in mechanical systems. The idea of the approach is to apply a curve--shortening process to a non--contractible curve in the configuration space. In the absence of the so--called gyroscopic terms this amounts to the well--studied problem of finding geodesics in a Riemannian metric, in particular, the Jacobi metric given by the kinetic energy.

In the presence of the so--called gyroscopic terms, however, there is no longer a metric whose geodesics give periodic solutions of the mechanical system. One can, nevertheless, find periodic solutions as the stationary curves for a "non--reversible metric" with non--symmetric indicatrix.

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CP 16

Analysis of a Method for Tracking Unstable Orbits in Experiments

We present theoretical as well as experimental results on an adaptive numerical method for tracking unstable orbits when the dynamical system is not known,and only an experimental time series is available. The orbit can be followed by adjusting an external system parameter, while treating the system as a black box. Special emphasis will be put on how this method applies to flows, and the effects of the time-delay parameter used in building the attractor from the experimental time series. We find *aposteriori* estimates of the controllability region of a given orbit in order to determine the steplength suitable to predict the next position of the orbit.

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Ioana Triandaf
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A Perspective Systems Approach to Problems in Computer Vision

This paper introduces observability and identifiability problems that arise in linear dynamical systems with perspective observation function. Such a perspective problem finds its applications in the field of Computer Vision specifically in the area of motion estimation of a rigid body with point, line or curve correspondence. The basic result of this paper is to study the correspondence problems in an unifying framework and it is shown that these problems arise as a special case of a more general Perspective System Problem. Problems in perspective system theory introduced in this paper are new.

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Using the Butterfly Effect to Direct Orbits to Targets in Chaotic Systems

The sensitivity of chaotic systems to small perturbations (the "butterfly effect") can be used to rapidly direct orbits to a desired state. We formulate a particularly simple procedure for doing this for cases in which the system is describable by an approximately one dimensional map, and demonstrate that the procedure is effective even in the presence of noise. We also present the first experimental verification that the butterfly effect can be used to rapidly direct orbits from an arbitrary initial state to an arbitrary accessible desired state.

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Model-based Control of Nonlinear Systems

We show that model-based control of nonlinear systems without feedback (open-loop control) can be obtained with many simple modelling procedures rather than the globally defined ODE's normally assumed. We also extend this technique to control from delay coordinate reconstructed state spaces. In the process, we find that the appropriate choice of delay coordinates can be critical, since the stability of the control is defined within the reconstructed state space.

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PD High-Gain Natural Tracking Control of Time-Invariant Systems Described by IO Vector Differential Equations

Novel system features called finite-time and infinite- time system trackability are defined. Trackability in this context is defined as the ability to follow a desired output while subject to external disturbances. The necessary and sufficient conditions for them are proven in the framework of time-invariant linear systems described by vector input-output differential equations.

A PD high-gain natural tracking control is synthesized to force a naturally trackable system to exhibit a prespecified elementwise exponential tracking. The adjective natural expresses the features characterized by a control possessing memory, self-learning, self-adaptation, simplicity of the control algorithm, robustness as its ability to guarantee a requested tracking property without measuring any disturbance and without using any mathematics description of the internal dynamics of a system being controlled.

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Dynamics and Control of a Flexible Beam

The high speed and energy-saving robots consists links which are made thinner and thus less rigid. Precise position control of these flexible arms requires accurate modeling of a flexible beam.
Previous work on the flexible beam dynamics seldom considered the hub inertia and the end mass together in the frequency equation, and the coupled system including the drive.
The scope of my presentation will be as follows:-
(1) Modeling of the flexible beam with both clamped-free and pinned-free boundary conditions using Assumed Modes method
(2) Modeling of the PWM amplifier and the servo-motor
(3) Computer simulation of the flexible beam under optimal control

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CP 17

Bifurcation Analysis of Turbulent Mixing Effects in the Chlorite-Iodide Reaction

Experimental investigations of the chlorite-iodide reaction in a flow reactor have shown that its dynamical behavior can be very sensitive to turbulent mixing effects. This finding is of fundamental importance for the kinetic study of chemical oscillators since it implies that homogeneous (ODE) models may be insufficient for understanding their dynamical behavior. Fundamental questions concerning the genesis of the observed dynamics can thus only be addressed after a full investigation of the effect of finite transport rates due to incomplete mixing. The simplest model which includes transport effects has the form of a nonlinear partial integro-differential equation (PIDE) which reduces to the ODE model in the limit of infinitely fast mixing. We have extended existing numerical bifurcation algorithms to analyze this PIDE system. Both parametric continuation and linear stability analysis results will be reported for the Citri-Epstein mechanism with the kinetic constants employed by Fox and Villermaux (Chem. Engng. Sci. **45**, 2857 (1990)). Initial numerical results, in qualitative agreement with the experimental results, indicate that at finite mixing rates a second pair of turning points and an additional Hopf bifurcation appear in the nonpremixed system.

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Roads to Turbulence in Dissipative Dynamical Systems: Amplitude Modulation as a New Road

This paper outlines the method for describing behavior of dissipative dynamical systems through the analysis of the collection of their attracting sets, and through classifying the ways in which the attracting sets might change as the system parameters are varied. The method utilizes a SIMD parallel processor, the Connection Machine model 2 (CM-2). A buckled fluttering plate on a supermaneuvering aircraft is a prototypical system. Due to its high-speed prediction capability, the CM-2, with framebuffer, offers "real-time" display of the solution as it evolves during the prediction process. This feature gives insight into the fundamental way in which the solution evolves. This is essential in defining the scenarios describing roads to chaotic behavior of the dissipative dynamical systems. Three, classical, scenarios: the Ruelle-Takens, the Feigenbaum, and the Pomeau-Manneville, have been observed. A new scenario, amplitude modulation road to the chaos, has been found. Consequently this research contributes to the understanding of the mechanism through which the transition between periodic and strange attractors occurs in dissipative mechanical systems.

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A Nonlinear Stability Analysis of a Unified Aerosol Model for Thin Layer Rayleigh-Bénard Convection

The weakly nonlinear stability of the pure conduction solution for an appropriate aerosol one-layer Rayleigh-Bénard model of a Boussinesq particle-gas system retaining the particle collision pressure and considering particle to particle radiative effects while relaxing the usual assumption of thermal equilibrium between those particles and the gas is investigated. Then an analysis of the criteria governing the occurrence of supercritically re-equilibrated stationary rolls yields a minimum Rayleigh number and a critical wavelength which are completely compatible in their layer-depth behavior with normal convective and columnar instabilities observed in mixtures of smoke with air or carbon dioxide.

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Flow-induced Liquid Crystallization and Pattern Formation in Suspensions

We consider flows of fluid suspensions of small, neutrally buoyant, non-interacting rod-like particles. Such flows are of importance in hi-tech manufacturing, and of theoretical importance in the study of non-Newtonian behavior. It is well known that particles rotate or align in response to the instantaneous local velocity gradient of the flow. We use dynamical and topological arguments to explore orientation dynamics of particles throughout the flowing suspension. Our arguments predict a new physical phenomenon (flow-induced liquid crystallization) characterized by a high degree of self-assembled order; we see a multiplicity of "phases" and crystal defects.

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Chaotic Behavior of Convective Motion in the Solar Atmosphere

The visible solar surface reveals a pattern of bright and darker structures on a scale of about 1000km known as granulation. The solar granulation is an overshooting of convective motions into a more stable atmosphere and is studied by means of spatially highly resolved spectra. The decay process of these motions is followed especially in the darker intergranular regions where we found enhanced turbulence indicating the onset of chaotic motions.

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MS 19

Attractors for Locally Damped Hyperbolic Equations

Sufficient conditions are given for the existence of a global attractor for a linearly locally damped wave equation. The hypotheses are related to the stabilization and the complete controllability of the linear undamped wave equation. Special applications are made to situations where the spatial domain is thin in some directions.

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Limits of Semigroups Depending on Parameters

Among the topics to be discussed are upper and lower semicontinuity of attractors for continuous and discretized flows, structural stability of flows, effects of the shape of the spatial domain in PDE on dynamics and the information that can be obtained by passing from a dissipative system to a conservative one.

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MS 20

Instabilities of Counterpropagating Light Waves in Kerr and Brillouin Media

An introductory review will be given of the three-dimensional instabilities of light waves counterpropagating in Kerr and Brillouin media. The physical mechanisms responsible for these instabilities will be described, as will the applications in which they occur. The initial development of the instabilities can be modeled as the interaction of the two incident waves and four small-amplitude sidebands produced by light scattering within the medium. This model accurately predicts the experimental conditions under which the instabilities occur. However, as the sideband amplitudes grow, additional nonlinear effects must be taken into account. Even the simplest nonlinear models of the instabilities exhibit nonlinear frequency selection, multistability and chaos, and predict the development of complex patterns in the transverse intensity profiles of the counterpropagating waves. Current studies of more realistic models will also be described briefly.

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Dynamics of Light Pulses in Periodic Structures

Light propagation in both nonlinear fibers and planar waveguides with linear periodic refractive index in the direction of propagation present rich scenarios of dynamics, instabilities and potential applications. In the linear regime, there is a gap of frequencies for which there is strong Bragg scattering of the light caused by the periodic structure of the medium. We will show that in such a fiber, at high intensities, pulses which are one or multi-soliton-like solutions of the governing equations propagate without distortion, acting as an effective eraser of the filter. For the waveguide, we will discuss the effect of modulational instabilities in transverse directions and we will pay special attention to the region close to the edge of the frequency gap, where the dynamics are described by the two dimensional nonlinear Schrödinger equation. As it is well known, this equation shows collapse, which in this case occurs at a finite propagation distance. We will discuss whether these dynamics lead to the generation of short high intensity pulses or to something else.

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Spontaneous Pattern Formation in Wide Gain Section Lasers

Two-level and Raman lasers with wide gain sections exhibit pattern forming instabilities closely analogous to that observed in large aspect ratio fluids convection. Unlike fluids however, these optical systems have simple exact traveling wave solutions which allow us to write down amplitude equations of the complex Newell-Whitehead type near threshold. Moreover, we can easily determine regions of stable traveling wave solutions beyond the instability threshold which are the analogs of the Busse balloon. The Raman laser offers a fascinating range of pattern forming instabilities which include a weakly turbulent sea of interacting defects generated via a modulational instability at right angles to the direction of the underlying traveling wave. We will compare and contrast pattern forming instabilities in two-level and Raman lasers.

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Localized States in Fluid Convection and Multi-Photon Lasers

Complex Ginzburg-Landau equations describe the evolution of solution envelopes in the vicinity of a pitchfork bifurcation. Multi-Photon lasers and binary fluid convection are both examples of physical circumstances where the nonlinear theory includes nonlinear gain terms, long thought to preclude the existence of long-term, spatially localized solutions. Using singular manifold methods, it is shown that long-term, localized solutions do, however, exist. A semi-analytic, semi-numerical approach shows that these solutions can be stable. A nontrivial nullspace makes these solutions extremely adaptable to different physical conditions.

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MS 21

Saturation of Outputs for Positive Feedback Networks at High Gain

Consider a network of n units having activation levels x_i and sigmoidal output functions $y_i = g_i(Kx_i)$ where $K > 0$ is the gain parameter weights are fixed. The dynamics is assumed to be of the form

$$\frac{dx_i}{dt} = H_i(x_1, \ldots, x_n, y_1, \ldots, y_n)$$

Positive feedback means $\frac{\partial H_i}{\partial y_i} > 0$. The main result is a generalization of J. Hopfield's saturation theorem for symmetric additive nets. A precise version of the following statement will be discussed. For sufficiently high gain, the outputs $y_i(t)$ along any stable trajectory are very close to the asymptotic values of the sigmoids g_i (typically ± 1), for a large proportion of t.

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Learning, Pattern Recognition, and Prediction by Self-Organizing Neural Networks

As we move about the world, we can attend to both familiar and novel objects, and can rapidly learn to recognize, test predictions about, and learn to name novel objects without unselectively disrupting our memories of familiar objects. This talk will describe neural networks, called ARTMAPs, that have these competences. ARTMAPs are described by nonlinear fast-slow dynamical systems of high dimension. They can learn to rapidly discriminate rare events, to stably classify large nonstationary data bases, and to automatically adapt the number, shape, and scale of their category boundaries to match statistical data properties. A Minimax Learning Rule conjointly minimizes predictive error and maximizes generalization under incremental learning conditions. Benchmark comparisons with genetic, machine learning, and other neural net algorithms will be made.

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Neural Networks In Control Systems

During the past three years numerous models using neural networks have been proposed for the identification and control of nonlinear dynamical systems. Extensive simulation studies have shown that the models proposed are very effective. While much of this past work has been of a heuristic nature, the success of the simulation studies has nevertheless generated new interest in making the proposed methods more rigorous. At the same time, although much effort has been expended on the mathematical properties of nonlinear systems very few constructive procedures currently exist by which controllers can be synthesized for nonlinear systems of even reasonable complexity. The aim of this paper is to demonstrate that results from nonlinear control theory and nonlinear adaptive control theory can be used to propose a theoretically rigorous and practically efficient methodology for the design of controllers using neural networks.

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CP 18

Bifurcations from Symmetric Relative Equilibria

A 'transfer of stability' need not occur at bifurcations from symmetric relative equilibria; bifurcations to stable asymmetric motions may occur throughout a range of parameter values for which the symmetric motion remains stable. Many geometric techniques cannot be applied to symmetric relative equilibria because of the singularity of the momentum map. However, a generalization of the reduced energy momentum method of Simo et al., which identifies relative equilibria by means of a variational problem on the configuration manifold, allows a computationally efficient analysis of symmetric states ranging from the sleeping Lagrange top to axially symmetric steadily rotating fluids.

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Conley Decomposition for Fixed Bounds on Pseudo-Orbit Deviations from True Orbits

The Conley Decomposition Theorem provides for the decomposing of a dynamical system into chain recurrent and gradient-like parts, where chain recurrence involves arbitrarily small deviations from orbits. In simple computer models, deviations at each iteration involve a fixed accuracy of the hardware/software configuration. The decomposition of a dynamical system with a fixed bound on the "error" at each iteration is one model for this computer simulation.

The speaker will describe some results relating such decompositions to the arbitrary "error size" decomposition and suggest implications for models of certain discrete dynamical systems by computer.

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An Extended System with Determined Auxiliary Vectors for Locating Simple Bifurcation Points

Using an extended system to locate a simple bifurcation point via an iterative method usually requires a good choice of an initial point as well as several auxiliary vectors. The method we propose here requires a good choice of an initial point only. Our method is based on an analysis of certain types of auxiliary vectors, which leads to the automatic determination of these vectors in terms of the initial point. Numerical implementation via a Newton-like method is discussed and examples are provided.

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Computer Generation of Symmetric Patterns

This presentation is on the area of pattern formation, especially the generation of symmetric patterns by computer graphics. A study of generating algorithms is invaluable to understand the intrinsic properties of the governing dynamical equation or mapping relating to the generated patterns. Dynamical equations in recursive form are widely used to create fractals, colorful patterns and to simulate the metamorphosis of living things. However, very limited results are obtained on the systematic generation of wall-paper and tiling patterns. In this persentation, conditions for dynamical equations to produce symmetric patterns of the seventeen plane symmetry groups will be discussed. A technique will be highlighted on how to look for appropriate dynamical equations to generate symmetric patterns.

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CP 19

Algebraic Decay and Phase-Space Metamorphoses in Microwave Ionization of Hydrogen Rydberg Atoms

We study the microwave ionization of hydrogen atoms using the standard one-dimensional model. We find that the survival probability of an electron decays algebraically. Furthermore, as the microwave field-strength increases, we find that the asymptotic algebraic decay exponent can decrease due to phase-space metamorphoses in which new layers of KAM islands are exposed when KAM surfaces are destroyed. We also find that after such phase-space metamorphoses, the survival probability of an electron as a function of time can have a crossover region with different decay exponents. We argue that this phonomenon is typical for open Hamiltonian systems.

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Hamiltonian Dynamical Analysis of A Basic Two-Wave Interaction in Plasma Physics

The Vlasov-Poisson equations, which describe the physics of collisionless plasmas, comprise an infinite-dimensional Hamiltonian dynamical system. An important class of solutions of these equations are the so-called BGK traveling waves. While recent studies demonstrate the existence of these waves arbitrarily close to the manifold of Vlasov equilibria, straightforward analysis suggests that superposition does not yield a new solution, even in the limit of small wave amplitude. However, our detailed investigation of the nonlinear equations of motion for charged particles in such superimposed fields shows otherwise. The analysis, which employs Hamiltonian methods within each of the topologically distinct regions of the phase space corresponding to the primary and higher-order wave-particle resonances, as well as in the exponentially thin stochastic or chaotic layers surrounding them, shows that BGK waves do satisfy an approximate principle of linear superposition. Such superimposed waves may be crucial in the basic understanding of the time evolution of nonlinear plasmas.

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Tori and Chaos in a Nonlinear Dynamo Model for Solar Activity

A nonlinear dynamo model for solar activity which includes the feedback of the helicity upon the mean magnetic field has been investigated. The qualitative behaviour of a seven dimensional system of ordinary differential equations obtained by truncation of that model has been studied numerically. It has been compared with results from a sixth order system derived from the seventh order system by a special polar coordinate transformation. In dependence on characteristic parameters the seven dimensional model exhibits periodic, quasiperiodic (on T^2 and T^3) and chaotic behaviour where a route to chaos via the transition $T^2 => T^3 => T^2$ chaos has been found to be typical. In contrast to be typical. In contrast to that no chaotic state occurs in the reduced system due to a nonregularity of the coordinate transformation.

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Thermodynamics of Dissipative Systems

Equilibrium thermodynamics studies the macrobehavior of the systems under slow change of parameters, while the relation between macrobehavior and chaotic micromotion is the subject of statistical mechanics. Thermodynamics and statistical mechanics were developed as asymptotical theories which are true in the limit of infinite number of degrees of freedom. Recently it was shown that all relations of thermodynamics and statistical mechanics are valid for ergodic and approximately ergodic Hamiltonian systems with any (even small) number of degrees of freedom. Some extensions of these results to nonergodic and dissipative systems are considered in this presentation. Thermodynamics of such systems differs essentially from classical thermodynamics. First, nonergodic Hamiltonian systems are characterized by a number of temperatures. Second, there are nonergodic Hamiltonian systems for which thermodynamical entropy does not exist. Existence of entropy is substituted for nonergodic Hamiltonian systems by the existence of some integral invariant. For limit cycles and strange attractors of systems with small dissipation, a universal relation is established which is an anology of the first law of thermodynamics.

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Permanence of Stochasticity Thresholds in KAM systems

The classical behaviour of a one-dimensional anharmonic chain with nearest-neighbor interaction via a Fermi-Pasta-Ulam potential, is numerically investigated. We test some numerical methods, widely implemented in the literarure, which seem to be rather poor for these kind of purposes. We introduce next two new parameters in order to verify the permanence of stochasticity thresholds when one increases the number of degrees of freedom: the Hausdorff dimension of the Fourier transform of a dynamical variable and the inverse square of the fluctuation of the total kinetic energy versus specific energy and number of degrees of freedom. Our results are definitely inconsistent with the vanishing of stocasticity thresholds (i.e. of the invariant KAM tori) in the thermodynamic limit.

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Control of Turbulence and Transport in the Small Tokamak TBR-1

Eletrostatic turbulence and magnetic fluctuations have been measured with probes in the TBR-1 plasma edge. The experimental set-up and the two-point correlation technique are similar of those in the TEXT tokamak (The University of Texas). In TBR-1 the MHD activity is unusually high and its frequency range contains the frequencies for which the electrostatic fluctuations and its associated particle transport is expressive. Striking localized (short radial extend) characteristics such as coherency and phase difference between magnetic and electrostatic fluctuations were observed. These effects could be caused by the propagation of electrostatic sound waves along stochastic magnetic field lines created by the high MHD activity. Furthermore, preliminary results indicate that the turbulence and the transport are sensitive to external currents, on resonant helical windings, used to control magnetic fluctuations.

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CP 20

Pattern Selection in Rotating Rayleigh-Bénard Convection in a Finite Cylinder

Convection in a finite cylinder rotating about its axis is studied at the onset of the convective instability using analytical and numerical techniques. Using symmetric bifurcation theory, we show that, generically, one expects the initial bifurcation to be to a Hopf bifurcation to a precessing pattern. This is in contrast to the results for an unbounded layer, which predict steady state solutions except for very small Prandtl numbers. We present solutions to the linearized Boussinesq equations for various values of the Taylor number and cylinder aspect ratio, and for both idealized and realistic boundary conditions. We discuss these results in light of recent experimental work on small aspect ratio cylinders (Zhong, Ecke and Steinberg, PRL, 67, 2473).

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Three-Dimensional Oscillations of a Fluid Conveying Tube with Discrete Symmetries

The postbifurcation behavior of a slender viscoelastic cantilever tube conveying incompressible fluid flow with a $\mathbf{D}_N$-symmetric elastic support is studied. Due to its symmetry properties this is a mathematically interesting and technically relevant problem. Sofar only $\mathbf{O}(2)$-symmetric tube problems have been treated in the literature.

Compared to previous work for the derivation of the tube equations director rod theory is used which allows to describe the nonlinear deformation of the tube in a geometrically exact way.

The dynamic system governed by a set of nonlinear partial differential equations is treated as a two parameter bifurcation problem using the methods of Equivariant Bifurcation theory.

For some values of N a mathematical classification, physical interpretation and comparison of the different types of the stationary solutions is given for some coincident eigenvalue cases of the corresponding linearized problem.

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Solitons on a Vortex Filament with Axial Flow

The extended local induction equation, which accounts for the axial flow, is investigated on the basis of the inverse scattering method. The present analysis provides N soliton solution with the intrinsic symmetry with respect to the constituent solitons.

The characteristic parameters of the vortex soliton, especially the effect of the axial flow, are determined from the experimental observation of solitary wave propagating along the vortex filament. Thought the two solitons collision process is consistent with the experimental observation, our theoretical analysis is unable to account the observed large phase jump after the head-on collision of two solitons.

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A Package for Determining Pattern Selection in Convecting Systems

A computer package has been developed to calculate (via an asymptotic expansion of the fluid equations in the vicinity of the onset of convection) the normal form coefficients relevant to pattern selection. While such reductions can be done by hand for specialized boundary conditions, the tedious manipulations and the requirement of numerical calculations for many realistic boundary conditions make quantitative comparison with experiment difficult and rare. By automating these algebraic and numerical calculations, this package allows reliable exploration of pattern selection in many convecting systems with a variety of boundary conditions and parameter values. Several systems such as binary fluids and rotating fluids have already been studied with this code.

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Lyapunov Exponents for Hydromagnetic Convection

We estimate the two largest Lyapunov exponents in a three-dimensional simulation of hydromagnetic convection in which there is dynamo action. It turns out that these first two exponents (from a total of $8x63^3$) are positive and of similar magnitude. Thus we conclude that the dynamo is chaotic. Furthermore, the consideration of local exponents helps in our understanding of the relevant dynamics. We find that the downdraft flows are more chaotic than the upward motions. Likewise, the velocity and magnetic fields have more chaotic dynamics than the temperature and density fields.

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Atmosphere-Ocean Models with Quasiperiodic or Stochastic Forcing

The atmosphere-ocean system displays features having coherence in space and time which, though nonperiodic, exhibit some stochastic regularity. Examples vary from atmospheric blocking episodes (timescale ~ 10 days) to ice ages (timescale ~ 10^5 years). Of great current interest is the El Nino - Southern Oscillation (ENSO) phenomenon of the equatorial Pacific, which, both directly and through conjectured teleconnections, is responsible for damaging climatic anomalies.

We report numerical experiments on simple conceptual models for ENSO, representing an ocean system subjected to quasiperiodic or stochastic forcing designed to mimic known physical influences. A critical appraisal of the data suggests crucial tests for the integrity of such models.

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Poster

Simulation of Sustained Reaction-Diffusion Oscillations on a Massively Parallel Computer

A computer simulation model has been adapted to follow chemical oscillations in a two-dimensional drum membrane. The model uses a 16,384 processor Massively Parallel computer and algorithms developed to study systems undergoing non-linear chaos. The membrane is represented by a two-dimensional circular surface within which an immobilized enzyme is uniformly distributed. The membrane is permeable to two substrates which diffuse and exhibit a non-linear reaction due to the presence of the enzyme. With the proper choice of kinetic parameters, oscillations develop spontaneously and sustain themselves. The model displays the time evolution of the sustained oscillations.

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Amplitude Expansions for Instabilities in Populations of Globally-Coupled Oscillators

We analyze the structure of amplitude expansions around the incoherent state for a continuum model of globally-coupled oscillators recently proposed by Mirollo and Strogatz. For the Fokker-Planck equation of this model, we derive the amplitude equations appropriate to both steady-state and Hopf bifurcation from the incoherent equilibrium state using center-manifold reduction. Of particular interest is the stability of bifurcating branches describing the onset of synchronized behavior and also the limit of zero diffusion, when the critical eigenvalues are embedded the continuous spectrum. Connections to similar instabilities in collisionless plasma theory are discussed and our calculations are compared to the recent theory of Bonilla, Neu, and Spigler.

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A Fractal Model of Diffusion in Extracellular Space (ECS) of the CNS

Diffusion is the underlying mechanism for information transmission in the ECS. The complex shape of the ECS, due to densely aggregated cells and the interdigitation of cellular processes, fundamentally alters the characteristics of diffusion. Fick's equations have been modified to account for the complex geometry. However, due to the influence of absorption the diffusion characteristics of neurotransmitters and neuropeptides are not adequately described. Furthermore, the modifications may not fully describe the geometry at different length scales. Investigations describing a fractal model of diffusion based on a random walk on a fractal substrate will be reported. Computer simulations of random walks on fractals with the same fractal dimension as the ECS will be described. This model can be modified to incorporate the effects of absorption on diffusion.

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Asessing Complexity in Biological Data Sets.

M.P. Paulus.

Biological data contain important sequential information that is not assessed adequately by calculating measures of the distribution functions. Moreover, linear methods, e.g. autocorrelation or FFT, may not detect sequential relationships in biological data, which are subject to highly nonlinear influences.. Nonlinear techniques, e.g. dimensions, Liapunov exponents, or dynamical entropies, have provided new measures to characterize sequential information in biological data. However, the estimation of the dimension or the Liapunov exponents is requires large data sizes and assumes that the generating process is deterministic with a few degrees of freedom. In contrast, the dynamical entropy can be computed for deterministic as well as for random systems. Efficient algorithms are available that maximally extract information based on nearest neighbor statistics allow to determine the generalized entropy function even for data sets of moderate size (n=500). Applications of dynamical entropy measures to different biological data will be presented and the estimation accuracy will be compared to generic nonlinear dynamical systems that are randomly perturbed.

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A Slightly Nonlinear Stability Model for Driven, Dissipative Magnetohydrodynamic Systems*

Magnetohydrodynamic (MHD) stability studies are ubiquitous in magnetic fusion research. However, much stability theory is restricted to linear perturbations of the ideal (inviscid, perfectly conducting) MHD equations to stationary equilibria. This work examines nonlinear stability when the transfer of energy from a driven, symmetric "equilibrium" to an unstable, asymmetric mode and dissipative effects are considered. A heuristic model is derived for the dynamics of the amplitudes of the driven, symmetric state and one linearly unstable ideal mode. The resulting two dimensional system is observed to undergo a supercritical pitchfork bifurcation at a critical Lundquist number in the autonomous case. A second bifurcation of the saturated fixed points is also seen.

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Bifurcation Structures of Minimal ODEs from Weighted Sobolev Projections of PDEs

In Kirby [1991], "Minimal dynamical systems from PDEs using Sobolev eigenfunctions" (to appear in Physica D), a modified Karhunen-Loève transform is derived using a Sobolev-type norm. This optimizes the approximations of the higher derivative terms in numerical simulations of partial differential equations and leads to a further reduction in the size of the associated system of ordinary differential equations. Here we consider the effect of varying the weighted Sobolev optimality criterion on the dynamics of these sets of ODEs by treating the weighting coefficients as bifurcation parameters in the ODEs and studying the resulting bifurcation structure. The Kuramoto-Sivashinsky equation is used as an example and we analyze the improved preformance of the new norm in terms of the bifurcation problem.

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Effect of Actuator Positions on the Performance of Ground Vehicle Systems

The preliminary results in the area of actuator placement in lumped parameter system like the ground vehicles has been reported in in this paper. A criterion has been developed relating the optimal actuator position to the location of a known disturbance.

Linear time invariant lumped parameter models of vehicle suspension system were chosen to investigate the effect of control actuator locations. Results of the simulations show that the optimal actuator location is the one closest to the source of the unknown disturbance. This work suggests to place the actuator as close as possible to the source of known disturbance.

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On the Characterization of Turbulence as Spatio-Temporal Chaos

Irregular spatio-temporal behavior in distributed dissipative systems involves a large number of degrees of freedom. A global attractor description of such a turbulent state uses a single point in phase space to represent the entire spatial domain. A difficulty is the large amount of data required to extract desired dynamical measures. Here, we describe a methodology to characterize turbulence as spatio-temporal chaos and apply it to 2-D thermal convection, the ocean, and the atmosphere. This general approach effectively deals with the many degrees of freedom by taking into account the spatial complexity of the turbulence.

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On the Fractal Nature of Human Heart Rate Variability and the Effect of Sympathetic Blockade

Human heart rate variability (HRV) is fractal in nature. The origin of these complex dynamics is uncertain. Because HRV is largely influenced by variations in parasympathetic (PNS) and sympathetic nervous system (SNS) activity, we evaluated the effect of SNS blockade on the fractal property of HRV. After evaluating the fractal component from >2 h HRV data by a renormalization technique (1), fractal dimension was calculated for both placebo and propranolol. Fractal dimension did not change with SNS blockade. The dynamic complexity of HRV appered to be maintained by the PNS.

[1.] YAMAMOTO, Y., AND R. L. HUGHSON. *J. Appl. Physiol.* 71:1143, 1991.

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Parasympathetic Blockade Reduces Dynamic Complexity of Heart Rate Variability

Complexity of heart rate variablity (HRV) is regarded as an important feature of the healthy heart. We studied the hypothesis that parasympathetic nervous system (PNS) activity was related to the origin of dynamic complexity of HRV. Dimensionality of 10 min HRV data was evaluated before and after the intravenous administration of atropine. Confirmation was made that the fractal dimension for 10 min data was not different from that for >2 h data using CGSA method (1). PNS blockade dramatically reduced the fractal dimension of HRV. Dynamic complexity of HRV appeared to be maintained by PNS activity.

[1.] YAMAMOTO, Y., AND R. L. HUGHSON. *J. Appl. Physiol.* 71:1143, 1991.

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Šil'nikov-Hopf Bifurcation

We present a 2-parameter Poincaré map modeling a 3D vector flow near the codimension-2 point defined by a Šil'nikov homoclinic orbit to a fixed point undergoing a Hopf bifurcation. In one parameter regime the map reproduces Glendinning and Sparrow's results for the Šil'nikov bifurcation [J. Stat. Phys. 1984] while in another regime it provides new results for a small Hopf cycle with a global reinjection mechanism. The map is analyzed finding primary homoclinic tangencies to the small Hopf cycle. Parameter dependence of periodic orbits associated with these tangencies is described. Global behavior of the tube-like unstable manifold of the Hopf cycle is studied in depth, analytically and numerically, locating its simplest subsidiary tangencies.

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Scaling in an Electroencephalogram

The relationship between chaotic dynamics and EEG signals has been explored by various researchers in an effort to understand the dynamics of the EEG. A behavior which is typically exhibited by a chaotic system is self-similarity, as indicated by the value of the fractal dimension of the signal. In order to avoid difficulties that can arise when using box counting on a temporal record, we have used rescaled range analysis to determine the scaling behavior of a set of EEG. Results indicate two scaling regions, each with a characteristic scaling exponent. These exponents may be useful in characterizing cognitive processes.

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A Lax Pair for the Three-Wave Interaction of Four Waves

Resonant wave-wave interaction is a weakly nonlinear process of great importance in the study of wave phenomena. Many aspects of this interaction have been considered covering from the most elementary interaction involving a single triplet of waves to more complicated multiple triplet cases. In here we consider a system of four interacting waves constituting two resonant triplets. We construct a Lax pair with a spectral parameter for this system, therefore proving its integrability, and exhibit the integrals of motion. We also obtain a criterion for the stabilization of the (explosive) instability that may occur when waves of positive and negative energy interact.

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Hemapoietic Models with Delays

From an age-structured model for erythropoiesis and thrombopoiesis a mathematical model is derived which contians two delays. This work is a collaboration with Jacques Bélair and Michael Mackey. A stability analysis of the differential equations with two delays determines when Hopf bifurcations occur. The model for erythropoiesis contains longer delays but proves to be more stable than the model for thrombopoiesis. The behavior of the model is compared to experimental data to ascertain which parameters may be significant in certain disease states.

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On Non Linear Normal Modes: Geometrical Concepts and Computational Techniques

This paper is concerned with special periodic motions called the non linear normal modes (NMM) which have been ocurred in a wide class of undamped or damped coupled oscillators.
We will be interest in the use of Poincaré map to study the bifurcations of the (N.M.M.)'s, the application of the homoclinic Melnikov analysis

for proving the existence of transverse intersections and the examination of the steady state motions with periodic excitations for the oscilladors considered. The results are applied to an example of a non linear spring-mass system with two degree of freedom.

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An Investigation of Transverse Effects in the Dynamics of Solid State Laser Systems

In order to meet power requirements for lunar and interplanetary exploration, solid state lasers are being developed which will be used for power transmission from space-based satellite platforms. In response to the need for understanding the transient development of the dynamical processes and in order to compute the far-field power distribution of the output beam, a mathematical model which accounts for axial and transverse variations in the dynamic quantities has been developed. The model describes the four-level operation of a solid state laser and accounts for transverse variations in the excitation of the laser as well as transverse effects due to diffraction by the apertures of the cavity. The model will be presented along with general qualitative characteristics and numerical results specific to Titanium doped sapphire and Nd:YAG lasers.

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Evolution of 2-D Instabilities in Circular Shear Layers

We present results of an analytical and numerical study of 2-dimensional rotating fluid flow observed in split-disc experiments (Chomaz et al. JFM. 1988. 187. 115). We study instabilities of a forced circular shear layer. and their saturation to discrete numbers of stationary or undulating vortices. Our numerical work. utilizes a highly accurate spectral algorithm solving the Navier-Stokes equations in an annular geometry. No-slip boundary conditions are imposed directly as constraints on the vorticity. while no artificial viscosity is necessary due to high (512^2) resolution of our simulations. We calculate bifurcated solutions exhibiting subharmonic modulations and transitions to time dependent states.

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Arnold Sausages for the Sawtooth Circle Map

A piecewise linear approximation to the classical sine circle map. f(x) = x + a - b sin(2 Pi x) (mod 1) has stable resonance regions that can be completely described analytically. The Arnold tongues in this case turn out to be more like "sausages." with nodes at which the tongues have zero width and at which the map reduces to the identity map. On the critical line for the map. the Cantor set of parameter values for which the dynamics is chaotic has fractal dimension zero.

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A Study of an Algorithm Using A Posteriori Error for Adaptive IIR Filters

An adaptive IIR filter is a nonlinear, time-varying system. In contrast to an FIR filter, an IIR filter can offer a significant reduction in computation. Unlike most output-error-type algorithms for adaptive IIR filters, the hyperstable adaptive recursive filter (HARF) algorithm, which uses a posteriori error, is globally convergent, but the requirement for a strictly positive real (SPR) transfer function is unnecessary and impractical. In this paper, a robust and rapidly convergent algorithm for adaptive IIR filters is proposed. Its global convergency is proved using the theory of Liapunov stability. Furthermore, the annoying SPR requirement is completely removed.

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Lie Symmetries for Three-Dimensional Models

Several methods have been devised for studying the existence of first integrals and the integrability of dynamical systems, as the singularity analysis or the direct method. The generalised Lie symmetries can be used also for finding the parameter values at which one or more integrals exist both for hamiltonian or non-hamiltonian systems. The integrals are found from Lie symmetries in a straightforward fashion. We use this method for studying domains of integrability for some three-dimensional models: the reduced three-wave interaction problem, the generalised Rössler system and the Lotka-Volterra model.

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Numerical Study of Separatrix Breaking of Adiabatic Invariants

The breaking of adiabatic invariants caused by orbits crossing a moving separatrix is studied for an archetypical, slowly time-dependent, one-degree-of-freedom Hamiltonian system. The known analytical results are reviewed. Using a highly accurate symplectic integration algorithm, we have made numerical computations of trajectories crossing the separatrix. Good agreement is found between the numerics and existing theory. The numerics however does indicate some additional features not captured by the analysis, namely a "Gibbs phenomenon" in the oscillations of the adiabatic invariant, and systematic errors of the formula for the adiabatic invariant change near its singularity.

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Helicity in Hamiltonian Dynamical Systems

For certain volume preserving vector fields **u** the quantity known as total helicity $\int \mathbf{u} \cdot (\nabla \times \mathbf{u})\, d\mathbf{x}$ is an integral invariant for the system. In this poster we discuss how helicity may be defined and under what conditions it is conserved, in the general setting of Hamiltonian dynamics. Cross helicity, a related quantity, is discussed on the same footing. We illustrate how conservation of helicity can imply a bound on other quantities of the motion in a nontrivial way.

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Bifurcations and Stability of Motions of One Mechanical System

The analysed system is a rigid body, suspended on a pivot-combination of pendulum and gyroscope. Experiments with suspended rigid body, connected with investigations of balance, tether, parachute systems, have shown unexpected step-wise changes of stationary motions.
In this work the multi-dimensional surface of stationary motions in the space of system's parameters was examined. The obtained singularities of mapping of this surface (the type of assemblings and foldings) determine bifurcations of the regimes and changers of their stability.
The used method allows to analyse only the limited class of motions, though geometrical approach gives an integral view on this class.

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Fractal Structures on the Viscous Fluid Surface

The stability of viscous fluid surface in case of external diffusion mass flow is studied. The evolution of fractal structures arising on the surface is analysed. This research is a naturally stage of fractal hidrodynamics.
The method of solution is based on description of pressure as a projection of generalized function with a boundary carrier on the subspace of harmonic functions. For the present the method allows to examine only plane flows. It's variation formulation is expected to make it possible the three-dimensional flows analyses. This work represents non-trivial example of fluid flow with variable boundary smoothness and connectivity.

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Classification of Heteroclinic Ω -Explosion

We consider one-parameter families of diffeomorphisms $\varphi_\mu : \mu \in R$ a closed surface, which have heteroclinic tangencies at $\mu = 0$ and are persistently hyperbolic, or Ω-stable for $\mu < 0$. Using the Palis Takens method [1] which was successful for analyses on homoclinic Ω-explosion, we classify bifurcations with Ω-explosion according to the signs of the eigenvalues of two saddle fixed points, the sides of tangency and the mode of connection. Moreover, we show some examples of such bifurcations which can be related to nonlinear oscillations in real physical systems.

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On The Dynamics of Some Endomorphisms of The Plane

We study a class of mappings of the plane which may be viewed as geometric analogues of unimodal mappings of the real line. The geometry of the maps, that is, the singular points and singular values, constrains the dynamics. For example, the region enclosed by the singular values serves as a trapping region for the dynamics while the number of cusp points constrain the number of attractors. For large parameter values the dynamics, on the invariant set, is conjugate to the shift map on infinite sequences of 4 symbols.

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Nonlinear Oscillation and Chaos in Backward Four Wave Mixing

The four wave mixing interaction of two counterpropagating pump waves, both of frequency ω_0, and probe and signal waves, of frequency $\omega_0 - \omega$ and $\omega_0 + \omega$, has been studied. The problem is of interest in intertial confinement fusion, optical phase conjugation and nonlinear fiber optics. It is a simplified model of the transverse modulational instability of counterpropagating light waves. Theoretical and numerical results for the spatial temporal evolution of each wave, including nonlinear saturation, periodic oscillation and chaotic behavior, are given for several different parameter regimes. A key issue to be resolved is how the system determines its dynamical behavior when there exist several possible steady states, as is the case for pump intensities exceeding their threshold values for absolute instabilty.

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Invariant Manifolds in Homogeneous Chemical Kinetics

We present a contraction mapping method for finding "attracting" invariant manifold structures in the (autonomous) ODEs of chemical (enzyme) kinetics. These manifolds form a nested hierarchy in phase space and are the stable fixed points of functional equations derived from the ODEs. The geometry of this hierarchy controls chemical relaxation, and the corresponding formulas suggest the best experimental conditions for obtaining rate constant information. We describe the stability analysis, bifurcation structure, perturbation theory, and computer algebra manipulations related to determining the manifold hierarchy.

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Chaotic Behavior in a "Prey-Predator" Model

The real observable dynamics of biological objects development often demonstrate a chaotic behavior. What is this stochastic behavior caused by? Is it a result of inner motives or connected with the inaccurate observations? According to the report chaotic behavior is a result of the interaction among inner periodical dynamics of biological system and periodical changes of external environment. The mathematical model of "prey-predator" type was used for verification of this hypothesis.
The arised complex regimes were examined by the calculations. It is illustrated how a frequency spectrum is changing and aperiodical regimes are developing.

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MOTION OF ENERGY EIGENVALUE LEVELS

Let H_0 and V be symmetric $n \times n$ matrices over $\mathcal{R}$. Let $\lambda \in [0, \infty)$. Then $H_\lambda = H_0 + \lambda V$ is a symmetric $n \times n$ matrix. Assume that the eigenvalues of H_λ are non degenerate. Let $\{u_j(\lambda) : j = 1, \ldots, n\}$ be the eigenvectors and $\{E_j(\lambda) : j = 1, \ldots, n\}$ be the eigenvalues. Then one can derive an autonomous system of ordinary differential equations [1] for the eigenvalues $E_n(\lambda)$ and the matrix elements $V_{mn}(\lambda) := (u_j(\lambda), Vu_j(\lambda))$, where λ is the independent variable and $(\,,\,)$ denotes the scalar product in the n dimensional Euclidean space. We describe an extension to symmetric matrices of the for form $H_\lambda = H_0 + \lambda_1 V_1 + \lambda_2 V_2$, $H_\lambda = H_0 + \lambda V + \lambda^2 V$ and $H_\lambda = H_0 + \sum_{k=1}^{m} f_k(\lambda) V_k$.

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Minimum Energy Optimal Control for Linear time-invariant discrete-time systems

Consider the time-invariant descriptor system $E\,x(k+1) = Ax(k) + Bu(k)$. E and A are not necessarily square matrices. The problem is this: find an input sequence which will drive x(k) from a given x(0) to a desired "Final Vector" x(N) in a given number of steps N while minimizing the cost $J_n(u) = \frac{1}{2}\sum_{k=0}^{N-1} u^T(k)u(k)$ by two methods using the "moore-penrose" inverse in one and optimal control theory in the other.

The novelty of this papers approach is in the use of the "moore-penrose" inverse to find an "optimal controller" which generates optimal sequence of state vectors and the performance index is minimum.

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Stable Invariant Manifolds

The theory of invariant manifolds plays an important role in the study of dynamics of nonlinear systems in finite or infinite dimensional spaces. Knowledge of the invariant manifolds of a dynamical system as well as their respective stable and unstable manifolds is not only of interest from a qualitative point of view, but can lead to quantitative results. In fact, by restriction to an invariant manifold, an original system is reduced to a lower-dimensional one which may be relatively simple.

In the present lecture, we show that, without much additional efforts, the results of O. Perron (1930) on the stability of perturbed linear systems imply most of the geometric results on stable manifolds, hyperbolic sets and the like which are known until now.

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Theoretical and Experimental Investigati on of the Powerful Acoustic Pulse Propagation in the Atmosphere

Recently, a new direction in the atmospheric acoustics is intensively developed - propagation of powerful acoustic pulses Such pulses permit one to make atmospheric sounding, to define the fine structure of the temperature profile, to define the velocity and direction of wind.

The paper gives the analysis of works on propagation of powerful acoustic pulses. The main attention is paid to mathematical description of nonlinearity effecting on parameters of an acoustic pulse.

A recently developed source of acoustic pulses is described which is based on detonation of petrol-air mixture in semi-closed volume. The results of experimental investigations are given.

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A GENETIC ALGORITHM FOR THE OPTIMIZATION OF MULTIOBJECTIVE ROUTING PROBLEMS

The dynamic complexity of flexible manufacturing systems (FMS) makes the search for optimal solutions to process planning selection problems (PPSP) a major challenge.

Optimization techniques often used to address these types of problems include integer programming, dynamic programming and, more recently, fuzzy logic approaches. Unfortunately these methods tend to become unwieldy and inefficient when dealing with larger routing networks that are common features of FMS.

This paper formulates the FMS-PPSP first as a multiobjective routing network using a matrix method. Subsequently, a *directed randomized technique* - known as a genetic algorithm - is adapted to find the optimal path within the network. In order to meet the problem domain requirements, novel operators have been introduced to modify the genetic algorithm.

The fundamental mechanisms of genetic algorithms are borrowed from the concepts of natural selection and natural genetics - hence the name. Their ability to handle nonlinear functions, finding the global solution, as well as using accumulated information to prune the search space, make genetic algorithms excellent candidates for use in PPSP.

The application of our algorithm to a realistic routing problem shows its promise in terms of robustness and its rate of convergence to a global optimum.

We suggest that this new algorithm should have superior performance characteristics when compared to other available techniques, particularly as the system considered becomes increasingly more complex. The algorithm can also be profitably adapted to problems in communication as well as transportation networks.

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The Dynamics of Electrostatic Discharges

Electrostatic discharges do a lot of damage to electronic equipment, aircraft, and buildings. Gaining a better understanding of discharges is paramount to developing methods to protect against the discharges. The discharge process is nonlinear and the fractal nature of discharges is very evident in lightning. Traditionally, the discharge process is considered to be random. We have built an electrostatic discharge system that computer monitors the time of the discharges from a Van de Graaf generator and plots a return map. We will show various return maps we have obtained from the experiments and talk about the system nonlinearities. The motor speed and discharge gap are variables in the experiment.

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Computational Analysis of a Bursting Neuron Model

A mathematical model for bursting oscillations in neuron R15 of Aplysia is presented. This model consists of ten coupled nonlinear ODEs whose time scales vary from milliseconds to seconds. The phase plane solutions, bifurcations and waveforms are studied. Application of the neurotransmitter serotonin, which is known to have medium-term modulatory effects on R15 is simulated and its effect on the bursting is analyzed. The response of the model neuron to classical synaptic inputs both at control and in the presence of serotonin, is investigated

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RESTRICTED FLOWS OF SOLITON EQUATIONS "A Golden Key"for Constructing and Solving Physically Interesting Integrable Mechanical Systems

Restricted flows of soliton equations provide a simple and effective way of constructing integrable sets of Newton equations or integrable dynamical systems. Vary many new systems arise this way. All these systems have a Lax representation and can be solved by the spectral curve method.The general method is illustrated by the KdV hierarchy example.

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Bubbles and Drops Soliton Solutions in the φ^6 Field Theory

We have studied the φ^6 model in the parameter domain $A > 1$. For this case we have found out a new type of soliton solutions such kinks, bubbles and drops. The investigation of these waves around the stable minimum shows that the sound velocity provide a rigid constraint for these oscillations to be or not to be stable. This is the question.

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Anchoring of filaments by localized inhomogeneities in 3D Excitable Media

Experimental studies in thin layers of cardiac muscle have shown that filaments of spiral waves can become anchored by localized inhomogeneities such as thin arteries or small areas of damaged tissue. It has been proposed that this phenomenon occurring in 3D cardiac muscle tissue may underlie dangerous pathological heart rhythms. Here we use a computer model (implemented on a parallel computer) to study the dynamics of anchoring in 3D. We find that when one end of the filament is anchored, the rest of the filament continues to drift, and often detaches from the anchoring point when the filament tension exceeds a critical value.

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Applications of Dynamical Systems with Controllable Memory

Dynamical systems with Controllable Memory are described by integral Volterra Equations (IVE) with unknown lower integral limits $Z(t) < t$. The quantity $t-Z(t)$ is called the system memory.

The bulk of applications of such IVE is a modelling of large-scale developing systems, consequences of large technological changes and industrial programs, technical rearmament, development and renovation of industrial and economical systems, modelling of technical progress and work's periods of industrial powers and equipment. Similar equations occur also in fluid mechanics with moving interfaces, in ecology when studying the variable life span or reproductive age, etc. The methods of such

IVE research are developed. The turn-pike theorems for optimal trajectories $Z(t)$ are proved.

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First-Order Analytic Approximations of Orbits on the Invariant Manifolds of the Forced Duffing Oscillator

First-order approximations of orbits on the [illegible]riant manifolds of the harmonically forced, undamped Duff[illegible]ator with negative stiffness are computed. The a[illegible]utions are then used to prove the existence of trans[illegible]oclinic intersections in the Poincare' map of the force[illegible] without resorting to Melnikov analysis. In principle [illegible]ysis can be carried to higher order of approximati[illegible] behavior at infinity of certain particular solution[illegible]etermined. To the author's knowledge the exact first o[illegible]analysis of this work has not yet appeared in the existing literature.

CANCELLED

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Dynamics of the Great Salt Lake from its time series

The volume and salinity of the Great Salt Lake undergo significant, persistent variations, and reflect an interplay of climatic and hydrologic forces. Recovering underlying dynamics from noisy time series is particularly challenging for natural systems, where the underlying physics is complex. An identification of the underlying dynamics is facilitated by an interpretation of Taken's Embedding theorem in the context of Markov Processes. We propose a multivariate, nonparametric approach for the estimation of probability measures, dimension identification and prediction. An application of these methods for identifying dynamical regimes of the Great Salt Lake, as well as short term forecasts is presented.

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NONTRIVIAL DYNAMICS IN A DRIVEN STRING WITH IMPACT NONLINEARITY

Consider a string with one end fixed and the other end forced to move periodically transversal to the string. A stop is positioned near the string, so that the dynamics become nonlinear when the string hits the stop. Experimentally and analytically some aspects of the planar motion are investigated with the driving frequency around the lowest resonance of the nondriven string. Varying driving frequency and amplitude one observes hysteresis and bifurcations : for instance transitions from periodic to chaotic motion, with a broad pyramid shaped spectrum around the driving frequency. A nonlinear symmetric standing wave of the nondriven string forms the theoretical 'backbone' for these phenomena.

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Controlling Infinite Dimensional Systems Exhibiting Chaotic Dynamics

It is frequently desirable to control a system evolving chaotically to exhibit a range of stable periodic motions without brutally altering the system at hand. We present a mechanism which is capable of controlling a chaotic system possessing an arbitrarily high, possibly infinite, number of degrees of freedom through small perturbations in an accessible parameter. Specifically, it is shown how unstable periodic orbits embedded in a chaotic attractor can be stabilized directly from a scalar time series, without assuming any knowledge of the underlying dynamical equations. Previously, control procedures involving parameter perturbations have been devised only for low-dimensional systems. Even in such cases, we show that the data requirements can be significantly reduced using our new formulation.

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An Investigation of the Effect of Dampers on the Response of a Harbour to Incident Waves

The anchorage of ships, buoys and other vessels in docks and harbours must be done with guarantee of safety of this equipment. The analysis of the response of a harbour to incident waves is important for this reason.
It is known that sometimes the response of a harbour to incident waves is frequency dependent. The ship and its mooring lines constitute a dynamical system and for certain frequencies of wave incidence resonance can occur with much navigational hazard. However, the placement of certain structures referred to here as 'dampers' can lead to significant attentuation of the surface water oscillation. The aim of the present paper is to look critically at the mathematical analysis of this important problem.

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Van Der Pol Oscillator: Behavior Under Periodic and Quasi-periodic Excitations

We present a detailed investigation of the behavior of a van der Pol oscillator subjected to periodic and quasi-periodic forcing terms. We investigate first the parameter space for which chaotic behaviour was recently reported for a van der Pol oscillator excited by a periodic force of the generic type $A\cos(\omega_1 t)$. A key point is to investigate how attractors change as functions of the different possible relations among the autoperiodic ω_0 and the external ω_1 pulsations. In particular we investigate effects of quasi-resonant excitation as well as locking effects for different degrees of approximation of ω_0/ω_1 by rational numbers

In addition, we present a detailed investigation of the effect of driving the same oscillator with a quasi-periodic bichromatic excitation characterized by ω_1 and ω_2 as well as of driving it with a periodic but complicate meromorphic function. Quasi-periodic excitation was recently reported to "reduce" chaotic behaviour of a van der Pol oscillator. We show that such changes are not due to quasi-periodic forcing but are also present under periodic excitation. In summary, we identify which phenomena are typical of periodic, meromorphic or not, and of quasi-periodic excitation.

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The Parameter Space of Codimension-two Dynamical Systems

We investigate the parameter space of codimension-two dynamical systems. In this space we classify each point according to whether trajectories starting from them evolve to either stable attractors, chaotic attractors or to the attractor at infinity. Such classification provides a three-color map of the parameter space where it is possible to see a number of periodically repeating structures as well as sharp lines and corners between borders of parameter-basins corresponding to the different types of attractors. We investigate the dynamical reasons for such structures and discuss features common to some familiar codimension-two dynamical systems such as the Henon map and the forced pendulum.

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Global Asymptotic Behavior of Some Iterative Implicit Schemes

The global asymptotic behavior of some popular iterative procedures used in solving nonlinear systems of algebraic equations arising from implicit Euler and trapezoidal formulae is analyzed using theory of dynamical systems. With the aid of a parallel Connectin Machine (CM2), the complex behavior and sometimes fractal like structure of the associated numerical basins of attraction of these iterative implicit schemes are revealed and compared. The results of the study can be used as an explanation for possible causes and cures of slow convergence and nonconvergence of steady-state numerical solutions when using the time-dependent approach for nonlinear hyperbolic or parabolic PDEs.

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Chaos Due to Homoclinic and Heteroclinic Orbits in Two Weakly Nonlinear Coupled Oscillators

We show that chaos arise in two autonomous quasilinear coupled oscillators when nonisochronism, the dependence of oscillation frequencies upon amplitudes, is included. [Phys. Rev. A 44, 3452 (1991); 43, 5638 (1991); in press] With either coupled active modes or coupled active-passive modes, the strange attractor emerges from homoclinic and heteroclinic orbits biasymptotic to saddle-focus equilibrium points. Thus, analytical methods that we have employed to locate the parameter region where such orbits form are also useful in identifying regions where chaos is probable. Some chaotic attractors develop from orbits with very long periods, which resemble tori but appear to have a heteroclinic origin. This system also displays novel three-frequency motion.

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Structural Stability and Complicated Behavior in Functional Differential Equations

Several examples of complex behavior for Poincare' mappings in FDEs are known. The functions on the right hand side of the equations are smoothed step functions resp. a sine-like nonlinearity. In all these examples, the 'chaos' is due to the presence of transversal homoclinic points.

Using a generalized theory of hyperbolic sets and a statement that links nearby equations to nearby Poincare' mappings as tools, one can prove a structural stability result which applies to the known examples.

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Large Numerical Study on the Homoclinic Orbit of Nonlinear Schördinger Partial Differential Equation

In some near integrable PDE, such as sine-Gordon and nonlinear Schördinger equations, there exist spatial coherence and temporal chaos. Many evidences show that the temporal chaos is due to the existence of homoclinic orbits in the systems. Particularly, in nonlinear Schördinger PDE, a pair of homoclinic orbits play a center role of the temporal chaos. In this study, we use numerical methods to investigate this pair of homoclinic orbits. Under the guidance of the numerical results, using other analytical methods, such as Melnikov function and singular perturbation, we are able to prove the existence of this pair of homoclinic orbits.

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MS 22

Speaker: George Sell
University of Minnesota

No abstract received at press time, 8 /31/92.

The Meaning of Different Length Scales in Turbulent Flows

The topic of this minisymposium is that of low dimensional reductions of PDE's using inertial manifolds. In greater generality, the idea of what 'low' or 'high' dimensionality means in a PDE has various meanings: some definitions of dimension may pick up the gross features of dynamics on an attractor but may miss information if the flow is intermittent. In this case, one may need to go down to very short scales indeed to resolve the dynamics fully. We discuss how different definitions of a 'natural' length scale can come about and use various examples to show how these can occur naturally out of the PDE's themselves. Only one of them fits closely (but not completely) with the definition conventionally used in the statistical theory of turbulence. We consider how these definitions of a scale fit with those that can be computed from the attractor dimension and the number of determining modes in the case of the $2d$ Navier-Stokes equations.

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On Wavelet Projections of an Evolution Equation

Taking the Kuramoto-Sivashinsky equation in one space dimension as an example and using periodic spline wavelets, we obtain ordinary differential evolution equations by projection onto a sequence of finite dimensional subspaces chosen to contain the dominant energy bearing scales. We use the spatial localization properties of these basis functions to further extract a spatially "small" subsystem. In so doing, we develop a tool to address the linear and nonlinear interactions in both physical space and wavenumber space (scale) involved in the "turbulence" exhibited by spatially extended systems. We also consider modelling issues such as accounting for neglected small and large scales and physical locations. Our long term goal is to illuminate the modelling of fluid turbulence by relatively low dimensional dynamical systems.

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Gal Berkooz
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CNRS, Pessac, France

Dynamical Systems Reduction Approaches

Bi-orthogonal decompositions (BOD) which provide the smallest euclidean space containing the dynamics permit an exact reduction of a partial differential equation to a set of ordinary differential equations. The latter is finite if the linear space is itself of finite dimension. Using the Kuramoto-Sivashinsky equation as an illustrative example, we show that a slightly more severe truncation, excluding minute energy scales, may lead to erroneous results, the solution being attracted to another limit set. In our examples, the right dynamics is recovered by modeling the nonlinear action of the small energy modes via an approximate inertial manifold technique. Our computations reveal that the inertial manifold approximation is superior in a BOD space than in the Fouriei space in our example.

Nadine Aubry and Wenyu Lian

Benjamin Levich Institute and Department of Mechanical Engineering, The City College of the City University of New York, New York 10031 (USA).

Low and Not so Low Dynamical Models

Canonical fluid problems such as Benard convection (a supercritical closed flow) and Poiseuille (channel) flow (a sub-critical open flow) provide excellent testbeds for ideas and techniques arising from chaotic dynamics. Based on physical and computational experiments we have a sound, if somewhat incomplete understanding of the mechanisms inherent in these flows, ranging from transition to turbulence. Accurate information on such diverse measures as spectra, fractal dimension mean flow quantities and fluxes are available.

For these cases it has been suggested that *coherent structures* are present and play an essential role in the dynamical processes. Each case has produced dynamical models of varying complexity and with the suggestion that underlying mechanisms are revealed by these.

Using the empirical eigenfunctions (Karhunen-Loeve) as a basis, hierarchical models for these and related flows will be considered. Various claims will be assessed on the basis of the degree of physics that is captured.

Lawrence Sirovich
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MS 23

Application of Dynamical Systems to Information Theory

Ideas originating in Shannon's work in information theory have arisen somewhat independently in a mathematical discipline called topological dynamics. On one hand, Shannon devised notions of entropy and channel capacity to determine the amount of information that can be transmitted through a channel. However, the question remains as how to actually do it. On the other hand, the notion of topological entropy, which turns out to be a generalization of noiseless channel capacity, was introduced to topological dynamics as an isomorphism invariant. The resulting isomorphism theory can be applied to construct finite state automata which can essentially achieve maximum channel capacity. In this mini-symposium we discuss these developments.

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MS 24

Higher Dimensional Targeting

This talk will describe ways to compute portions of stable and unstable surfaces that are more than one dimensional. Some applications, such as targeting and control in higher dimensional chaotic dynamical systems, will be discussed.

Eric Kostelich
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Noise Reduction for Signals from Nonlinear Systems

The study of chaotic dynamics in physical systems requires methods for reducing noise from sampled data when the underlying signal of interest has a broadband spectrum. We discuss methods that are designed to be useful even if the clean signal is contaminated with 100% or more noise (signal-to-noise ratio less than or equal to zero). The methods consist of numerical algorithms based on time delay embedding using coordinates generated by appropriately-chosen prefilters.

Timothy Sauer
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When Trajectories of Higher Dimensional Systems Cannot be Shadowed

A numerical trajectory can be "shadowed" if it is an actual trajectory that remains close to the numerical trajectory. When one of the Liapunov exponents of a chaotic attractor is near zero, numerical trajectories can be spurious, that is, they do not remain near any actual trajectory of the system.

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MS 25

Bursting Oscillations and Slow Passage Through Bifurcation Points

Bursting oscillations are observed in chemical and biological systems and correspond to a sucession of alternating active and silent phases. The active phase is characterized by rapid oscillations while the silent phase is a period of quiescence. For some of these problems, transitions between active and silent phases correspond to slow passages through bifurcation or limit points. We identify these slow passage problems and apply results previously obtained for elementary Hopf bifurcation and limit point problems.

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Plateau Fractions for Models of Pancreatic β-Cells

Pancreatic β-cells undergo bursting electrical activity (BEA) consisting of alternating active and silent phases in which the membrane potential exhibits rapid oscillations and slow changes, respectively. This BEA is related to the secretion of insulin which regulates blood glucose. Specifically, the rate of release of insulin from β-cells as a function of glucose concentration is correlated to the plateau fraction, the ratio of the active phase duration to the total period of the BEA. There are several different models for BEA in pancreatic β-cells, each consisting of three highly nonlinear ordinary differential equations for two fast variables, the membrane potential and a conductance variable, and a slow variable, the intracellular calcium concentration. In this talk we outline a method for computing the plateau fraction for these models as a parameter is varied. The plateau fraction then can be compared with existing data and thus permits determination of a functional dependence between this model parameter and glucose concentration.

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Complex Oscillations in Insulin-Secreting Cells: On Beyond Bursting

Pancreatic β-cells regulate the influx of Ca^{2+} ions needed to secrete insulin by organizing their electrical activity into bursts of action potentials. In mathematical models, bursting results from modulation of a fast periodic subsystem by a slow process. One difficulty is that, by most accounts, β-cells only burst when coupled electrically; the typical behavior of isolated cells is continuous spiking with no silent period. Moreover, efforts to incorporate experimental data from isolated cells have failed to show conclusively whether such currents can combine to produce the bursting observed in coupled ensembles. In modeling studies, coupled bursters phase-lock on the slow time-scale but may have fast spikes which are out-of-phase or even aperiodic. Some implications are that gross properties of the slow oscillation, such as the period and the parameter ranges in which it can occur, depend on the fast dynamics. Indeed, one can couple cells none of which are competent to burst and obtain robust bursting.

Arthur Sherman
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Bursting Oscillations and Homoclinic Orbits to a Chaotic Saddle

We seek to understand mathematically the bursting dynamics and its genesis in a class of dynamical systems like the Hindmarsh-Rose model. It is proposed and tested numerically that the bifurcation from continuous spiking to bursting is caused by a crisis which destabilizes a chaotic state of continuous spiking; and that the bursting corresponds to a homoclinicity to this unstable chaotic state. The study suggests a unified description of bursting, homoclinic systems, and the Pomeau-Manneville intermittency.

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CP 21

A Dynamical Systems Approach to the Stability of Geophysical Features

We use a dynamical systems approach to compute the fixed points and analyze their stability for a highly nonlinear equation which expresses conservation of potential vorticity in a quasigeostrophic system. The fixed points are computed numerically using a Newton-Kantorovich technique with double Fourier expansion and Galerkin discretization. For a test problem, we compute modons in . ..ar flow. The modon is an analytic solution incorporating the full nonlinearity. With the modon as a first guess, shear is added in small amplitude portions, using continuation to obtain a moderate amplitude shear. Solutions are obtained for both symmetric and antisymmetric shears. The matrix computed in this algorithm is precisely the same one that describes the dynamical properties of the system about the fixed point. Therefore, we compute eigenvalues of this matrix to determine the stability of the system. For the modon-in-shear example cited above, we trace the stability of the fixed points as a function of the shear amplitude.

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Nonlinear Dynamics of Complex Two-Phase-Flow Systems: Heat Exchangers and Nuclear Reactors

A system of vertical parallel heated channels with two-phase flow comprises a complex dynamical system of considerable industrial interest, e.g., heat exchangers, boiling water nuclear reactors (BWRs). The coupled nonlinear PDEs that model the flow in each channel can be converted exactly to a set of coupled nonlinear functional ODEs which, when coupled to those for the other parallel channels, lead to a large complex nonlinear dynamical system. Our analytical studies show that the equilibrium flow loses stability through a supercritical Hopf bifurcation. Our numerical studies of the FDEs show that when the system is made nonautonomous by introducing time-dependent heat inputs, pressure drops, etc., it exhibits complex behavior, evolving to high-order limit cycles, invariant tori, and chaotic attractors. Since BWRs are comprised of such two-phase-flow parallel channel systems heated by fission energy, they inherit essentially all these nonlinear behaviors, as shown by our simulations of their nonlinear dynamics based on the above-mentioned FDEs coupled nonlinearly to the space-time neutron kinetics equations. The results of these simulations will be discussed, as will their connections with recent observations of off-normal power oscillations in operating nuclear reactors.

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Some Connections Between Localization in Plasticity and in Combustion

A model is derived of the localization of plastic strain into an *adiabatic shear band* during rapid plastic shear. This model is shown to have a number of similarities with a model of a thermal reaction in a rigid solid explosive. Using small strain-rate-sensitivity asymptotics, which is analagous to high activation-energy asymptotics in the mathematical theory of combustion, it is shown that there is an analogue in thermoelastic-plastic flow in solids of the *ignition problem* in chemical combustion. This raises the interesting question: *Does an adiabatic shear band result from a thermal explosion?*

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Quasiperiodicity and Chaos in a Dynamical System of Amplitude Equations Describing Gasless Combustion

It has been observed that the gasless combustion of thermites can proceed in a variety of nonsteady propagation modes that range from periodic to chaotic in character. While the nature of the primary transition from steady to nonsteady, but periodic, combustion is now well understood, the various mechanisms by which more complex (e.g., chaotic) modes of burning are realized are not. However, it has been shown that mode interactions which arise after the neutral stability boundary is crossed do lead to secondary and higher-order bifurcation of combustion waves that exhibit more complicated spatial and temporal behavior. Here, we focus on the case of temporally resonant mode interactions that can occur near multiple Hopf bifurcation points, and show how such interactions can provide new routes to quasiperiodicity and chaos in gasless systems. In the latter case, the propagating combustion wave corresponds to chaotic, "multiple-point" combustion, and is characterized by the random movement of hot spots that appear, disappear, and reappear on the sample surface. The resulting strange attractor is studied in detail, and an estimate of its (Lyapunov) dimension is provided.

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Multi-Dimensional Acoustic Analysis of A Solid Propellant Rocket Motor

Nonlinear flow and combustion interactions which manifest themselves as pressure fluctuations are the primary cause of solid rocket motors failure. The objective of this work is to create a theoretical background and a computational capability to study the acoustic fluctuation modes and their coupling with other flow variables in a chemically reacting, compressible flow field created by the time dependent burning of solid fuel in a typical solid propellant rocket motor. Previous considerations of this problem have been limited to one-dimensional acoustical analysis and didn't effectively consider the mass and heat release effects on the pressure field fluctuations. Numerical solution of the pressure field subject to forcing functions due to the mass and heat release effects is presented which will serve as a guide to assess most of the nonlinear flow interactions in a consistent framework of reference.

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One-Dimensional Flow Analysis of a Solid Propellant Rocket Motor

The flow in a solid propellant rocket motor is subject to several complex physical phenomenon including mass and heat addition due to chemical reactions. The combustion process is highly coupled with the flow field dynamics and other complex heat transfer processes. In order to be able to study these effects the complete nonlinear flow equations in one space dimension and time is considered. The mass, momentum, and energy addition due to the solid fuel evaporation and reaction appear as source terms in the governing equations. Unlike past considerations which neglected the surface regression effects, this analysis simultaneously considers the temporal variation of propellant surface area due to surface combustion. Highly accurate numerical results based on upwind TVD schemes are presented that provide the temporal distribution of velocity, pressure, and temperature along the axis of the chamber and nozzle.

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CP 22

Horseshoe Maps with Sinks Near Homoclinic Tangencies

Let f be a diffeomorphism on a compact 2-manifold M. Assume that f has a hyperbolic saddle point p and that there is a cubic homoclinic tangency of the invariant manifolds of p. It is shown that there are small perturbations of f possessing horseshoe-like maps which have both chaotic invariant sets and a sink. The chaotic behavior is examined. The basin of attraction of the sink is examined and is shown to have a fractal boundary.

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An Analogue to the Birkhoff-Smale Homoclinic Theorem for Snapback Repellers of Entire Mappings

A snapback repeller is an entire orbit which tends to an unstable fixed point in backward time and snaps back to the same fixed point in forward time. We give an elementary proof that periodic orbits accumulate near a snapback repeller for an iterated analytic mapping. The proof uses the global semiconjugacy of an entire analytic mapping to the linearized mapping at the unstable fixed point and standard tools from complex variables, especially the Theorem of Rouche. We generalize Marotto's result about the chaotic motion near a snapback repeller and give an independent proof.

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Transition to Chaotic Travelling Waves via a New Type of Global Bifurcation

A new mechanism for the transition to chaotic travelling (rotating) waves in systems with periodic boundary conditions on a line is described. In many cases the O(2) symmetry of such systems is responsible for the presence of a global connection between circles of nontrivial states and circles of standing waves via strongly modulated travelling waves. Under appropriate conditions this connection is responsible for a succession of bifurcations from travelling waves to modulated (quasiperiodic) travelling waves, followed by a cascade of torus-doubling bifurcations to chaotic travelling waves. The mechanism is illustrated by careful numerical integration of a system of ordinary differential equations with O(2) symmetry.

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A Novel Homoclinic Bifurcation in a Hamiltonian System

An autonomous, reversible, fourth-order Hamiltonian system modelling an elastic strut is studied numerically. The existence of a unique, reversible homoclinic orbit to the origin has recently been proved by Amick & Toland for parameter values $P < -2$. We compute a path of this orbit as P increases, using standard continuation techniques incorporating a method due to Beyn of truncating to a finite time-interval with projection boundary conditions. It is found that, for $P \geq -2$, many homoclinic orbits bifurcate from the primary one. Only two of these orbits persist until $P = 2$, where the dynamics is governed by a certain normal form.

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Infinitely Many Sinks for a Singular Map

The subtle dynamical behavior of one parameter families of diffeomorphisms in two dimensions bifurcating to infinitely many sinks exists when certain stable and unstable manifolds form nondegenerate homoclinic tangencies. This indicates that some maps do not have transitive strange attractors, but infinitely many distinct attractors.

An important tool in establishing the existence of infinitely many sinks is to show that thick Cantor sets of stable manifolds lead to a persistent tangency.

Using this tool the speaker will show the existence of infinitely many sinks for a one parameter family of maps of the plane which are not diffeomorphisms.

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Dynamical Behaviors in Kolmogrov Models

An important tool to determine the conditions chaos occures is Melnikov function. The integrate of the function is very complex and almost is impossible if explicit forms of the homoclinic on heteroclinic orbit of unperturbed systems cannot be expressed. In this paper, author use special way to determine the existence of 0 points in the melnikov function to avoid using the explicit forms and integrates and then almost get some efficiency.
The speaker will discribe the dynamical behaviors in kolmogrov model with time periodic and little resource perturbation.

$$\begin{cases} \dot{x} = x(r - a_1 x - by - cxy) + \varepsilon f(x,y)\sin\omega t \\ \dot{y} = y(-R + a_2 x + ey + (xy)) + \varepsilon g(x,y)\cos\omega t \end{cases}$$

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MS 26

Numerical Schemes Based on the Algebraic Approximation of the Attractors

In this lecture we will present some methods of approximating the global attractors of dissipative partial differential equations by finite dimensional algebraic sets, as well as some algorithms for approximating the global dynamics on the attractor by suitable dynamics on those algebraic sets. In particular, this provides low dimensional approximating dynamics for the family of all trajectories on the attractor over a fixed long period of time.

C. Foias
Indiana University
Bloomington, IN

Inertial Sets and Exponential Attractors for Navier-Stokes Flows

We present results on new fractal objects with physical relevance to Navier-Stokes flows: "Inertial Sets" (I.S.) also called "Exponential Attractors." These are fractal enlargements of the global attractors for the N.S. Dynamics which are more flexible than inertial and/or approximate manifolds. They attract all trajectories at a uniform exponential rate, and capture both the ultimate asymptotics and slow-transient dynamics. We discuss the robustness and the full continuity of I.S. under several numerical approximation schemes. We develop the concept of "Inertially Stable" approximation schemes. We conclude with applications to the 2-D generalized Kolmogorov flows.

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Alp Eden
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Ciprian Foias
Roger Temam
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Spatiotemporal Behavior of Approximate Inertial Forms for the 2-D Navier-Stokes Equation

We discuss the implementation of approximate inertial manifolds for a problem in planar fluid flow. Such a manifold provides an interaction law between large and small eddies. This law leads to a finite dimensional dynamical system, an approximate inertial form, whose temporal behavior can be similar to that of the infinite dimensional fluid flow. The spatial characteristics are then completed by means of the interaction law. We compare the spatiotemporal complexity of the flow on several different approximate inertial manifolds with that of a traditional Galerkin discretization of the 2-D Navier-Stokes equation, with periodic boundary conditions. In particular, we will seek the minimal dimension of the approximate inertial form that captures the converged behavior of the Galerkin method.

Michael S. Jolly
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Numerical Study of Dynamics and Symmetry Breaking in the Wake of a Circular Cylinder

The flow past a circular cylinder is one of the prototypical open fluid flows. While it is well characterized at low Reynolds numbers, at moderate Reynolds numbers the dynamics are not yet understood. In particular, details of the transition to three dimensionality and the subsequent symmetry-breaking bifurcations in the wake of the cylinder are not yet well characterized. We present a detailed numerical study of this system. We combine direct numerical simulations of the Navier-Stokes equations, numerical Floquet analysis of the time-periodic wake, and bifurcation studies of low-dimensional systems of ODE's. These reduced ODE models are constructed using the Karhunen-Loeve expansion/POD to obtain a hierarchy of global "modes" from direct numerical simulations, followed by a Galerkin expansion of the Navier-Stokes on these modes. The symmetries of the system are taken into account explicitly in the construction of the ODE models. The dynamics and symmetry-breaking bifurcations in the ODE models are compared to results of large-scale direct computations.

Dwight Barkley
George Em. Karniadakis
Ioannis G. Kevrekidis
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MS 27

Digital Processing of Chaotic Signals

Chaotic signals are of increasing interest in engineering and science because they model a wide range of physical phenomena and contain a considerable amount of inherent structure. This structure suggests several engineering applications as well as a large set of associated signal processing problems. For example, chaotic signals are potentially applicable in areas such as communication systems, remote sensing, and data modeling. From a signal processing perspective, algorithms for performing classical signal processing tasks, e.g. signal separation, noise reduction and deconvolution, which exploit the the unique characteristics of chaotic signals will be important components of these applications. This talk deals broadly with the relationships between chaos and signal processing. As an example of processing chaotic signals, an algorithm for performing blind deconvolution of chaotic data will be presented.

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Modeling Chaotic Systems with Hidden Markov Models

The problem is that of modeling chaotic dynamical systems, based only on observations of the system. A hidden Markov model for a class of chaotic systems is developed from noise-free observations of the output of that system. A combination of vector quantization and the Baum-Welch algorithm is used for training. This combined iterative approach is important. This model is used to clean noisy outputs from the system and to detect the system output in the presence of noise. Two non-iterative cleaning algorithms, one based on a maximum likelihood approach and one based on a maximum aposteriori approach are defined.

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Determining Robust Dynamical Maps From Observed Time Series

We extend the investigation of prediction from experimental time series to the determination of aspects of the dynamics which relate to the behavior of the nonlinear system off the attractor. The observed time series lies on the attractor by definition. Global methods are developed for determining the basins of attraction and the dimensions of the basin boundaries. The prediction functions are established using the observation of a relatively small number of vectors in a reconstructed phase space.

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A Method to Distinguish Possible Chaos From Colored Noise and Determine Embedding Parameters

We present a computational method to determine if an observed time series possesses structure statistically distinguishable from high-dimensional linearly correlated noise, possibly with a non-white spectrum. A nonparametric statistic is explored that permits a hypothesis testing approach. The algorithm can detect underlying deterministic in a time series contaminated by additive random noise with identical power spectrum at signal to noise ratios as low as 3 dB. With less noise, this method can also be used to get good estimates of the parameters needed to perform the standard phase-space reconstruction of a chaotic time series.

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MS 28

Nucleating Solutions for the Cahn–Hilliard Equation in Higher Space Dimension

The nucleation phenomenon in the context of the nonlinear Cahn–Hilliard equation has been recently studied by Bates and Fife who have in particular proved, for the case of one space dimension, the existence of nucleating solutions. These are stationary solutions corresponding to the situation where a certain number of small nuclei are immersed in a homogeneous phase with a different concentration.

We make a first step towards a rigorous mathematical study of the nucleation phenomena in $n > 1$ space dimensions by proving the following.

Theorem: Given a constant u^- in the metastable set and an integer $N \geq 1$ there exist: a constant $u_- \neq u^-$, N points $x_1, \cdots, x_N$ in Ω and a family of stationary solutions u_ϵ of the Cahn Hilliard equation, $0 < \epsilon < 1$, such that (i) $\lim_{\epsilon \to 0} u_\epsilon(x) = u^-, x$ in $\Omega\{x_1, \cdots, x_N\}$ (ii) $\lim_{\epsilon \to 0} u_\epsilon(x_i) = u_-, i = 1, \cdots, N$.

Giorgio Fusco
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University of Rome II, Italy

Equilibrium and Dynamics of Bubbles for the Cahn–Hilliard Equation

We discuss some results about existence of circular fonts in solutions to the Cahn–Hilliard equation. The time interval in which a circular interface persists is estimated to depend exponentially on ϵ^{-1} and criteria for the existence of equilibria with a circular interface are also discussed.

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Large-Time Behavior of Monotone Discrete-Time Dynamical Systems

Typical examples of strongly monotone dynamical systems are those generated by (1) a single parabolic PDE; (2) an irreducible cooperative system of ODE's; and (3) an irreducible cooperative system of weakly coupled parabolic PDE's. If such an evolution equation is periodic in time, the corresponding period map T generates a discrete-time dynamical system $\{T^n : n \geq 0 \text{integer}\}$ in a subset X of a strongly ordered Banach space V. The mapping T is strongly monotone, i.e.,

$$0 \neq y - x \geq 0 \quad \Longrightarrow \quad Ty - Tx \in \mathrm{Int}(V_+) \quad \text{for all } x,\ y \in X,$$

where $\mathrm{Int}(V_+)$ denotes the interior of $V_+ = \{v \in V : v \geq 0\}$ in V. Using only the monotonicity and differentiability of T and the compactness of all trajectories we will show that almost all trajectories are stable and approach a cycle. We give a full description of the set of all stable (unstable, resp.) points. The set of all unstable points is the union of at most countably many Lipschitz hypersurfaces of codimension one in V and hence, it has zero Gaussian measure. Under additional hypotheses on T we obtain that every trajectory converges to a single point. However, if these hypotheses are dropped, asymptotically stable cycles can occur. We give a few examples of such cycles.

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Department of Mathematics
Vanderbilt University

Structural Stability of Global Attractors for Partial Differential Equations of Dissipative Type

I will discuss the structural stability of global attractors of infinite dimensional dynamical systems defined by parabolic equations, elliptic equations and delay-differential equations.

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MS 29

From Partial Differential Equations to Minimal Dynamical Systems

The numerical simulation of partial differential equations (PDEs) by minimal systems of ordinary differential equations (ODEs) will be considered. A modified Karhunen-Loeve transform using a weighted Sobolev norm will be derived. By optimizing the convergence of a flow and its derivatives the modeling of the dissipation terms is improved and the number of terms required to retain a stable approximation is reduced. The Kuramoto-Sivashinsky equation is used as an example to demonstrate how a Galerkin procedure, based on eigenfunctions determined by the Sobolev optimality criterion, improves the performance of the standard Karhunen-Loeve procedure.

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Detecting Symmetry Creation in PDEs

An attractor of a symmetric PDE has symmetry which can be characterized by a subgroup of the symmetry group of the problem. In a one-parameter family of attractors the type of symmetry can change. In particular, there are mechanisms leading to symmetry creation, which has been observed recently in several dynamical systems. Since in general attractors possess symmetry only on average, a direct numerical approach is very expensive. Based on the Karhunen-Loeve procedure we will present a more efficient numerical method for the detection of symmetry creation in PDEs.

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The Use of Symmetries in Dynamical Systems

Bi-orthogonal decompositions consist in decomposing a space-time function into orthogonal temporal modes in a Hilbert space H(T) and orthogonal spatial modes in a Hilbert space H(X) which are coupled by a unique dispersion relation. The latter permits the treatment of space-time symmetries in a straightforward manner and the detection of spatio-temporal symmetry related bifurcations. Conversely, in certain (identified) situations, the knowledge of both the symmetries of the solution and one spatio-temporal pair of modes permits the full expansion of the solution. When the symmetries are those of the dilation-translation groups, our approach is, in a certain sense, analogous to a spatio-temporal wavelet transform. Galerkin projections based on orthogonal sets of this kind lead to renormalized equations. Fully developed turbulence will be given as an illustrative example.

Nadine Aubry[1], Zhen-Su Cao[1] and Ricardo Lima[1,2]

(1) Benjamin Levich Institute and Department of Mechanical Engineering, The City College of the City University of New York, New York 10031 (USA).
(2) Centre National de la Recherche Scientifique, Centre de Physique Théorique, Luminy, 13288 Marseille (France).

Non-Linear Extensions To The POD and Systems With Symmetry

ABSTRACT: The proper orthogonal decomposition provides a decomposition of phase space into orthogonal modes with associated eigenvalues. In case the dynamics occur in a finite dimensional closed linear subspace the number of non-trivial POD modes (i.e. eigenvalue different than zero) is finite. However, in case the dynamics occur on a finite dimensional manifold (which can be rigorously proven for some dissipative PDE's) the number of non trivial POD modes may be infinite. In case the manifold is of a graph form $F{:}R \to R^{\perp}$ one obtains no information regarding F from the POD. We discuss some non-linear extensions to the POD that shed light on F in particular in cases of systems with symmetry. Our results include non-trivial conditions for the existence of F, the advantage of using POD eigenfunctions in the formulation of the subspace R, a constructive procedure to compute F, in particular in cases of systems with symmetry.

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CP 23

Physical Modelling of the Human Circulatory System for Cardiovascular Device Testing

A primary criterion in modelling the circulation for testing devices such as artificial hearts, prosthetic valves and vascular grafts is matching the input impedance of the model to the actual system. Preliminary results for a commonly used model with three discrete linear hydraulic elements (e.g. resistance, compliance and inertance) indicate that significant improvements are possible. Computer analysis involving multi-dimensional solution of simultaneous nonlinear algebraic equations suggests that an alternative 3-element model will yield improved dynamic response and that further, though smaller, improvements are possible with 4 and 5-element models. An improved 3-element model will be built and tested.

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Dynamics of the Calcium Subsystem in Cardiac Cells

We examine the stability properties of a set of equations describing electrical and chemical activity in the cardiac Purkinje fibers. In this paper we concentrate on the part of the cell that transmits cell membrane information to subcellular calcium stores with a view toward explaining the sequence of events that lead to certain arrhythmias of the heart.

We use standard analytic and numerical methods to investigate bifurcation phenomena. The package AUTO was used extensively but we encountered difficulty in explaining the global dynamics of the system when certain local bifurcations occurred.

We present a dynamical system solution to the problem of determining the role of membrane currents in the onset of arrhythmias. Using the DiFrancesco-Noble model of the Purkinje fiber, we examine the dynamics of excitation-contraction coupling under abnormal conditions. Our results indicate that the system has considerable "structural instability" and can explain a number of experimental observations.

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A Simple ODE Model for the Nonlinear Dynamics of the Heart Sinus Node

The sinus node is the normal pacemaker for the heart. Previous models of it, usually based on circle maps, have been very simple. Although more complicated, the 2-D ODE model we have developed, based on an extension of the normal form for the supercritical Hopf bifurcation, is still very simple. In this model the angular velocity is not constant; rather, it is smaller (larger) when the trajectory is outside (inside) the limit cycle -- an important property that cannot be modelled reasonably by circle maps. Thus, simulations of the response of sinus node aggregates to external electrical stimuli show that the model correctly reproduces two features observed in experiments on chick embryo sinus node cultures that circle maps cannot reproduce. Following a single electrical pulse, it yields a transient with an initially increased or decreased period (depending on the phase at which the stimulus is applied), followed by a gradual return to normal sinus rhythm; and following a rapid series of pulses, it results in a transient with a more greatly increased or decreased period, followed by a more gradual return to normal sinus rhythm.

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A Transplanted Human Heart as a Deterministic Nonlinear Dynamical System

Usually, the heart rhythm in a transplant patient is almost perfectly periodic, i.e., nearly regular sinus rhythm. However, we have observed heart rhythm in a newborn transplant patient that clearly is aperiodic, and based on the EKG morphology we have concluded that it results from the presence of a second pacemaker -- an atrial ectopic pacemaker. We have recorded the beat-to-beat (R-R) intervals which exhibit a variety of aperiodic behaviors, and we have developed a quantitative interpretation of specific types of extended epochs of these data as the output of a low-dimensional chaotic dynamical system. Our quantitative analyses indicate that the recorded aperiodic data is not random, that the heart is behaving as a chaotic dynamical system with a correlation dimension of about 2.8 and embedding dimension of 7, and based on our analyses of the time series and power spectrum, that it is exhibiting type-I intermittency. Further, transitions between this behavior and periodic sinus rhythm indicate that the type-I intermittency can be explained in terms of an inverse tangent bifurcation that results from the slow variation of a control, possibly the circulating blood adrenaline level.

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A Coupled Oscillator Model for the Dynamics of a Transplanted Human Heart

Typically, because the feedback control of the sinus node by the autonomic nervous system is eliminated, a transplanted heart exhibits near perfectly periodic sinus rhythm. However, we have clinically observed rhythm in a neonatal heart transplant patient that is aperiodic, but not random. Further, the morphology of the EKG indicates the presence of an atrial ectopic pacemaker in addition to the sinus node. Hence, we have developed a simple coupled nonlinear oscillator model of the two pacemaker system. Each of the two oscillators is based on the normal form for the supercritical Hopf bifurcation extended so that the angular velocity is larger for points outside the limit cycle than for those inside it. The oscillators have slightly different phase response curves, and are coupled through phase resetting by the heart depolarization which in turn is initiated when one of the oscillators passes through zero phase. The model yields chaotic time series similar to many of the extended epochs of beat-to-beat (R-R) interval data observed clinically, and it is being used to explore the physiological mechanisms that result in the various types of epochs in the data we have recorded.

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Investigations on a Model of Neuronal Bursting

Special maps of the interval have proven to be successful in modelling neuronal activity (c.f. Labos, Cybernetics and Systems '84, 1984). Using this basic idea, a model of neuronal bursting has been constructed to simulate some basic properties of periodical nerve bursting. The discrete map consists of piecewise monotonic and continuous functions, and produces bursts of spikes in a nearly periodical manner. It displays an apparent random behaviour since the number of spikes in a burst seems to vary randomly. We shall show that the length of the period is mainly determined by the intermittency due to the quadratic map defined in a neighbourhood of zero, while the (negative) slope of the subsequent linear map, m, controls the bursting characteristics. We shall give a formula for the probability distribution of the number of bursts as a function of m.

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CP 24

Some applications of Peano dynamics in classical and quantum mechanics

We give a bijection between an extended Menger-Urysohn dimension and an n dimensional Serpinski-Peano space obtained by lifting the triadic Cantor set to higher dimensions. We subsequently show how the obtained dimensions:
d = (1.5849 ; 2.5121 ; 3.9815 ; 6.3106 ; 10.0021 ; 15.853 ; 25.1265)
for n = 1 to n = 8 respectively could be related to fully developed turbulence and a quantum spacetime.

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Dealing with Multiple Objectives in an Econometric Model

Consider a multi-period econometric model with endogenous, exogenous, and policy variables. The values of the endogenous variables will then depend on the values of the policy variables as well as the future values of the exogenous variables.
Clearly, these future values are not known with certainty. There are, however, usually a small number of forecasts available which predict the values of the exogenous variables. Similarly, there are frequently a number of different objectives, i.e. welfare functions, put forward by different decision makers stressing different policies.
For each pair of objectives and forecasts, we can now determine the value of any of the endogenous variables for each of the periods. Given unknown probabilities for the different forecasts to actually materialize, we can use Starr's domain criterion to determine domains in which any one of the endogenous variables, e.g. unemployment or inflation, is smaller for one objective than

for any of the others. Based on the volumes of these sets, we are then able to recommend policies which satisfy decision makers favoring any one of the alternative objectives.

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Chaotic Phenomena in Communication Networks

Performance measures in communication networks, such as user-perceived response times, are primarily determined by contention for network facilities. For this reason, performance is traditionally evaluated using stochastic, steady state queueing theory models. However, these models do not readily capture the fact that communication networks are in reality complex, nonlinear dynamical systems capable of interesting time behavior that can significantly influence performance. We describe several communication systems that exhibit a range of dynamic phenomena, such as bistability, oscillations and chaos, and demonstrate this behavior using actual field data. We then model these systems by discrete time fluid flow models, and derive analytical conditions for various modes of oscillation. These oscillations degrade network performance, and we use the dynamical system formulation to propose and validate suitable controls.

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Physically Realizable Polynomial Systems

In many cases, the problem of the modelling and designing of nonlinear dynamical systems is treated as the problem of the constructive approximation of the corresponding operators, the information on a system to be constructed being given only in the form of an abstract operator possessing the properties of this system: stationarity, stability, memory etc. Because of physical meaning of the modelling problem, a number of specific requirements is imposed on the approximating operator S. In particular, it is required that this operator S possess the family of the characteristics corresponding to physical properties of a real systems and be physically realizable.

The speaker will discribe new results in this field.

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Stable and Unstable Quasiperiodic Oscillations in Robot Dynamics with Delay

Digital control of force controlled robots often results instability due to the time delay in the system. Experiments present nonlinear vibrations around the unstable equilibria. These can be identified as two or three dimensional tori in the phase space.

The examples on retarded dynamical systems presented mainly in control engineering apply bifurcation theory. However, the reduction of the infinite dimensional problem to the 4 (or more) dimensional center manifold usually makes it impossible to present analytical results. The bifurcation analysis of the robot model in question gives a unique pure analytical investigation of infinitely many codimension two bifurcations in the system.

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DYNAMICS OF FLEXIBLE MANIPULATORS
Part One: Analytical Modeling
Part Two: Numerical Analysis

This paper presents an application of Continuum (i.e. Lagrangian) and Finite Element Techniques to flexible manipulator arms for derivaiton of the corresponding Dynamic Equations of Motion. Specifically a one-link flexible arm is considered for detailed analysis, and the results are extended for the case of a two-link flexible manipulator. Numerical examples are given for the case of both one and two link flexible arms, and the resulting dynamic equations are solved and thoroughly discussed. In addition, both methods are compared in the sense of modeling and the required time and accuracy for computation.

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MS 30

Attractor Reconstruction

The delay coordinate embedding method for attractor reconstruction is placed on a scientifically firmer basis. A report on joint work with Tim Sauer and Martin Casdagli.

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System Reconstruction Using Embedding Techniques

Delay coordinate embedding techniques are being used widely for computing invariants of nonlinear systems and for forecasting purposes. We discuss the implementation of numerical algorithms based on embedding to accomplish these goals in the presence of noisy data.

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Geometric Noise Reduction

Guan-Hsong Hsu, University of Missouri

No abstract received at press time, 8/31/92.

Analysis of experimental data

An experimentally observed time series produced by a low-dimensional dynamical system is irregular and sustained, sometimes very noisy, and its possesses a broadband spectrum. Even the signal-to-noise ratio (SNR) may be impossible to estimate by conventional signal processing methods. We present an empirically based method for estimating from the behavior of a geometric noise reduction algorithm: (1) initial SNR, (2) values of embedding dimension, d_{pk}, to give peak SNR improvements, (3) number of times, n_M, to iterate the algorithm to achieve maximum improvement, (4) corresponding SNR improvement, δ_M, AND (5) lower bound on the topological dimension, M.

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MS 31

Enhancement of Optical Bistability by Periodic Layering

The effect of a periodic perturbation in the index of refraction of a nonlinear optical medium is studied analytically and numerically. Using a one-dimensional model for monochromatic waves incident on the medium, it is found that near resonance between the perturbation and the modulation of the electric field there can be a significant enhancement of optical bistability in the low intensity regime. In particular, the case of the primary resonance is discussed in detail, since it is responsible for the most significant effects. It is shown how the bistability curve can be optimized for implementing optical switches, based on the information provided by the resonance structure.

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Mode dynamics in nonlinear optical fibers

The study of the dynamics of optical modes in fiber optics have generated intense research activity in both in theoretical and the experimental areas. In this talk, we will give a survey of some of the most relevant theoretical work in the case where the dominant dynamics is Hamiltonian and integrable. Examples such as the study of the central mode and two sidebands within the modulational instability band of the nonlinear Schrödinger equation, four photon mixing processes and the dynamics of first or first and second Stokes, anti-Stokes modes in a birefringent fiber and second harmonic generation in a fiber are some of the relevant phenomena that will be discussed. We will play special attention to the important question of studying these models with additional effects that are viewed as perturbations.

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Perturbation Effects on the Dynamics of a Mode and Two Sidebands in an Optical Fiber

The interaction of three modes, the fundamental mode, sitting at the most unstable value in the modulational instability region of the Nonlinear Schrödinger equation and the two side bands that also fall inside this modulational instability region is investigated. Homoclinic structures that are the framework of the phase space are described, as well as their breakup which results from physical perturbations such as the Raman effect, second harmonic generation, dissipation and gain, weak birefringence, and fiber tapering. This breakup results in chaotic interaction between the modes. Methods used to study this problem are Hamiltonian reduction and reconstruction, the multi-dimensional Melnikov method, Poincaré return map construction, and a new method for finding orbits homoclinic to resonance bands, which is a combination of the Melnikov method and singular perturbation methods. This new method may be used to discover exotic homoclinic orbits in both dissipative and conservative near-integrable ordinary differential equations. These homoclinic orbits are obtained by piecing together parts of heteroclinic orbits and curves of equilibria that exist in the corresponding unperturbed problems.

Gregor Kovacic
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Homoclinic Chaos due to Competition among Degenerate Modes in a Ring-Cavity Laser

Coupling of two degenerate modes in a laser-matter system is shown to cause chaotic dynamics in the amplitude equations describing the mode behavior. In particular, the interaction of a quasiperiodic motion of one mode and a homoclinic motion of the other mode results in intersections of the stable and unstable manifolds of the quasiperiodic mode. These intersections are transverse on the common level surfaces of two conserved quantities and imply the existence of chaotic dynamics on an invariant Cantor set of circles for an appropriately chosen Poincaré return map.

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MS 32

Chaotic Transport in Symplectic Maps

An integrable area preserving twist map has a phase space foliated with invariant circles, and every orbit lies on such a circle. Upon perturbation invariant circles are destroyed, resonance zones formed, and some orbits become chaotic. Transport processes are described as a succession of transitions through resonance zones. The most resistant barriers to transport are remnants of invariant circles the cantori. Analogous obstructions to transport appear to exist in higher dimensions. We can prove that cantori exist for maps sufficiently close to the "anti-integrable limit", and a construction of the invariant set associated with a resonance can be given.

James D. Meiss
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Transport in Two and Four Dimensions

Transport problems arise in fluid dynamics, chemical reaction dynamics, and plasma physics. One wants to describe the evolution of an initial ensemble of states in phase space: for example a drop of ink in water, three atom interactions for varying impact parameters, the motion of an electron in a cyclotron. Idealized models of this problem are given by area preserving and symplectic maps of two and four dimensions. Transport through special regions of phase space is studied. Areas are computed using an action principle developed by MacKay, Meiss, and Percival. Difficulties in extending the two dimensional results will be discussed.

Robert W. Easton
Applied Mathematics
University of Colorado, Boulder, CO 80309

The Birkhoff Signature: Identification and Applications

Homoclinic structures play an important role in determining transport and mixing properties of phase space area. We present analytical estimates of the transport rates using the perturbation tools which we developed recently. Previously we observed that simple invariance properties of the manifolds enables one to express the total amount of transport of areas in terms of the fate of the "turnstile lobes." Here we suggest an algorithm which supplies a priori estimate for transport rates and reveals the basic mechanism for transport. A comparison with a brute force calculation for a few parameter values is presented.

Vered Rom-Kedar
The Department of Applied Mathematics and Computer Sciences
The Weizmann Institute of Science
Rehovot, Israel

Phase space structure near resonant equilibria of 3 Degree-of-freedom Hamiltonian systems

In this talk I will discuss phase space geometry near the 1:2:2 resonance and 1:1:2 resonance in three degree-of-freedom Hamiltonian systems. Particular attention will be given to the role played by these geometrical structures in relation to phase space transport issues. Analytical and computational issues associated with "high dimensional" geometry and dynamics will be discussed. Applications to problems of energy transfer in triatomic molecules will be considered.

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California Institute of Technology, Pasadena, CA 91125

MS 33

Attractor Reconstruction, Filtering, and Ill-Posed Problems

The action of filtering acts as a transformation on an attractor reconstruction. Inverse filtering is also recognized as an ill-posed problem. The interaction of these two facts leads to questions of when filtering is a true reconstruction (embedding) of the attractor from data. In the presence of data noise this leads to the use of concepts from fuzzy set theory to define proper noisy notions of embeddings and to generate algorithms that regularize filters and other data transformations.

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Cascading of Synchronized Chaotic Systems

Under the right conditions, chaotic systems may be synchronized by taking a signal from a full chaotic system and using it to drive a properly chosen subsystem of the chaotic system. It is also possible to cascade these driven subsystems to produce a "chaos filter" which can be used to make the chaotic equivalent of a phase locked loop.

Thomas L. Carroll
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Chaotic System Identification Using Linked Periodic Orbits

It is quite common to analyze the behavior of a chaotic systems by means of scalar time series. However, traditional techniques such as Fourier analysis do not reveal much of the structure and behavior of the system, making classification of the system difficult. The broadband nature of the signal makes it hard to distinguish dynamics from noise. I will discuss a method to extract characteristic descriptors from a reconstructed system. This involves topological invariants based upon the organization of low-period saddle orbits with the system attractor. The goal is to recognize and predict a change of state of the system.

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Tracking Unstable Periodic Orbits in Experiments: A New Continuation Method

In a chaotic system, much new information can be gleaned from a time series using novel methods of embedding a signal in phase space. This talk will extend the signal processing tools of the experimentalist. A new continuation nethod will be shown to track unstable orbits while changing a system parameter. The method is applicable to experimental situations in which there is no analytical knowledge of the system dynamics, and only an experimental time series of the dynamics is available. Important issues include tracking the orbit through bifurcation points, the effect of noise, and the location of new attractors.

Ira B. Schwartz and Ioana Triandaf
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CP 25

Transient Perturbations Prior to Instability in Periodically Excited Oscillators

Periodically forced nonlinear oscillators may lose their stability via a number of well-defined mechanisms. The degradation of stability is apparent in the behavior of perturbation-induced transients, and from the resulting time series characteristic (eigenvalues) multipliers can be obtained numerically. This is basically a numerical analogy of Floquet theory, and is shown to work well in mechanical experiments as well as simulations. This method has implications for predicting the future behavior of evolving nonlinear dynamical systems.

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Numerical Experiments in Noise Reduction and Attractor Restoration

We describe several numerical experiments using the scaled probabilistic cleaning methods of Abarbanel and Marteau (AM). In the first case, the frequency spectrum of the Henon Map is altered, and then restored, by using the AM Algorithm on the Inverse FFT time series. Second, attractors in a 3D Map are broadened substantially with additive noise and then cleaned with [illegible]essive passes through the noise reduction algorithm. Third, a [illegible]lensity time history for a high altitude Barium cloud release [illegible]ned; most of the dominant features in the time series are [illegible]uced successfully.

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Thermodynamics of Duffing's Oscillator

Numerical simulations are conducted in order to establish the range of validity of thermodynamical relations for limit cycles and strange attractors of Duffing's oscillator: $\ddot{x} + \mu\dot{x} + \alpha x + \beta x^3 = a + b\sin\nu t$. Thermodynamic relations link slow changing force, a, and amplitude of the periodic excitation, b, with averaged characteristics of the solution, $< q >$, $< q\sin\nu t >$, where $< \cdot >$ means averaging along the attractor. The averaged Lagrangian, $< \frac{1}{2}\dot{x}^2 - \frac{\alpha}{2}x^2 - \frac{\beta}{4}x^4 >$ plays the role of thermodynamical potential. It is shown that thermodynamical relations which were originally derived for nondissipative systems (*Berdichevsky 1992*) are also valid for a relatively large range of the friction μ.

Akif Özbek
Georgia Institute of Technology
Atlanta, Georgia

Victor Berdichevsky
Georgia Institute of Technology
Atlanta, Georgia

CP 26

Modifications to a Model of Chaotic Dopamine Neurodynamics.

We have recently explored the complex dynamics of a modified model of the nigrostriatal dopaminergic system. The modifications are very simple and may be equated with observable physiological changes in the system. We show that by varying one or both of two parameters, mean firing rate of nigrostriatal neurons and postsynaptic striatal receptor density, the system exhibits a wide range of dynamics which may help explain both normal and pathological behavior in humans. These findings are testable and we believe they are especially significant in light of recent work being done in the area of experimental control of chaotic dynamics.

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Block Copolymers and the Visual Cortex: the Striped Pattern

There are several systems in nature that exhibit a striped pattern. Some examples are: microphase separated block copolymer mixtures, ocular dominance areas in the primary visual cortex, fingerprints and the zebra skin. The diversity of these systems suggests an underlying common mechanism for the formation of stripes which is independent of the details of the particular system. In this work the copolymers system is compared to the visual cortex. A cell dynamical system model previously used to describe the microphase separation in block copolymer melts* is suggested for the formation of ocular dominance stripes in the visual cortex.

*Y. Oono e M. Bahiana, Phys. Rev. Lett. 61, 1109(1988)
M. Bahiana e Y. Oono, Phys. Rev. A 41, 6763(1990)

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Analysis of a Double Porosity Bioreactor Model

We present a double porosity model used to describe the breakdown of substrates (e.g., toxic chemicals) in a bioreactor composed of porous pellets in a packed bed configuration. Within each porous pellet, a reaction-diffusion system describes microbial growth, cell motility, and attachment to and detachment from the pellet walls, together with substrate diffusion and uptake by the micro-organisms. A second set of equations describes the transport of microbes and substrates in the bulk fluid flowing through the macro-pores between the individual pellets. These two systems of equations are coupled through boundary conditions describing transport across the pellet-bulk fluid interface.

Using a combination of dimensional analysis, singular perturbation methods, and numerics, we obtain a much simpler "lumped parameter" system of differential equations. The model parameters are used to fit laboratory data. In addition, we may discuss some interesting aspects of the steady-state behavior of the system.

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Curt Vogel
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Planting and Harvesting for Pioneer-Climax Models

Kolmogorov-type systems of ordinary differential equations are presented, where per capita growth rates are either decreasing (pioneer) functions or one-humped (climax) functions of weighted population densities. Varying an intraspecific crowding parameter destabilizes the system and may result in chaotic attractors. This effect may be reversed by planting the pioneer or harvesting the climax population. The dynamical behavior of these systems is analyzed using averaging methods and bifurcation theory.

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On the Bifurcation of Positive Solutions Arising in Population Genetics

A semilinear elliptic equation is considered, which arises in population genetics, involving two alleles. It is assumed that the selection coeficient varies over $\mathbb{R}^n$, but the two alleles are equally advantaged overall.

The problem is studied on all of $\mathbb{R}^n$ n=1,2. Existence and asymptotic properties of solutions are investigated and, by using ODE methods type arguments, global bifurcation results are obtained.

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ADDENDUM -- POSTER Presentation

Effective Potentials and Chaos in Quantum Systems

The usage of the technique of effective potentials dynamically is motivated and established. The 1-Loop effective potential (1LEP) and the Gaussian effective potential (GEP) are derived from Ehrenfrest's theorem by using adiabatic elimination. An application is made to the Henon-Heiles problem and comparison is made with previous results; it is shown that quantum effects destroy chaos in two ways: a) quantum fluctuations make the curvature more positive and b) tunneling dominates the dynamics. Further,this technique is applied to a time-dependent system (the forced Duffing oscillator) and the effects of quantum mechanics are studied through the Melnikov function.

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AUTHOR INDEX

* = Speaker MS = Minisymposium CP = Contributed Presentation
IS = Invited Speaker ABST = Abstract Page

NAME	DAY	TIME	END	SESSION	ABST	ROOM
C						
Caldas, I.L.*	Fri AM	11:40	12:00	CP9	A15	Superior B Room
Caldas, I.L.*	Sat PM	04:10	04:30	CP19	A28	Superior A Room
Calderer, M.C.*	Fri AM	10:00	10:30	MS9	A11	Ballroom 1&2
Camassa, R.*	Mon AM	10:00	10:30	MS31	A47	Wasatch Room
Campbell, D.K.	Sat PM	07:30	09:30	Poster	A32	Gold. Cliff & Foyer
Campbell, S.A.*	Fri PM	06:20	06:40	CP15	A20	Maybird Room
Cao, Y.*	Fri PM	06:40	07:00	CP13	A19	Wasatch Room
Cao, Z.-S.	Sun PM	08:30	09:00	MS29	A44	Maybird Room
Carlson, N.*	Fri AM	11:30	12:00	MS9	A12	Ballroom 1&2
Carpenter, G.A.	Sat PM	03:10	03:50	MS21	A26	Wasatch Room
Carr, T.	Sat AM	10:00	10:30	MS16	A21	Ballroom 1&2
Carroll, T.*	Mon AM	10:30	11:00	MS33	A48	Ballroom 1&2
Castro, R.M.	Sat PM	04:10	04:30	CP19	A28	Superior A Room
Cawley, R.*	Mon AM	11:30	12:00	MS30	A47	Magpie Room
Chachere, G.R.*	Fri PM	06:00	06:20	CP14	A19	Superior B Room
Champneys, A.R.*	Sat PM	07:30	09:30	Poster	A33	Gold. Cliff & Foyer
Champneys, A.R.*	Sun PM	02:00	02:20	CP22	A41	Superior B Room
Chen, X.*	Sun PM	09:00	09:30	MS28	A43	Wasatch Room
Cheng, F.*	Sun PM	02:40	03:00	CP22	A42	Superior B Room
Cheng, Y.	Fri AM	11:30	12:00	MS11	A13	Wasatch Room
Chicone, C.*	Fri AM	11:00	11:20	CP9	A14	Superior B Room
Chin, W.*	Fri AM	11:00	11:20	CP10	A15	Maybird Room
Chivilikhin, S.A.*	Sat PM	07:30	09:30	Poster	A33	Gold. Cliff & Foyer
Chung, D. K-W.*	Sat PM	03:30	04:00	CP18	A27	Maybird Room
Closky, D.T.*	Sun PM	02:20	02:40	CP22	A41	Superior B Room
Clune, T.*	Sat PM	03:30	03:50	CP20	A29	Superior B Room
Corless, M.J.	Thu AM	10:55	11:15	CP2	A5	Superior A Room
Coughlin, K.*	Fri PM	03:30	03:50	CP11	A18	Maybird Room
Coutsias, E.A.	Sat PM	07:30	09:30	Poster	A32	Gold. Cliff & Foyer
Craig, W.L.*	Thu PM	02:30	03:00	MS8	A7	Ballroom 1&2
Crawford, J.D.*	Fri AM	10:20	10:40	CP10	A15	Maybird Room
Crawford, J.D.*	Sat PM	07:30	09:30	Poster	A30	Gold. Cliff & Foyer
Crouch, P.E.	Thu AM	11:15	11:45	MS3	A2	Wasatch Room
D						
da Silva, R.P.	Sat PM	04:10	04:30	CP19	A28	Superior A Room
Dabbs, M.F.*	Fri PM	06:40	07:00	CP15	A20	Maybird Room
Davies, P.	Thu PM	06:40	07:00	CP6	A11	Wasatch Room
Davis, M.J.*	Fri PM	02:30	03:00	MS12	A16	Magpie Room
Dayawansa, W.P.	Thu AM	11:45	12:15	MS3	A3	Wasatch Room
de Almeida, M.A.	Sat PM	07:30	09:30	Poster	A32	Gold. Cliff & Foyer
de Castro Moreira, I.*	Sat PM	07:30	09:30	Poster	A32	Gold. Cliff & Foyer
de Sousa Vieira, M.*	Fri AM	10:00	10:20	CP9	A14	Superior B Room
de Stefano, A.	Thu AM	11:45	12:15	MS3	A3	Wasatch Room
Deift, P.*	Thu AM	10:45	11:15	MS1	A1	Ballroom 1&2
Delchamps, D.F.*	Fri AM	11:00	11:30	MS10	A12	Magpie Room
Dellnitz, M.*	Sun PM	08:00	08:30	MS29	A44	Maybird Room
Deng, B.*	Thu PM	03:30	04:00	MS5	A6	Magpie Room
Ding, M.*	Sat PM	02:30	02:50	CP19	A27	Superior A Room
Dobrinskaya, T.A.*	Sat PM	07:30	09:30	Poster	A33	Gold. Cliff & Foyer
Dockery, J.	Mon AM	10:40	11:00	CP26	A50	Superior B Room
Doedel, E.J.	Thu AM	11:55	12:15	CP1	A4	Superior B Room
Dorning, J.J.	Sat PM	02:50	03:10	CP19	A28	Superior A Room
Dorning, J.J.	Sun PM	01:20	01:40	CP21	A40	Superior A Room
Dorning, J.J.	Sun PM	08:10	08:30	CP23	A45	Superior B Room
Dorning, J.J.	Sun PM	08:30	08:50	CP23	A45	Superior B Room
Dorning, J.J.*	Sun PM	08:50	09:10	CP23	A45	Superior B Room
E						
Easton, R.W.*	Mon AM	10:30	11:00	MS32	A48	Maybird Room
Eden, A.	Sun PM	08:00	08:30	MS26	A42	Ballroom 1&2
Eiselt, H.A.*	Sun PM	07:50	08:10	CP24	A46	Superior A Room
El Naschie, M.S.*	Thu PM	06:00	06:20	CP7	A11	Maybird Room
El Naschie, M.S.*	Sun PM	07:30	07:50	CP24	A45	Superior A Room
Ellison, J.A.*	Sat AM	08:30	09:30	IP7	11	Ballroom 1&2

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NAME	DAY	TIME	END	SESSION	ABST	ROOM
Heagy, J.	Fri PM	02:30	02:50	CP12	A18	Superior B Room
Heller, M.V.A.P.	Sat PM	04:10	04:30	CP19	A28	Superior A Room
Henderson, M.E.*	Fri PM	03:10	03:30	CP11	A17	Maybird Room
Henze, C.*	Sat AM	11:00	11:30	MS17	A22	Wasatch Room
Hirsch, M.W.*	Sat PM	02:30	03:10	MS21	A26	Wasatch Room
Hirschberg, P.*	Sat PM	07:30	09:30	Poster	A31	Gold. Cliff & Foyer
Hitzl, D.L.*	Mon AM	10:20	10:40	CP25	A49	Superior A Room
Hjorth, P.G.*	Sat PM	07:30	09:30	Poster	A33	Gold. Cliff & Foyer
Hogan, W.A.*	Sat PM	07:30	09:30	Poster	A29	Gold. Cliff & Foyer
Holden, L.	Sun PM	01:00	01:30	MS25	A39	Maybird Room
Holm, D.D.*	Mon AM	11:30	12:00	MS31	A48	Wasatch Room
Holmes, P.*	Thu AM	09:00	10:00	IP1	6	Ballroom 1&2
Holmes, P.*	Sun PM	01:30	02:00	MS22	A38	Ballroom 1&2
Holte, J.E.	Sun PM	07:50	08:10	CP23	A44	Superior B Room
Hsu, G.-H.	Mon AM	11:30	12:00	MS30	A47	Magpie Room
Hsu, G.-H.*	Mon AM	11:00	11:30	MS30	A47	Magpie Room
Huang, J.Y.	Fri AM	10:00	10:20	CP9	A14	Superior B Room
Hubler, A.*	Fri PM	03:30	04:00	CP12	A18	Superior B Room
Hughson, R.L.	Sat PM	07:30	09:30	Poster	A31	Gold. Cliff & Foyer
Humphries, A.R.*	Thu AM	11:15	11:35	CP1	A4	Superior B Room
Hunt, F.*	Fri PM	06:40	07:00	CP14	A20	Superior B Room
I						
Ichikawa, Y.H.	Sat PM	03:10	03:30	CP20	A29	Superior B Room
Isabelle, S.*	Sun PM	07:30	08:00	MS27	A42	Magpie Room
Its, A.R.*	Thu AM	10:15	10:45	MS1	A1	Ballroom 1&2
Ivanov, A.F.*	Fri PM	06:00	06:20	CP13	A19	Wasatch Room
J						
Jacquez, J.	Thu AM	10:15	10:45	MS4	A3	Maybird Room
Jakobsen, P.	Sat PM	04:00	04:30	MS20	A26	Magpie Room
Jalife, J.	Sat AM	11:30	12:00	MS17	A23	Wasatch Room
Jalife, J.	Sat PM	07:30	09:30	Poster	A35	Gold. Cliff & Foyer
Jimbo, S.	Thu PM	03:50	04:10	CP3	A8	Superior B Room
Johnson, R.*	Thu AM	10:15	10:35	CP2	A5	Superior A Room
Johnson, R.*	Thu PM	04:00	04:30	MS5	A6	Magpie Room
Johnson, R.*	Sat AM	10:00	10:30	MS15	A21	Magpie Room
Johnson, R.*	Sat AM	10:00	10:30	MS15	A21	Magpie Room
Jolly, M.S.*	Sun PM	08:30	09:00	MS26	A42	Ballroom 1&2
Jones, C.K.R.T.	Thu PM	06:20	06:40	CP6	A10	Wasatch Room
Jung, P.*	Fri PM	02:30	03:10	MS13	A16	Ballroom 1&2
K						
Kadtke, J.B.*	Fri AM	10:40	11:00	CP8	A13	Superior A Room
Kan, I.	Fri AM	11:00	11:20	CP10	A15	Maybird Room
Kaper, T.*	Sat AM	10:00	10:30	MS18	A23	Maybird Room
Kapitaniak, T.*	Thu PM	06:40	07:00	CP7	A11	Maybird Room
Kath, W.	Sat AM	11:30	12:00	MS16	A22	Ballroom 1&2
Kato, K.	Sat PM	07:30	09:30	Poster	A31	Gold. Cliff & Foyer
Kellman, M.E.*	Fri PM	04:00	04:30	MS12	A16	Magpie Room
Kennel, M.*	Sun PM	09:00	09:30	MS27	A43	Magpie Room
Khoury, P.	Fri AM	10:00	10:20	CP9	A14	Superior B Room
Kim, K.I.	Thu AM	11:35	11:55	CP2	A5	Superior A Room
Kim, S.*	Thu AM	11:35	11:55	CP2	A5	Superior A Room
Kim, Y.T.	Thu AM	11:35	11:55	CP2	A5	Superior A Room
Kirby, M.	Sat PM	07:30	09:30	Poster	A30	Gold. Cliff & Foyer
Kirby, M.*	Sun PM	07:30	08:00	MS29	A43	Maybird Room
Kiriki, S.*	Sat PM	07:30	09:30	Poster	A33	Gold. Cliff & Foyer
Knobloch, E.	Sat PM	02:30	02:50	CP20	A28	Superior B Room
Knobloch, E.	Sat PM	07:30	09:30	Poster	A31	Gold. Cliff & Foyer
Knobloch, E.*	Fri PM	04:10	04:30	CP11	A18	Maybird Room
Knobloch, E.*	Sun PM	01:40	02:00	CP22	A41	Superior B Room
Kocak, H.	Thu PM	02:30	03:00	MS5	A6	Magpie Room
Kodama, Y.*	Thu AM	11:45	12:15	MS1	A1	Ballroom 1&2
Konno, K.*	Sat PM	03:10	03:30	CP20	A29	Superior B Room
Kostelich, E.*	Sun PM	01:00	01:40	MS24	A39	Wasatch Room
Kovacic, G.*	Sat AM	10:30	11:00	MS18	A23	Maybird Room
Kovacic, G.*	Mon AM	11:00	11:30	MS31	A47	Wasatch Room

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Kumar, P.K.J.	Sat PM	07:30	09:30	Poster	A31	Gold. Cliff & Foyer
Kurths, J.*	Sat PM	03:50	04:10	CP20	A29	Superior B Room
L						
Lai, Y.-C.*	Sat PM	02:30	02:50	CP19	A27	Superior A Room
Lall, U.*	Sat PM	07:30	09:30	Poster	A36	Gold. Cliff & Foyer
Langari, G.	Thu PM	03:10	03:30	CP4	A9	Superior A Room
Lani-Wayda, B.*	Sat PM	07:30	09:30	Poster	A37	Gold. Cliff & Foyer
Lax, P.D.*	Thu PM	03:00	03:30	MS8	A7	Ballroom 1&2
Leibovich, S.	Sat AM	11:30	12:00	MS15	A21	Magpie Room
Levi, M.*	Sat AM	12:00	12:30	MS18	A23	Maybird Room
Lewis, D.*	Sat PM	02:30	02:50	CP18	A27	Maybird Room
Li, J.	Sat PM	07:30	09:30	Poster	A33	Gold. Cliff & Foyer
Lian, W.	Sun PM	02:00	02:30	MS22	A38	Ballroom 1&2
Lichtenberg, A.J.	Fri AM	10:00	10:20	CP9	A14	Superior B Room
Lieberman, M.A.	Fri AM	10:00	10:20	CP9	A14	Superior B Room
Lima, R.	Sun PM	08:30	09:00	MS29	A44	Maybird Room
Lin, X-B.*	Thu PM	02:50	03:10	CP3	A8	Superior B Room
Lindquist, A.*	Thu AM	10:45	11:15	MS3	A2	Wasatch Room
Lomov, A.S.*	Thu PM	04:10	04:30	CP3	A9	Superior B Room
Loparo, K.A.*	Fri AM	11:00	11:30	MS10	A12	Magpie Room
Lord, G.J.*	Thu AM	11:35	11:55	CP1	A4	Superior B Room
Lunel, S.V.*	Fri PM	03:00	03:30	MS14	A17	Wasatch Room
Lynov, J.P.	Sat PM	07:30	09:30	Poster	A32	Gold. Cliff & Foyer
M						
Mackey, M.C.*	Sat PM	01:30	02:30	IP8	12	Ballroom 1&2
Magnan, J.F.*	Sat PM	07:30	09:30	Poster	A31	Gold. Cliff & Foyer
Mahaffy, J.M.	Sat PM	07:30	09:30	Poster	A31	Gold. Cliff & Foyer
Mahalov, A.	Sat AM	11:30	12:00	MS15	A21	Magpie Room
Makhankov. V.G.	Sat PM	07:30	09:30	Poster	A35	Gold. Cliff & Foyer
Mandhyan, I.*	Sat PM	07:30	09:30	Poster	A33	Gold. Cliff & Foyer
Marcus, P.S.	Fri PM	03:30	03:50	CP11	A18	Maybird Room
Margolis, S.B.*	Sun PM	02:00	02:20	CP21	A40	Superior A Room
Markman, G.	Sat PM	07:30	09:30	Poster	A34	Gold. Cliff & Foyer
Marsden, J.E.	Fri AM	10:00	10:30	MS10	A12	Magpie Room
Marsden, J.E.*	Mon AM	08:30	09:30	IP12	17	Ballroom 1&2
Martin, C.*	Thu AM	11:45	12:15	MS3	A3	Wasatch Room
Mayer-Kress, G.*	Fri PM	02:50	03:10	CP12	A18	Superior B Room
McCormack, C.J.	Sat PM	07:30	09:30	Poster	A35	Gold. Cliff & Foyer
McKay, S.R.	Sat PM	07:30	09:30	Poster	A37	Gold. Cliff & Foyer
McKinstrie, C.J.	Sat PM	07:30	09:30	Poster	A33	Gold. Cliff & Foyer
McKinstrie, C.J.*	Sat PM	02:30	03:00	MS20	A25	Magpie Room
McLaughlin, D.W.	Sat AM	11:00	11:30	MS16	A22	Ballroom 1&2
McLaughlin, D.W.*	[illegible] AM	08:30	09:30	IP4	9	Ballroom 1&2
Meghdari, A.	Sun PM	09:10	09:30	CP24	A46	Superior A Room
Meier, P.F.	Fri AM	11:40	12:00	CP8	A14	Superior A Room
Meiss, J.D.*	Mon AM	10:00	10:30	MS32	A48	Maybird Room
Melbourne, I.*	Fri AM	10:30	11:00	MS11	A13	Wasatch Room
Meneveau, C.*	Thu PM	02:30	03:00	MS6	A6	Wasatch Room
Menyuk, C.*	Sat AM	10:30	11:00	MS16	A21	Ballroom 1&2
Mercader, I.	Sat PM	02:30	02:50	CP20	A28	Superior B Room
Meron, E.*	Sat AM	10:00	10:30	MS17	A22	Wasatch Room
Meyer-Spasche, R.*	Fri PM	02:30	02:50	CP11	A17	Maybird Room
Meyers, C.*	Sun PM	08:00	08:30	MS27	A42	Magpie Room
Milnor, J.*	Thu PM	05:00	06:00	IP3	8	Ballroom 1&2
Mirollo, R.E.*	Thu PM	03:30	04:00	MS7	A7	Maybird Room
Mischaikow, K.*	Fri PM	04:00	04:30	MS14	A17	Wasatch Room
Miura, R.*	Sun PM	01:30	02:00	MS25	A39	Maybird Room
Moeckel, R.*	Sat AM	11:00	11:30	MS18	A23	Maybird Room
Moloney, J.V.*	Sat PM	03:30	04:00	MS20	A26	Magpie Room
Monteiro, A.C.	Thu AM	11:55	12:15	CP1	A4	Superior B Room
Moon, F.C.	Thu AM	11:15	11:35	CP2	A5	Superior A Room
Moore, D.R.	Sun PM	01:40	02:00	CP22	A41	Superior B Room
Moorman, J.R.	Sun PM	08:30	08:50	CP23	A45	Superior B Room
Moorman, J.R.	Sun PM	08:50	09:10	CP23	A45	Superior B Room
Morita, Y.*	Thu PM	03:50	04:10	CP3	A8	Superior B Room
Moser, H-R.*	Fri AM	11:40	12:00	CP8	A14	Superior A Room

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