ABSTRACTS OF PRESENTATIONS
AND
WORKSHOP PROGRAM

MONDAY – AUGUST 19, 2002

8:15-8:20 AM **Firdaus Udwadia**, University of Southern California, Los Angeles, CA
Opening and Announcements

8:20-8:30 AM **Chrysostomos Nikias**, Dean, School of Engineering, University of Southern California, Los Angeles, CA
Welcome

TECHNICAL SESSION 1: 8:30-10 AM

Session Chair: ***George Leitmann***, University of California, Berkeley, CA

8:30-9:00 AM **Rudolf Kalman**, ETH, Zurich, Switzerland, and University of Florida, Gainesville, FL
Randomness and Probability and Fuzziness

Examination of real data is forcing the conclusion that classical probability is not a satisfactory model for randomness or uncertainty. The same holds for all things fuzzy. The alternative is to insist on a scientific approach, i.e., study the way in which randomness arises in Nature.

9:00-9:30 AM **V. Lakshmikantham**, Florida Institute of Technology, Melbourne, FL
Monotone Approximations and Rapid Convergence

The method of quasilinearization developed by Kalaba uses convexity assumption and provides lower bounding monotone sequence that converges to the assumed unique solution, once the initial approximation is chosen in an adroit fashion. If we utilize the technique of lower and upper solutions combined with the method of quasilinearization and employ the idea of Newton-Fourier, it is possible to construct concurrently lower and upper bounding monotone sequences whose elements are the solutions of the corresponding linear problems. Of course, both sequences converge rapidly to the solution. Furthermore, this unification provides a framework to enlarge the class of nonlinear problems considerably to which the method is applicable. For example, it is not necessary to impose usual convexity assumption on the nonlinear function involved, since one can allow much weaker assumptions. In fact, several possibilities can be investigated with this unified methodology and consequently, this technique is known as generalized quasilinearization. Moreover, these ideas are extended, refined, and generalized to various other types of nonlinear problems. We shall discuss some aspects.

9:30-10:00 AM **Angelo Miele**,
Rice University, Houston, TX
On Feasibility of Launch Vehicle Designs

We study various launch vehicle designs for a spacecraft to be launched vertically and ascending to an Earth orbit located at Space Station altitude (h = 463 km). We optimize the trajectory from the maximum payload viewpoint with respect to the angle of attack time history and thrust setting time history. We consider single-stage, double-stage, and triple-stage configurations. To perform the study, we employ a newly developed member of the family of sequential gradient-restoration algorithms for optimal control problems, the multiple-subarc sequential gradient-restoration algorithm.

Assuming that the engine specific impulse has the best value available today (Isp = 450 sec), we study the effect of the structural factor ε (ratio of structural mass to sum of structural mass and propellant mass) on the payload and then develop simple equations connecting the structural factor to the payload. With these equations, we are able to predict the limiting value of the structural factor for which the payload vanishes. To two significant digits, the limiting value is approximately $\varepsilon \cong 0.11$ for a single-stage configuration, $\varepsilon \cong 0.27$ for a double-stage configuration, and $\varepsilon \cong 0.34$ for a triple-stage configuration. Based on these results, we conclude that, given the current values of the engine specific impulse and spacecraft structural factor, a single-stage configuration is not feasible at this particular time, while double-stage and triple-stage configurations are feasible.

TECHNICAL SESSION 2: 10:15-11:45 AM

Session Chair: ***Lotfi Zadeh***, University of California, Berkeley, CA

10:15-10:45 AM **George Leitmann**, University of California, Berkeley, CA
A Direct Method of Optimization and its Application to a Class of Differential Games

Many problems in economics and engineering can be posed as dynamic optimization problems involving the extremization of an integral over a given class of functions subject to prescribed end conditions. These problems are usually addressed via the Calculus of Variations or the Maximum Principle of optimal control theory, applying necessary conditions to obtain candidate optimal solutions, and then assuring optimality via sufficient conditions if available. These methods are variational in that they employ the comparison of solutions in a neighborhood of the optimal one.

A different approach was first proposed in the 1960's and more recently expanded in Refs. 1-3. This approach permits the direct derivation of global extrema for some classes of dynamic optimization problems without the use of comparison techniques. Instead, it employs coordinate transformations and the imposition of a functional identity. The direct method is readily applicable to a class of open-loop differential games, as shown in Ref. 4.

10:45-11:15 AM **Andrew N. Krasovskii** and Nickolai N. Krasovskii, Russian Academy of Sciences, Ural Branch, Russia
Stable Mutual Tracking of Motions for the Real Dynamical Object and its Virtual Model

The talk is devoted to the problem of the stochastic stable mutual tracing of the motions of real dynamical *x-system* and some computer *z-model-leader* under the dynamical and informational disturbances. The control dynamical system is described by the ordinary vector differential equation nonlinear in control action u and disturbance v. Consider the case when the so-called saddle point condition in a small game

(Isaacs-Bellman condition) is not valid. It requires to construct the mutual tracing of *x*- and *z*-motions in the stochastic forms. The stochastic process is based on the appropriate constructions of the *extremal shift* [1] of one motion to another one. The right part of the differential equation for the controlled *x*-object contains some random dynamical disturbances restricted by the mathematical expectation. Note that we also consider the case when the position of *x*-object in the feedback control scheme is estimated with some informational random error. The statement of the control problem and the methods of its solutions are based on the mathematical formalization for the problems on the optimization of the processes under the criterion of *ensured result* and in particular for the problems of the control in the conception of zero-sum differential games developed in Ekaterinburg at Urals State University and Institute of Mathematics and Mechanics of the Urals Branch of Russian Academy of Sciences [2,3,4,5]. The elaborated algorithms are applied to the solution of some control model problems. Results of computer simulation of these problems are presented.

11:15-11:45 AM **Firdaus E. Udwadia** and Robert E. Kalaba, University of Southern California, Los Angeles, CA
Constrained Motion with Nonideal Constraints

In this paper we present the general structure for the explicit equations of motion for general mechanical systems subjected to holonomic and nonholonomic equality constraints. The constraints considered here *need not* satisfy D'Alembert's principle, and our derivation is *not* based on the principle of virtual work. Therefore the equations obtained here have general applicability. They show that in the presence of such constraints, the constraint force acting on the system can always be viewed as made up of the sum of two components. The explicit form for each of the two components is provided. The first of these components is the constraint force that *would have existed* were all the constraints ideal; the second is caused by the non-ideal nature of the constraints, and though it needs specification by the mechanician and depends on the particular situation at hand, this component nonetheless has a specific form. The paper also provides a generalized form of D'Alembert's principle which is then used to obtain the explicit equations of motion for constrained mechanical systems where the constraints may be nonideal. We show an example where the new general, explicit equations of motion obtained in this paper are used to directly write the equations of motion for describing a nonholonomically constrained system with non-ideal constraints. Lastly, we provide a geometrical description of constrained motion and thereby exhibit the simplicity with which Nature seems to operate.

TECHNICAL SESSION 3: 1:30-3:00 PM

Session Chair: ***Angelo Miele***, Rice University, Houston, TX

1:30-2:00 PM **Vladimir Matrosov**, Russian Academy of Sciences, Stability and Nonlinear Dynamics Research Center of RAS, Moscow, Russia
Methods of the Stability and Different Dynamic Properties Analysis for Mechanical and Control Systems

The method for dynamic analysis of stability, asymptotic stability, instability, attraction to sets and other properties of complex systems, described by nonlinear differential equation in a finite-dimensional, Hilbert and Banach spaces with discontinuous right sides are developed. The methods are based on using scalar or vector Lyapunov functions, that satisfies some differential inequalities. The mathematical theory for mechanical systems with sliding friction was elaborated. The classical Painleve paradoxes with effect of nonexistence and nonuniqueness of the motions of mechanical systems with big sliding friction were explained. The logic dynamical theory has been developed for interconnected control systems representing complex systems containing the mathematical models of subsystems with changing structure and interconnections, that allows reconfiguration and hybrid description. The vector Lyapunov functions method has been elaborated for their qualitative investigations: stability and other dynamical properties, algorithmic principle for inference of theorems on dynamical properties of stability and control type has been invented. The theorems on different type of stability, stabilizability, controllability, fault tolerance, survival and stability under constantly acting perturbations, possibility of sustainable development and soon has been obtained. Examples for investigation of: - the synthesis of fault-tolerant and exponential invariant attitude control system of spacecrafts,

- global survival and possibility of sustainable development of nature and society in modified mathematical model "World Dynamics" has been described.

2:00-2:30 PM **A. V. Balakrishnan**, University of California, Los Angeles, CA

Superstability: Theory and Experiment

Can the free response of a linear system be faster than exponential? The answer is surprisingly: Yes -- as we shall show. We illustrate this first with a physical model – a Timoshenko Beam (or a smart string) with self-straining actuators. We make a precise definition of superstability and indicate one sufficient condition for a system to be superstable. We discuss some practical limitations that determine how closely we can attain superstability in a laboratory experiment. We note that the general questions of both characterization and realizability are still largely open.

2:30-3:00 PM **Marianna Shubov**, Texas Tech University, Lubbock, TX

Asymptotic and Spectral Analysis of Aircraft Wing Model in Subsonic Airflow

The aircraft wing model, which will be discussed in this talk, has been developed in the Flight Systems Research Center of UCLA in collaboration with NASA Dryden Flight Systems Center. The mathematical formulation of this model has been originally presented in the works by A.V. Balakrishnan. The model has been recently tested in a series of flight experiments at Edwards Airforce Base. The experimental results have shown very good agreement with the theoretical predictions of the model for at least several lowest aeroelastic modes. The objective of the entire wing modeling project is to treat the flutter phenomenon in aircraft wing.

In this talk, I will present the results of my six recent works and of a joint paper with A.V.Balakrishnan devoted to the mathematical analysis of the model. The model is governed by a system of two coupled linear integro – differential equations and a two-parameter family of boundary conditions modeling the action of self-straining actuators. The differential parts of the equations of motion form a coupled linear hyperbolic system; the integral parts are of the convolution type. The aforementioned system is equivalent to a single operator evolution – convolution equation in the state space equipped with the energy metric. The Laplace transform of the solution of this equation can be represented in terms of the so-called generalized resolvent operator, which is an operator – valued function of the spectral parameter. This generalized resolvent operator is a finite – meromorphic function on the complex plane having a branch – cut along the negative real semi – axis. Its poles are precisely the aeroelastic modes and the residues at these poles are the generalized projectors on the corresponding eigenspaces.
I will describe the following results:

- Asymptotics of the eigenvalues and eigenvectors of the nonselfadjoint operator, which is a dynamics generator of the differential part of the model.
- Riesz basis property of the generalized eigenvectors of the above operator in the state space.
- Asymptotics of aeroelastic modes and mode shapes for the entire model.
- Riesz basis property of the mode shapes.
- Application of the results of asymptotic and spectral analysis to the representation of the solution to the main initial – boundary value problem in the space – time domain.
- The problem of flutter control will be discussed.

TECHNICAL SESSION 4: 3:15-4:45 PM

Session Chair: ***Eberhard Hofer***, University of Ulm, Germany

3:15-3:45 PM

Roger Jelliffe[1], A Botnen[1], A Schumitzky[1], D Bayard[2], M Milman[2], M Van Guilder[1], X Wang[1], and R Leary[3],
[1] Laboratory of Applied Pharmacokinetics, USC Keck School of Medicine, Los Angeles, CA
[2] Guidance and Control Section, Jet Propulsion Laboratory, Pasadena, CA
[3] San Diego Supercomputer Center, UCSD, San Diego, CA

Optimizing Individualized Drug Therapy with Nonparametric Population Models and Multiple Model (MM) Bayesian Adaptive Control

For drugs having narrow margins of safety, one must individualize their dosage, to achieve target goals such as desired serum concentrations with maximal precision. Our laboratory has developed software for nonparametric (NP) population modeling of the behavior of drugs, for small linear models having analytic solutions, and for larger and nonlinear models requiring differential equation solvers. These NP models, having discrete parameter joint densities, serve naturally as the Bayesian prior for "multiple model" (MM) dosage design to achieve target goals with minimal expected weighted squared error. We have coupled the small linear models with a method for obtaining Bayesian interacting multiple model (IMM) posterior parameter densities, to track unsuspected changes in parameter values during the period of data analysis, to better understand the behavior of drugs in acutely ill, unstable patients. These components have been integrated into the MM-USC*PACK program for therapy with drugs having 3-compartment linear models. Examples will include an interesting unstable patient receiving tobramycin, whose clinical status changed greatly during her therapy. This patient's parameter distributions gave a very poor fit to the data using conventional MM Bayesian updating. In contrast, the fit was much improved using IMM updating. The MM-USC*PACK package is ready for clinical use for drugs having 3-compartment linear models. Similar software for larger and nonlinear models is under development. That software should be useful for therapy with drugs such as phenytoin, carbamazepine, cyclosporine, and combination regimens of nonlinear, interacting drugs for patients with AIDS, cancer, transplants, and bacterial and viral diseases.

3:45-4:15 PM

On-Uma Kheowan[1], Vladimir S. Zykov[2], and **Stefan C. Müller**[3],
[1] Mahidol University, Bangkok, Thailand
[2] Technische Universität Berlin, Institut für Theoretische Physik, Germany
[3] Otto-von-Guericke-Universität-Magdeburg. Institut für Experimentelle Physik, Germany

Control of Spiral Waves in Excitable Media

The propagation of spiral-shaped excitation waves is a prominent example of self-organization in nonequilibrium systems. The properties of these waves are studied in a chemical model system – the Belousov-Zhabotinsky (BZ) reaction – and in various biological excitable media such as heart or neuronal tissue. An important aspect lies in finding tools for external control of these waves. A light-sensitive variant of the BZ reaction has proven to be a suitable system for investigating local and global control by means of a time-dependent uniform illumination. A local feedback control, in which short light pulses are applied at instants corresponding to the passage of a wave front through a measuring point, results in a drift of the

spiral center along a discrete set of stable circular orbits. In a confined-domain control, where the illumination intensity is taken to be proportional to the average wave activity observed in a circular domain of the reaction layer, the stabilization and destabilization of spiral wave trajectories are demonstrated. The implications of these results for the control of biological excitation waves are discussed.

4:15-4:45 PM **Rui Dilão**, Instituto Superior 7pcnico,
Nonlinear Dynamics Group, Lisbon,
Portugal

Turing patterns in the Neighborhood of a Hopf Bifurcation

Turing patterns are generally believed to be associated with the morphogenesis of some common biological patterns. We here introduce a general theoretical framework to analyze pattern formation in reaction-diffusion systems when the local dynamics shows damped or sustained oscillations. This approach enables to describe all possible types of qualitative behavior found in reaction-diffusion models for autocatalysis and morphogenesis as the Brusselator, the Oregonator, the Gray-Scott and the Gierer-Meinhardt systems.
The parametric conditions leading to the existence of non zero stationary solutions or Turing patterns for this non-linear reaction-diffusion equation are derived. The corresponding bifurcation diagrams as a function of the diffusion coefficients and of the local parameters are obtained. This analysis is done for one and two-dimensional spatial domains with zero flux at boundaries. Several numerical simulations are shown in agreement with the predicted results.

TUESDAY – AUGUST 20, 2002

TECHNICAL SESSION 5: 8:30-10:00 AM

Session Chair: ***A. V. Balakrishnan***, University of California, Los Angeles, CA

8:30-9:00 AM **Lotfi Zadeh**, University of California, Berkeley, CA
It is a Fundamental Limitation to Base Probability Theory on Bivalent Logic

A thesis that is put forth in this paper is that standard probability theory, call it PT, has fundamental limitations—limitations which are rooted in the fact that PT is based on bivalent logic. It is this thesis that underlies the radically-sounding title of the paper: It is a Fundamental Limitation to Base Probability Theory on Bivalent Logic.

The principal negative consequences of basing PT on bivalent logic are the following.

1. Brittleness (discontinuity.) Almost all concepts in PT are bivalent in the sense that a concept, C, is either true or false, with no partiality of truth allowed. For example, events A and B are either independent or not independent. A process, P, is either stationary or nonstationary, and so on. In particular, brittleness of independence creates serious problems in construction of Bayesian nets since only an epsilon separates independence from dependence.

2. The dilemma of "it is possible but not probable." A simple version of this dilemma is the following. Assume that A is a proper subset of B and that the Lebesgue measure of A is arbitrarily close to the Lebesgue measure of B. Now, what can be said about the probability measure, P(A), given the probability measure P(B)? The only assertion that can be made is that P(A) lies between 0 and P(B). The uniformativeness of this assessment of P(A) leads to counterintuitive conclusions.

3. Incapability to operate on perception-based information. This is the most serious limitation of PT. It is rooted in the fact that much of human knowledge is perception-based, e.g., "Most Swedes are tall;" "It is foggy in San Francisco during the summer," "It is unlikely to be warm tomorrow." and "Usually Robert returns from work at about 6pm." The intrinsic imprecision of perceptions puts them well beyond the reach of conventional meaning-representation methods based on bivalent logic. As a consequence, PT, by itself, lacks the capability to operate on perception-based information.

The principal thrust of what was said above may be viewed as a call for a recognition that standard probability theory has serious limitations—limitations which are rooted in its bivalent base and the fundamental conflict between bivalence and reality. What is needed to circumvent these limitations is a restructuring of the foundations of probability theory—a restructuring aimed principally at endowing probability theory with the capability to operate on perception-based information.

9:00-9:30 AM **Felix Chernousko**, Russian Academy of Sciences, Institute for Problems in Mechanics, Moscow, Russia
Modeling of Snake-like Locomotion

Locomotions of snakes and other limbless animals have been studied in biomechanics and have stimulated research and development of biologically inspired crawling robots. It was shown that a snake usually tries to utilize surface irregularities (vertical or inclined walls, slopes, stones, etc.) by pushing against them and thus producing additional horizontal reactions directed forward along the snake's path. Snake-like crawling robots consist of separate links equipped with wheels. For these nonholonomic systems, the wheels play the role similar to that of vertical walls.

In this paper, snake-like locomotions of multilink wheel-less mechanisms are investigated. The multibody systems under consideration consist of two, three, or many links connected by revolute joints and moving along a horizontal plane. Dry friction forces obeying Coulomb's law act between the linkage and the plane. Control torques are created by actuators installed at the joints.

It is shown that the multilink mechanisms can perform lengthwise and sideways motions as well as rotations on the spot. Hence, the linkage can be brought to any prescribed position in the plane. The proposed motions of two-link and three-link mechanisms consist of alternating slow and fast phases. For multilink mechanisms with more than four links, slow quasi-static motions are possible.

Dynamics of periodic snake-like locomotions is investigated, and the respective control algorithms are designed. Displacements, average speed of locomotions, and the required magnitudes of control torques are evaluated for different types of multilink systems.
Optimal geometrical and mechanical parameters are found which correspond to the maximal speed of motion. Results of computer simulation are presented. Due to the simplicity of snake-like mechanisms, they are of interest for the design of mobile robots, especially for mini-robots.

9:30-10:00 AM **Richard Day**, University of Southern California, Los Angeles, CA
Engineering Control and Economic Policy

The concepts of servomechanism, constrained optimization and dynamic programming play fundamental roles in engineering and economics. This talk compares their uses and explains why crucial distinctions need to be made in their application to the two disciplines.

TECHNICAL SESSION 6: 10:15 AM - 11:45 PM

Session Chair: ***Felix Chernousko***, Russian Academy of Sciences, Institute for Problems in Mechanics, Moscow, Russia

10:15-10:45 AM Eberhard Hofer and **Frank Lehn**, University of Ulm, Germany
A Time-Delay Approach for Modeling Chronic Radiation Injury Dynamics

Decision support for medical doctors who are in charge of diagnosis and therapy of the radiation syndrome is a major issue also for engineers. After the Chernobyl reactor disaster in 1986 lack of assistance for the acute radiation case became drastically evident. A very large number of irradiated persons had to be treated by only a very small number of medical doctors. Here, it became obvious that, in general, medical doctors usually have no special knowledge and experience in the area of radiation injuries.

In the Department of Measurement, Control and Microtechnology at the University of Ulm the development of a decision support system for the estimation of the severity level after an acute radiation exposure is rather advanced. The system is based on a biomathematical model of human granulopoiesis. Granulocytes which are a subgroup of white blood cells represent an outstanding indicator for the estimation of the severity level of such a radiation exposure. The term granulopoiesis describes the cell renewal system of the granulocytes, i.e., the dynamic process of the emergence of granulocytes starting at the level of stem cells in the bone marrow and ending with the release of fully matured granulocytes into the peripheral blood. In the past, very good results based on a model of granulopoiesis by Fliedner and Steinbach have been obtained. This model consists of a system of 37 nonlinear ordinary differential equations. The evaluation of the severity level of an irradiated person results from an estimation of the initial values of these model equations where a quadratic performance index consisting of the model output and real granulocyte measurements is minimized.

In a recent project an alternative modeling approach of the granulopoiesis based on delay differential equations has been studied, where the delays introduced to the model occur as state-dependent due to the biological knowledge. The resulting tasks concerning simulation and parameter estimation for this class of differential equations with time-delays have been carried out and appropriate numeric procedures have been developed, tested, and implemented. Due to the multitude of control applications for technical and non-technical systems with time-delays suitable algorithms are necessary and in strong demand. Especially, problems associated with parameter estimations are not widely known.

As a result of our research in radiation injury dynamics the system MODRAT (MOdel based RAdiation syndrome Treatment) has been developed and very good results for the acute irradiation case using real patient data turned out. Motivated by these good results for the acute irradiation case in a further step the chronic irradiation case was studied. In order to describe the dynamics of chronic irradiation the basic model equations for the acute case have been extended and a so-called kill rate has been introduced. Using this model very good results in agreement with real data have been obtained. By estimating the kill rate which uniquely represents chronic irradiation the numerical effort can be drastically reduced.

For the implementation of MODRAT special emphasis was devoted to high efficiency of the used algorithms for simulation and parameter estimation in order to ensure acceptable computing times within the range of a few minutes. Runge-Kutta methods combined with Hermite interpolants for the simulation, and SQP optimization methods as well as procedures of Automatic Differentiation for the solution of the optimization problem have been implemented in C++.

10:45-11:15 AM **Ruedi Stoop**, ETH, Switzerland

What is behind "*Synchronization and Control by Hard Limiters*"?

Experimentally, synchronization and control by hard limiters has been a very successful approach. No other control mechanism can compete with this method when emphasis is on the speed and on robustness of the control. However, from the theoretical point of view, control by hard limiters is only poorly understood. In my talk, I will describe the mechanisms behind this method. By solving the involved renormalization group equation, I will derive universality properties of the control. The control space properties and the changes that are induced by the control method on the periodic orbits of the original system, are analyzed. I will point out possible use and applications of this control method in biological and artificial neural networks.

11:15-11:45 AM **Punit Parmananda**, UAEM, Mexico
Suppressing Spatio-Temporal Complexity Using Local Forcing

We present numerical and experimental results exhibiting the suppression of spatio-temporal complexity via external forcing. Under the influence of periodic forcing applied both locally and globally the natural chaotic behavior of the extended system was converted to periodic dynamics. For the numerical results we chose a spatially extended model system used for the description of CO-oxidation on a Pt(110) single crystal surface. Using an electrochemical cell set-up to study the potentiostatic electrodissolution of an array of iron electrodes in a sulfuric acid buffer the experimental verification was achieved. Furthermore we used a time series from a human electroencephalogram (EEG) as a local perturbation to a reaction-diffusion model exhibiting spatio-temporal chaos. For certain finite ranges of amplitude and frequency it is observed that the strongly irregular perturbations can induce transient coherence in the hyper-chaotic system. This could be interpreted as "on-line" detection of an inherently correlated pattern embedded in the EEG.

TECHNICAL SESSION 7: 1:30-3:00 PM

Session Chair: ***V. Lakshmikantham***, Florida Institute of Technology, Melbourne, FL

1:30-2:00 PM Ziyad Masoud and **Ali Nayfeh**, Virginia Polytechnic Institute, Blacksburg, VA
A Delayed-Position Feedback Controller for Cranes

When using cranes, it is important to transfer cargo in the most efficient manner to ensure both safety of the cargo and safety of the personnel handling it, and to guarantee cost effectiveness of the transfer operations.

During cargo-transfer operations, cargo pendulations are excited by operator commanded motion of the crane. In the case of mobile cranes, the motion of the base on which the crane is mounted can produce hazardous cargo pendulations. In this work, we will show that it is possible to significantly reduce these pendulations for the most common types of cranes by channeling the operator commands through a delayed-position feedback controller before directing them to the crane actuators.

The controller design is based on the concept that imposing a delayed percentage of the horizontal cargo motion to the operator commands produces enough damping the crane system to stabilize hoisted cargo and eliminate or significantly reduce pendulations. The simplicity of the controller makes it possible to retrofit existing cranes with this controller for minimal cost. Moreover, since the control action is superimposed on the operator commands, it is completely transparent to the operator.

The controller is developed for and applied to boom cranes, rotary cranes, and gantry container-cranes. Computer simulations on full nonlinear three-dimensional models of these cranes with and without the controller are provided.

Results for the ship-mounted crane model demonstrate that the pendulations can be significantly reduced, and therefore the range of sea conditions in which cargo-transfer operations could take place can be greatly expanded. Results for the gantry container-crane model demonstrate the effectiveness of the controller in significantly shortening the loading and unloading cycles, and eliminating residual pendulations in record time.

Experimental validation of the simulation results is conducted on a scaled model of the ship-mounted boom crane and on a scaled model of a land-based rotary crane. Using the existing crane actuators, and adding a few sensors to provide a measure of the cargo pendulations, the controller is capable of producing the required control action with minimal additional power requirement.

2:00-2:30 PM

Jonathan Nichols[1], M. D. Todd[2], M. Seaver[2], and L. N. Virgin[1],
[1] Pratt School of Engineering, Duke University, Durham, NC
[2] U.S. Naval Research Laboratory, Washington, WA

Attractor-based Approaches in Structural Health Monitoring

In this work, an attractor-based approach to structural health monitoring is described. The technique focuses on using chaotic signals for the purpose of interrogating the structure of interest. By utilizing the unique properties possessed by chaotic signals, in conjunction with the Kaplan-Yorke conjecture, the dimension of the structural response may be controlled. The resulting low dimensional response may then be analyzed in phase-space for changes which are indicative of damage to the structure. The emphasis is on extracting attractor-based "features" which serve as precise damage classifiers in the presence of ambient variation. Results are presented for the dynamic response of an experimental cantilever beam with varying amounts of damage. In the analysis, estimates of correlation dimension are compared to the more suitable Taken's dimension estimator with regard to detecting both the presence and magnitude of structural degradation. Comparisons are also drawn between the standard modal-based methods and a new feature, the nonlinear cross-prediction error.

2:30-3:00 PM

- Rvp de Espindola and J.M.S. Neto, Federal University of Santa Catarina, Brazil

A Generalized Fractional Derivative Approach to Viscoelastic Material Properties Measurement and Vibration Control Design

To properly design a vibration control strategy with viscoelastic materials, two basic dynamic properties must be measured: the material loss factor and the dynamic modulus of elasticity.

In the past the rheological model for viscoelastic material was based on the classical concept of derivative (with respect to time) of integer order. These constitutive equations contain too many parameters to be identified, which makes it computationally impractical. Over the last two decades the concept of fractional (or generalised) derivative has gained the reputation of an extremely adequate tool to model viscoelastic materials

Fractional derivatives are such an intimate descriptor of rheological materials behaviour that only five, even four parameters are enough to accurately represent a particular material. This fact bears enormous consequences as to the approach to measure the loss factor and the dynamic modulus, as well as to the optimum design of viscoelastic devices for vibration control. In this presentation a new approach for the measurement of loss factor and dynamic modulus will be produced.

The quality and simplicity of the approach will be stressed throughout. How this new model impacts on the design procedures of viscoelastic devices for vibration control will be discussed. Experimental and numerical results will also be presented and discussed.

TECHNICAL SESSION 8: 3:15-4:45 PM

Session Chair: ***Ali Nayfeh***, Virginia Polytechnic Institute, Blacksburg, VA

3:15-3:45 PM **Masanori Sugisaka**, A. Loukianov, F. Xiongfeng, T. Kubik, and K. B. Kubik, Oita University, Oita, Japan

Development of an Artificial Brain for LifeRobot

The objective of our research is that the artificial brain has to provide the robot with abilities to perceive an environment, to interact with humans, to make intelligent decisions and to learn new skills. Application areas of the LifeRobot is for human welfare, service tasks, and data collection.

The research issues of LifeRobot prototype are navigation, learning, information processing, human-robot interface, and reasoning. In the navigation, *Mobile robot localization* is investigated. The problem is to estimate the robot location in environment using sensor data. Localization issues are position tracking, global localization; recovery from errors and incorrect location information. In the navigation, *path planning* is investigated. The problem is to find out how to move to the desired place basing on the topological map of the environment. In the learning, *learning skills* is investigated. Learning issues are to provide intelligent robot with an ability to adapt to changes in environment and to eliminate the need in robot programming by allowing the robot to interactively acquire new skills. In the human-robot interface, *face tracking* is considered. The problem is to find a face in the image taken by robot's cameras and trace its movements. These problems are under our investigations. This paper describes the new techniques developed in our researches for LifeRobot.

3:45-4:15 PM **Alexander Kurzhanski**, Russian Academy of Sciences, MSU, Moscow, Russia, and University of California, Berkeley, CA

On the Problem of Measurement Feedback Control

The presentation deals with the problem of measurement feedback control under unknown but bounded disturbances with various types of bounds. The applied techniques are based on Dynamic Programming methods and a respective Principle of Optimality formulated for the related class of problems.

The original problem is decoupled into two: the state estimation problem for calculating the information ("consistency") domain, which is a level set for the value function of a special forward HJB equation, and a game-type feedback control problem, whose solution is described by an HJBI equation in the infinite-dimensional space of value functions for the first problem. The overall scheme requires complicated calculations. For linear systems these may be simplified by applying ellipsoidal calculus, the application of which is finally described.

4:15-4:45 PM **Aghalaya Vatsala**, University of Louisiana, Lafayette, LA

Generalized Quasilinearization Method for First Order Initial Value Problems

The quasilinearization method of Kalaba is a useful technique in obtaining lower or upper bounding monotone iterates which converges quadratically to the unique solution of the nonlinear problem on the interval of existence. One can obtain lower or upper bounding monotone iterates which converges quadratically to the unique solution of the nonlinear problem. By this method one can obtain lower or upper bounding monotone iterates depending on the right-hand side function being convex or concave. In this talk, we present a method to obtain simultaneous lower and upper bounding monotone iterates when the forcing function is the sum of a convex and a concave function. The monotone iterates are linear and converges quadratically to the unique solution between the upper and lower solutions of the nonlinear problem. We extend this result to the system of nonlinear equations with initial conditions.

WEDNESDAY – AUGUST 22, 2002

TECHNICAL SESSION 9: 8:30–10:00 AM

Session Chair: **Henryk Flashner**, University of Southern California, Los Angeles, CA

8:30-9:00 AM **Dragoslav Siljak**, Santa Clara University, Santa Clara, CA
Inclusion Principle for Complex Systems: A Progress Report

In controlling complex dynamic systems, it is desirable to work with a model of low dimension, for which effective control laws can be formulated, yet a sufficiently large model that represents salient features of the original system. A mathematical framework for comparing dynamic systems of different dimensions is provided by the *Inclusion Principle*. The representative part of motions of the original large-scale system is reproduced by a smaller system, that is, the solution space (and, perhaps, performance indices) of the smaller system is *included* in the solution space (and indices) of the larger system.

Alternatively, a system with *overlapping subsystems*, which share common parts and impose on control laws an overlapping information structure constraint, may be expanded into a larger space for the subsystems to become disjoint. Decentralized control laws can be obtained in the expanded space using the standard methods for disjoint subsystems. Subsequently, the laws are contracted for implementation in the original space. The expansion-contraction process is carried out within the framework of the inclusion principle.

The objective of my talk is to present recent results on the theory and applications of the inclusion principle. I will consider models with linear time-varying, nonlinear, and stochastic elements. My emphasis will be on design of robust decentralized controllers involving multicontroller-multiplant configurations. Throughout the talk I will describe applications of the principle to models as diverse as electric power systems and segmented telescope, platoons of vehicles and hybrid systems.

9:00-9:30 AM **Srinivasa Leela**, State University of New York at Geneseo, Geneseo, NY
A New Concept Unifying Lyapunov and Orbital Stabilities

A new concept of stability which unifies Lyapunov and orbital stabilities as well as leads to notions in between them is defined in terms of a given topology of the function space following Messera. An attempt is made to offer sufficient conditions to obtain stability criteria for such concepts to hold.

9:30-10:00 AM **Ye-Hwa Chen**, Georgia Institute of Technology, Georgia, GA
Fuzzy Theorems: Principles and Applications

In the Pythagoras' theorem (1,500 BC), the sum of the squares of the two shorter sides of a right triangle is equal to the square of the longest side. This has been considered a "useful" result by many engineers. Suppose there is a young, motivating, and serious student who intends to find out the exact meaning of the theorem and determines to apply it "correctly." She should start with the definition of a triangle, which consists of three straight lines. After going through all details, she may declare that the theorem is not all that useful in the real world for there do not exist straight lines (in the sense of Euclidean geometry) and therefore right triangles. Fortunately, most of other engineers are not so serious. Before applying the theorem, what was performed by each engineer, at least tacitly, was a fuzzification process. The exact form of the theorem was converted into the following: if a geometric shape is very close to a right triangle, then the sum of the squares of the two shorter sides is close to the square of the longest side. This may be deemed a fuzzy theorem which serves to justify the practicality of the original Pythagoras' theorem. The first study of fuzzy theorems is by Zadeh (1975). There has been, however, practically no progress. It is believed that this may serve as one fundamental vehicle to apply exact sciences to the not-so-exact real world problems. In this presentation, we shall outline some basic principles and illustrate them by simple applications.

TECHNICAL SESSION 10: 10:15 AM – 11:45 AM

Session Chair: **Hubertus von Bremen**, University of Southern California, Los Angeles, CA

10:15-10:45 AM **Helio Mitio Morishita**, University of São Paulo, Brazil

Dynamics and Control of a Two-Body Floating System under Realistic Environmental Loads

In some countries such as Brazil oil is found in offshore deep-water fields where fixed platforms cannot be employed and the oil has to be taken to the shore through a shuttle vessel. Among several systems to exploit the oil, the Floating Production, Storage and Offloading (FPSO) system has received special attention due to its economical advantages. In general, an FPSO is a tanker converted to function as a temporary oil storage system. In fact all the oil processing facilities are installed on the main deck and the crude oil is treated before its storage. This vessel has to be kept in the desired position in spite of forces and moments due to the current, waves and wind. Different types of station keeping systems have been developed in order to adequate cost and safety of operations. In this paper two station keeping systems are considered, namely Differentiated Compliant Anchoring System (DICAS) and turret-type. The DICAS is composed of a set of mooring lines that connect the vessel to anchors on the seabed in which different pre-tensions of the lines assure some freedom to the ship to adjust itself to the predominant direction of the incoming weather. On the other hand, turret-type allows a complete yaw freedom of the vessel since it is positioned though a large cylindrical structure (turret) that cuts through the vessel vertically, working as a vertical bearing. Then, the mooring lines connect the turret to anchors on the seabed. In both cases, during the offloading a shuttle vessel is connected to the FPSO through a hawser in tandem configuration.

One of the main concerns in the design and operation of these large systems is clearly their dynamical behavior under the action of wind, current and waves in order to avoid collision of the vessels. However, the comprehensive understanding of the dynamics of those kinds of systems is extremely difficult due to non-linearity of their mathematical model. The Newtonian six-degree-of-freedom model results in a set of twelve first-order non-linearly coupled differential equations.

In this paper a comprehensive and systematic study of the dynamics of Turret FPSO in single and tandem configuration and DICAS-FPSO in tandem configuration is carried out and some control strategies for the shuttle vessel are discussed. As a preliminary step equilibria are calculated along with their stability properties for a range of values of the main parameters defining each configuration: wind and current speeds, significant height and mean period of waves and relative angles of incidence. The influence of the draught of the shuttle vessel as well as turret position are also assessed. Static solutions are obtained numerically due to complexity of the mathematical models and then their stability properties are investigated through time-domain simulations. The system displays a variety of different regimes of solutions in which both their number and their stability may change as one or more parameters are varied.

The results are summarized in a series of bifurcation diagrams in which the evolution of steady-state heading response of the ships is displayed as a function of parameters characterizing the environmental state. Based on the analysis of the static solutions and taking into account a criteria for acceptable relative positioning between the vessels, a control strategy for the shuttle vessel is also presented.

10:45-11:15 AM **- HWp de Souza**, University of São Paolo, Brazil

Nonlinear Dynamics of an Archetypal Model of Ships Motions in Tandem

Large converted tankers operate as floating platforms for the production of oil in offshore fields whose depth approaches 2000m. Their dynamics are influenced by wind, currents, and waves, and also by the physical characteristics of mooring lines. In addition to the single-vessel operation mode, a two-ship tandem arrangement is employed during the transfer of cargo (offloading) from the main production vessel to a shuttle vessel that takes the oil to other processing plants. It is essential to design the system in a way that ensures that the dynamical behavior of the vessels during offloading is safe. Mathematical models that represent the motions of moored ships in the sea can be complex, particularly when detailed modelling of hydro- and aerodynamic effects is required. In this work a simplified (archetypal) model is developed and explored that includes wind and current effects, and the elastic interaction between vessels. The model is validated against time series and bifurcation diagram results of a complete, industrial-strength model, and also through comparison with experimental data, showing good agreement. The use of a simplified model produces here a more refined exploration of dynamical features of the system such as its bifurcational structure and basins of attraction. The engineering relevance of these results is also assessed through the identification of static and dynamic solutions that lead to dangerous proximity between vessels.

11:5-11:45 AM **Nina Matrossova**, Stability and Nonlinear Dynamics Research Center of RAS, Moscow, Russia

On the Stability of Motions in Critical Cases

In this paper, critical cases of nonlinear stability theory, in the Lyapunov sense, are studied.

1. For the simplest critical cases for autonomous systems with analytical right side that were first investigated by Lyapunov, we have studied cases of a single zero root and a pair of imaginary roots of the characteristic equation by the method of interval analysis for simplified quantitative investigations.

2. The vector Lyapunov function method (VLFM) is used for more general critical cases with decomposition of nonautonomous nonlinear systems into asymptotically stable subsystems and subsystems with critical variables.

3. To generalize these results, theorems on stability of sets and of the zero solution of differential equations in Banach spaces using the VLFM method and comparison systems have been proved. For obtaining sufficient conditions for the presence of comparison properties in the comparison systems the theorem on stability of the zero solution from finite dimensional ordinary differential equations has been used. Theorems for analysis of stability in possible critical cases of differential equations in Banach spaces using the VLFM are presented.

4. As an application, a result on the stability of the trivial solution of nonlinear functional-differential delay equations is obtained.

TECHNICAL SESSION 11: 1:30–3:00 PM

Session Chair: ***Alexander Kurzhanski***, Russian Academy of Sciences, MSU, Moscow, Russia, and University of California, Berkeley, CA

1:30-2:00 PM

Christophe Deissenberg, Petya Manolova, and Charles Laitong, GREQAM, Universite de la Mediterranee, France

Real Effects of Money in an Economy with Heterogeneous Agents

The impact of money supply on the real variables and on utility is an important question in monetary economics. Most previous works study this impact in representative agent economies, often under perfect foresight. This paper, by contrast, analyses the way an injection of money propagates throughout an economy where agents interact locally with one other. It investigates the influence of such an injection on the consumption and production decisions of single agents. In particular, it looks at the transitory and permanent impact of a local or global injections of money on the transient dynamics of produced and exchanged quantities, prices, and individual welfare, and on the mechanisms that explain this evolution. The analysis is done analytically as far as possible, with recourse to simulations for the rest.

2:00-2:30 PM

Henryk Flashner and Michael C. Golat, University of Southern California, Los Angeles, CA

Bifurcation Analysis of Nonlinear Periodic Systems Using Expanded Point Mapping

A study of bifurcations in nonlinear periodic systems will be presented. In the study we employ a newly developed methodology referred to as the *Expanded Point Mapping (EPM*. The EPM combines the methods of *cell mapping* and the *point mapping* into a comprehensive analytic/numerical methodology that allows for investigation of global properties of the system as well as investigation of local properties of given solutions. The methodology is applicable to multi-degree of freedom systems, systems with any number of independent parameters. In addition, the EPM approach allows *analytical* investigation of local stability characteristics of steady state and the formulation analytical conditions for the stability characteristics of solutions. Stability conditions are obtained without expanding the solution in terms of a small parameters and therefore are especially suited for bifurcation analysis. In the presentation we shall formulate the the bifurcation analysis procedure using the EPM. Then the method will be demonstrated on two examples of pendulum with periodically excited support along a line and in the plane.

2:30-3:00 PM

D. Belato, **Hans Ingo Weber**, and J.M. Balthazar, PUC, Brazil

Using Information of the Transient Behavior to Approach the Phase Portrait of a Dynamical System

The investigation of the behavior of a nonlinear dynamic system implies in a good acknowledgement of the geometric structure of the solution surface, where the global behavior obtained by the variation of a control parameter can be represented. The methods based in the analysis of the Jacobian matrix are capable to provide a clear demonstration of the main bifurcational occurrences close to hyperbolic solutions, describing their domains of stability. However, when the degree of nonlinearity of the set of differential equations increases, this analysis is not sufficient to describe all the topologic aspects on the respective phase portrait since close to certain limits of resonance the solutions become more and more complicated.

This work will focus on an alternative numeric process to determine the stability of a set of differential equations concerning the variation of a chosen control parameter, using for this feature their transient trajectories. The process consists in building functions using the first points on some of the Poincaré sections, obtained by a set of initial condition for each value of the control parameter. Then, each of these functions is fitted by a polynomial where the change in their real coefficients can indicate or not the presence of a bifurcation. The set of these functions also provide a better visualization of the geometric structure of the phase portrait, identifying the bifurcational process of the system near the main resonance regions.

TECHNICAL SESSION 12: 3:15–5:15 PM

Session Chair: ***Vladimir Matrosov***, Russian Academy of Sciences, Stability and Nonlinear Dynamics Research Center of RAS, Moscow, Russia

3:15-3:45 PM **Nicolai Haydn**, University of Southern California, Los Angeles, CA

The Limiting Distribution of Return Times in Dynamical Systems

We consider dynamical systems that have an invariant measure with 'good' mixing properties (i.e. are (ϕ, f) – mixing) and look at the distribution of the times it takes for a generic point to pass through a neighbourhood of a given point. We develop a general framework with which we can show that those return times are in the limit Poisson distributed. The limit involves that the observation time and the size of the neighbourhood both are scaled by the local 'density' of the invariant measure.

Our approach uses a result that connects the convergence of factorial moments to the mixing properties of transformations which typically are expressed through the decay of correlations.

3:45-4:15 PM **Josp Manoel Balthazar**, State University of São Paolo at Rio, Brazil

On a Control Technique by Using Internal Resonance's and Saturation Phenomenon Applied to Ideal and Non-Ideal Machinery

In this paper, we analyzed a portal frame foundation excited by an DC motor with (Ilimited, that is ideal) and limited power supply (that is Non-ideal- Its characteristic has been taken as linear) near of the resonance region (the frequencies of the first and second modes are in resonance with the average frequency of the energy source) and the physical and geometric properties of the frame are chosen to tune the natural frequencies of these two modes into a 1:2 internal resonance. In this particular case, we may observe the modal interactions of the foundation (the saturation appear in the energy transference from a higher frequency mode to a lower frequency mode) and an interaction between foundation and energy source. We also investigate an implementation of a control strategy based on the saturation phenomenon due the internal resonance (modal and physical coupling between the Non-ideal vibrating system and the controllers) to suppress the motions of a portal frame foundation of an unbalanced rotating machine (Ilimited) limited power supply. The appearance of chaos is also analyzed. Finally we analyze an application to an ideal and Non-ideal Duffing oscillator with chaotic behavior.

4:15-4:45 PM

Hubertus von Bremen, University of Southern California, Los Angeles, CA

Beneficial Effects of Time Delays in the Control of Structural and Mechanical Systems

The active control of large-scale structures usually requires the generation of large control forces which often needed to be provided at high frequencies. The actuator and sensor dynamics do not permit the instantaneous generation of such forces and hence the effective control gets delayed. In order to accommodate for time delays, the mathematical formulations of the problem of controlling large structures are usually more complicated than the formulations without time delays. The fact that the models including time delays are more complicated and that in some cases the presence of time delays destabilize the control has generated the predominant view that time delays are an undesirable element in the control of structures. In this paper we show that for some cases the presence of time delay can actually stabilize a system that is unstable without time delays and that in some cases an appropriately chosen time delay can increase the performance of an active control system.