number of rate constants unlike other canonical forms such as the well-established "uncoupled" scheme. For many models proposed in the literature, our form has dramatically fewer links than the uncoupled form. The new form, which is based on the number of independent open-closed transitions, leads naturally to new strategies for searching for the simplest model.

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A New High-Order High-Frequency Integral-Equation Method for the Solution of Wave Scattering Problems

The effort and interest in the design of improved algorithms for computational electromagnetics and acoustics applications has consistently grown over the last twenty years as these simulations have become relevant in an increasing number of fields and have been facilitated by remarkable developments in computing resources. Still, current state-of-the-art algorithms are limited by the competing demands of accuracy, which typically requires an increasing number of degrees of freedom to resolve on the scale of a wavelength, and efficiency, which favors coarse discretizations. In this talk, we will present a new strategy for the solution of the integral equations of electromagnetic and acoustic scattering that successfully deals with these requirements by avoiding the need to discretize on the scale of the wavelength at high-frequencies, while retaining error-controllability and high-order convergence characteristics. The approach is based on the derivation of an appropriate ansatz for the phase of the (unknown) currents, on explicit treatment of shadow boundaries, and on localized high-order integration around critical points. Joint work with O. Bruno and C. Geuzaine.

JOHN RINZEL
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Fast-Decaying Inhibition Can Facilitate Spiking

In classical postinhibitory rebound (PIR), a neuron can generate a spike when it is suddenly released from a long-lasting inhibitory input. During the inhibition, the membrane becomes hyperpolarized and some of the negative feedback (e.g., K+ conductance) that is present at rest is reduced – thereby making the cell hyperexcitable. We find that even very brief inhibition $g_{inh}(t)$ can induce a spike or facilitate the response to a subthreshold excitatory input $g_{ex}(t)$ – enough to cause a spike, if $g_{inh}$ decays fast enough and occurs in a favorable time window preceding $g_{ex}$. Such pairings can occur by chance during the presentation of random trains of $g_{inh}$ and $g_{ex}$, and can form a significant fraction of spikes seen in simulated spontaneous states. Such effects occur in various spike-generating models, including the standard HH model. Phase-plane analysis of 2-variable models shows that if PIR occurs, then so does the extreme behavior of spike generation for the limiting brief case of a delta-function pulse of hyperpolarizing current. Such neuron models have two thresholds, for instantaneous jumps in membrane potential, in both the depolarizing and hyperpolarizing direction. Joint work with R. Dodla (Center for Neural Science, New York University).

GARETH J. RUSSELL
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Modeling Epidemics Based on Uncertain Timing Data

We adapt a likelihood model for the spread of a contagious process on a network of susceptible nodes so that it incorporates uncertainty in the timing of the node-level events (initial infection, the onset of contagiousness, etc.) that comprise the epidemic. The timing uncertainty is modeled as a uniform distribution of probability between known limits
(although other distributions are possible in principle), over which basic transmission functions are integrated. This general model is made specific to a particular case by incorporating functions that describe the nature of transmission process between nodes (e.g., nearest-neighbor only, rate as a function of Euclidean distance, etc.). Each specific model may be fit to data by maximizing its overall likelihood as a function of those parameters that describe the transmission process. Because the output of the model is a likelihood, it can be used to choose between alternative models of the transmission process. Increasing timing uncertainty reduces our ability to distinguish between models, and we present two case studies of the spread of tree pathogens which provide contrasting examples of how much can be learned from efforts to track the spread of the disease. Joint work with Jacqueline W. T. Lu (City of New York, Department of Parks and Recreation).

**WILLIAM M. SALLAS**  
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*Deconvolution and Regularization: Connection to Linear Least Squares and Application to Estimating Insulin Secretion in Patients with Type 2 Diabetes*

Deconvolution is applied to estimating insulin secretion in patients with type 2 diabetes in a clinical study with a meal challenge to assess $\beta$-cell function. C-peptide, which is cosecreted with insulin in an equimolar ratio, is preferred to insulin as a basis for estimating insulin secretion. Mathematically, we need to solve for the insulin secretion rate $r$ given the impulse response $h$, and plasma C-peptide $c$, where

$$c(t) = \int_{-\infty}^{t} h(t-s) r(s) ds.$$  

The impulse response is the pharmacokinetic model for an intravenously administered unit bolus dose of C-peptide when the endogenous C-peptide production has been suppressed, i.e.,

$$h(t-s) = \frac{1}{V} \left[ f e^{-\alpha(t-s)} + (1-f) e^{-\beta(t-s)} \right]$$

where $V$, $f$, $\alpha$, and $\beta$ are a subject’s parameters, which are generally unknown. However, from clinical studies, these parameters have been estimated in terms of a subject’s disease status, body surface area, age, and gender (van Cauter et al. 1992). Thus, $h$ becomes known. Three approaches to solving for $r(s)$ are reviewed: 1) solutions of linear systems of equations assuming either a piecewise constant function or a piecewise continuous linear function $r(s)$, 2) linear least squares solutions assuming smoothness criteria on the insulin secretion rates, and 3) a model that estimates insulin secretion rates accounting for changes in plasma glucose (Mari et al. 2002). Joint work with Huadong Tang (Wyeth Pharmaceuticals, Pearl River, New York) and Andrea Mari (C.N.R. Institute of Biomedical Engineering, Padova, Italy).

**CLYDE SCANDRETT**  
Mathematics Department, Code MA/Sd, Naval Postgraduate School, Monterey, CA 93943  
*Cancellation Techniques in Scattering from Fluid Loaded Plates*

Reduction and elimination of scattered acoustic signals by cancellation techniques involving piezoelectric materials is considered. Following formulation of the problem and a brief description of underlying principles, results on a few canonical problems will be given. These include radiation and scattering from heavy, fluid-loaded plates with either singly or periodically attached piezoelectric elements. Analytical treatments employing invariant embedding methods, Floquet theory, and asymptotics, will be compared with finite difference/boundary integral techniques.
**Following Coherent Structures**

Spiral waves, line defects, sources, and sinks, are examples of localized structures embedded in a background of waves with characteristic wavenumbers. Although these structures often appear to be very robust, the persistence under variations of system parameters turns out to be a delicate question due to essential spectrum caused by the background waves. We show how methods from dynamical systems can be used to prove robustness and bifurcation theorems, hence enabling a path-following type exploration of large-scale nonequilibrium systems. We also present examples where our approach exhibits structural barriers to pathfollowing: coherent structures can suddenly disappear.

**The Curse of Dimensionality in Genomics: Beyond the Likelihood Paradigm**

Genomic sequences involve an enormously large number of positions or sites (loci), each one having a purely qualitative categorical response (4 categories A, C, G, T for DNA nucleotides and some 20 amino acids in RNA codons). Thus, there is a very high dimensional categorical data model with the number of positions (K) often much larger than the number of sequences (n), so that K >> n. The prospect of incorporating the asymptotics for the likelihood function and all its ramifications (including the empirical likelihood) depends not only on managing the complex categorical data models arising in this context but also on low sample size high-dimensional perspectives. As of now, there has not been any great methodologic advances in this respect. Statistical learning or knowledge discovery and data mining tools are useful from the computational point of view, but they may lack, to a certain extent, statistical methodologic support.

Although, it is often assumed that the positions have independent responses, in reality, inter-site stochastic dependence is very much perceptible. Hamming distance-based methodology, therefore, has been advocated recently. They allow a dimension reduction taking into account the inter-site stochastic dependence to a certain extent. Pinheiro et al. (2000, 2005) have considered some MANOVA procedures based on variants of the Hamming distance. There has been some further research in this direction which incorporate second-order decomposability of Hoeffding’s (1948) U-statistics, and achieving asymptotic normality of the pseudo-U-statistics arising in this context. Applications to real data have also been considered. Joint work with Hildete P. Pinheiro and Aluisio S. Pinheiro (University of Campinus, Sao Paulo, Brazil).

**Swimming Worms, Swimming Sheets**

Motivated by experiments on “swimming” by active materials and the locomotion of nematodes, I will discuss different models and simulations of dynamic flexible bodies interacting with fluids. In two very different instances, we study how locomotion is generated by the propagation of large amplitude waves through a body, and how locomotion is affected by changes in the fluidic medium.
Metabolic and Electrical Oscillations in Insulin-Secreting Pancreatic Beta-Cells

The hormone insulin is the primary regulator of glucose concentrations in the blood and is important for regulation of consumption and storage of energy from carbohydrates, protein, and fat in general. Insulin concentrations in the blood oscillate with a period of about 5 minutes, and such oscillations have been shown to be disturbed in patients with diabetes. The whole-body oscillations are believed to be driven by oscillations in calcium in the beta-cells of the pancreatic islets of Langerhans, but there has been contention over whether the oscillations are metabolic or electrical in origin. We will discuss a beta-cell model with interacting metabolic and electrical oscillators. Both oscillators serve as readouts of the metabolic state of the cells, but are semi-independent in the sense that either can occur without the other. The two oscillators can also phase-lock in interesting ways. We will illustrate a wide variety of phenomena that can be explained by the combined model, but not readily with only one of the two sub-systems, including the glucose dose response curve and compound oscillations (bursts of bursts).

Surfactant Effects on Drop Detachment

Surfactant effects on the processes leading to drop detachment are studied for the case of a viscous drop detaching in a viscous fluid. In the absence of surfactants, neck pinch-off occurs at the primary neck and displays self-similar dynamics that are governed locally by the balance of capillary and viscous stresses in creeping flow. For viscous drops surrounded by viscous liquids, this regime has been predicted by scaling arguments, verified in experiment, and studied using boundary integral simulations. We study these effects numerically in the presence of surfactants in either the insoluble or adsorption-desorption limits.

In the absence of surfactants, the rate of surface dilatation is most negative just above the primary neck. When surfactants are present, they accumulate there. Since surface tension response is highly nonlinear at concentrations comparable to the maximum packing, regions of high surfactant packing have low local surface tensions and hence low capillary stresses. Necking dynamics are significantly altered. Drops break at the primary neck at low surfactant coverage, at the secondary neck at moderate coverages, or fail to neck at elevated coverages, suggesting a transition from dripping to jetting modes. These transitions are highly dependent on the surfactant sorption dynamics; phase diagrams for drop detachment regimes as a function of surfactant transport dynamics are developed. Joint work with Fang Jin and Nivedita Gupta (Department of Chemical & Biomolecular Engineering, Johns Hopkins University).

Dynamics and Stability of Capillary Surfaces: Designing Droplet Switches

A “capillary surface” is a liquid/liquid or liquid/gas interface whose shape is determined by surface tension. For typical liquids (e.g., water) against gas, capillary surfaces occur on the millimeter-scale and smaller where shape deformation due to gravity is unimportant (or on larger scales for soap-film surfaces). Capillary surfaces can be combined to make a switch – a system with multiple stable states. The simplest capillary switch consists of two droplets (or bubbles), coupled by common pressure.
The static response and stability (thermodynamics) of a capillary switch is given by its energy landscape. We use a theorem attributed to Poincaré to predict energy landscapes. Transition from one stable state to another (kinetics) involves the flow of fluid and is necessarily dynamical. Trajectories of the corresponding dynamical system can be computed directly. Or, alternatively, basins-of-attraction can be mapped (robustness). In this case, the fate of certain finite-amplitude disturbances is pre-determined by identifying trapping regions -- regions of disturbances that must always return to (or can never return to) a specified stable base state. We illustrate the prediction of thermodynamics, kinetics, and robustness of capillary switches using bifurcation theory, boundary-integral computations, and energy inequalities, respectively. Predictions are compared to observation of soap-film and droplet-scale realizations in the laboratory.

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Verification of Detonation Shock Dynamics by Numerical Simulation in Complex Geometries and in Multi-Material Systems

An extensive body of theoretical work has been carried out to derive front evolution equations that can describe the motion of detonation shocks in both condensed and gaseous explosives. The basic mathematical model for the explosive is the compressible Euler equations for pre-mixed materials, with a single one-step reaction from reactants to products. The explosive is represented by a pressure, volume, reactant progress variable equation of state (EOS), with a reaction rate law with similar arguments. The asymptotic theory of detonation shock dynamics (DSD) is a hydrodynamic flow theory that corrects a planar detonation to account for changes due to the shock curvature and unsteadiness. The asymptotics are based on the assumption that the radius of curvature of the shock is much larger than the reaction zone that supports the shock, and that changes to the shock shape are slow when measured on a time scale of a particle passage time through the reaction zone. Both are realistic for many systems of physical interest. A higher order theory includes unsteady effects such as shock acceleration and other higher derivatives in the surface.

Different forms of the detonation shock evolution equation can be obtained, and their validity and suitability for quantitative prediction of the flow states and the lead shock dynamics depends on the initial state of the flow and how close that state is to the assumption used in the asymptotic description. Of course, the theory for the discrepancy between the asymptotic predictions and the realization of the full system (i.e., a direct numerical simulation, properly resolved or alternatively the realization of the physical experiments themselves) is absent. To make these assessments, one relies on simulation and experiment.

In this talk, the current state of what is known about how well the asymptotic front theory predicts the detonation shock evolution of full systems, will be discussed. This will include a review of the different types of evolution equations obtained, such as the relation between detonation normal velocity and total shock curvature, and inclusion of higher order terms that can even lead to cellular detonation dynamics and chaos. The computed systems will include those with converging and diverging geometries, and complex multi-material interactions of shock with embedded inerts. Finally, if time permits, we will include applications of computed results to the design of novel miniaturized explosive systems currently be developed at University of Illinois.

**HOWARD STONE**

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The Stokes equations, which are the linearized version of the Navier-Stokes equations, describe a large number of flow problems in biophysics and the engineering and physics of thin films. In this talk, we describe two variants of these problems, which have a common solution feature, even though the physical contexts are very different. First, we consider the translation mobility of an ellipsoidal particle, which is trapped in a membrane or surfactant-coated interface, and protrudes into the surrounding fluid. The theoretical predictions for the mobility are compared with experimental measurements. Second, we consider the influence of substrate or particle deformability on the sliding lubrication of a sphere near a wall; deformation is responsible for the existence of a force normal to the wall. In both problems, neither of which had been treated successfully before, the Reciprocal Theorem, which is a variant of Green’s Theorem, is applied to obtain the final results while bypassing much of the (tedious) calculations associated with a direct approach to these problems.

**DE WITT SUMNERS**

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DNA Knots Reveal Chiral Packing of DNA in Phage Capsids

Bacteriophages are viruses that infect bacteria. They pack their double-stranded DNA genomes to near-crystalline density in viral capsids and achieve one of the highest levels of DNA condensation found in nature. Despite numerous studies, some essential properties of the packaging geometry of the DNA inside the phage capsid are still unknown. Although viral DNA is linear double-stranded with sticky ends, the linear viral DNA quickly becomes cyclic when removed from the capsid, and for some viral DNA the observed knot probability is an astounding 95%. This talk will discuss comparison of the observed viral knot spectrum with the simulated knot spectrum, concluding that the packing geometry of the DNA inside the capsid is non-random and writhe-directed.

**JEAN-MARC VANDEN-BROECK**

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Nonlinear Capillary Waves in Electrified Fluid Sheets

Nonlinear capillary waves propagating on fluid sheets are calculated in the presence of uniform electric fields acting in directions parallel or perpendicular to the undisturbed configuration. The fluids are taken to be inviscid, incompressible, and irrotational. Both conducting and non-conducting fluids are considered. Waves of arbitrary amplitude and wavelengths are calculated and the effects of the electric fields are studied. Fully nonlinear solutions are obtained by boundary integral equation methods. In addition, long-wave nonlinear waves are also constructed using asymptotic methods. As time permits, recent new results for Stokes flows will also be presented. Joint work with Demetrios Papageorgiou (NJIT).
**MIGUEL R. VISBAL**

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*High-Order Finite-Difference Schemes for Time-Domain Computational Electromagnetics and Acoustics*

This presentation will review recent progress achieved in the application of high-order finite difference schemes to the solution of multi-physics conservation laws on curvilinear geometries. We focus primarily on 4th- and 6th-order compact schemes coupled with up to 10th-order low-pass spatial Pade-type filters. Unlike standard numerical damping, the high-order filter operator provides selective dissipation of only the high-wavenumber content of the solution, which is already corrupted by the dispersion errors of the baseline discretization. These spatial algorithms are combined with explicit and implicit time integration methods to examine wave propagation in electromagnetics and acoustics. It is shown that without the incorporation of the filter, application of the high-order compact scheme to non-smooth collocated meshes results in spurious oscillations which inhibit their applicability. Inclusion of a discriminating low-pass high-order filter restores the advantages of the high-order approach even in the presence of localized large grid discontinuities. The filter operator in combination with highly stretched meshes also provides an alternative robust treatment of far field radiation conditions. Proper evaluation of coordinate transformation metrics is adopted to enforce the geometric conservation law on highly distorted and dynamically deforming curvilinear meshes. Finally, incorporation of high-order interpolation techniques and one-sided filter operators enable the extension of the approach to non-coincident overlapped meshes typically encountered in complex geometries.

**Z. JANE WANG**

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*Fore- and Hind-Wing Interactions in Dragonfly Flight*

Dragonflies are one of the most maneuverable insects. A distinctive feature of dragonflies is their use of two pairs of wings instead of one pair. This reflects their ancient origin. As such, understanding the coupling between their fore-and hind-wings might shed light on the evolution of flight based on four wings to that based on two. In this talk, I will describe the tracking of 3D wing motion of a tethered dragonfly, our computational method for simulating multiple wings, and our findings of the role of wing interactions and its effects on the forces and efficiency in hovering dragonfly flight. Joint work with David Russell.

**WENDY ZHANG**

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*Viscous Entrainment: Singular and Nearly Singular Liquid Spouts*

A small air bubble rising in syrup remains spherical. A larger air bubble deforms, developing an increasingly tapered trailing end. For an even larger air bubble, the rising movement is so severe in deforming the bubble that a thin tendril of air is deposited behind the rising bubble. Inspired by such familiar examples of viscous entrainment and recent experiments, we analyze the entrainment dynamics in a simple model problem where a long-wavelength model describes the essential dynamics. We show that both continuous and weakly discontinuous entrainment transitions are possible when the interface shape on the largest length-scales is constrained so that the base of the entrained tendril approaches a conical shape. Finally, we show that two kinds of critical transition exist in the full problem because the scale-invariant dynamics supports a saddle-node bifurcation. After the bifurcation, scale-invariant solutions which can link onto physical large-scale conditions do not exist.