Sixth Annual Front Range Applied Mathematics Student Conference
March 6, 2010

Breakfast and Registration: 8:30 - 8:55

Morning Session I - Room NC1605
9:00 - 11:00

9:00 - 9:20	Jeffrey Larson *University of Colorado, Denver*	Derivative-Free Optimization Using a Trust Region Framework
9:25 - 9:45	Eric Sullivan *University of Colorado, Denver*	An Ill-Posed Problem in Fluid Flow Through Porous Media
9:50 - 10:10	Daniel B. Larremore *University of Colorado, Boulder*	Role of Network Topology in the Dynamic Range of Coupled Excitable Systems
10:15 - 10:35	Keith J. Wojciechowski *University of Colorado, Denver*	High-order Numerical Scheme for Solving a Nonlinear Volterra Partial Integro-differential Equation Modeling a Swelling Porous Material on a Polar Geometry
10:40 - 11:00	Per Sebastian Skardal *University of Colorado, Boulder*	Coarsening of Calcium-Driven Alternans in Cardiac Tissue

Morning Session II - Room NC1603
9:00 - 11:00

9:00 - 9:20	Marshall Carpenter *University of Colorado, Boulder*	Self-Affine Fractal Sets
9:25 - 9:45	Henricus Bouwmeester *University of Colorado, Denver*	Towards an Efficient Tile Matrix Inversion of Symmetric Positive Definite Matrices on Multicore Architectures
9:50 - 10:10	Erik Benzal, Connor Janowiak, Patrick O'Brien *University of Colorado, Boulder*	Modeling Ant Colony Behavior
10:15 - 10:35	Manuchehr Aminian *University of Colorado, Denver*	Overview and Generalization of Image Segmentation Algorithms
10:40 - 11:00	Brock Mosovsky *University of Colorado, Boulder*	Transitory Dynamics and Transport in Hamiltonian Systems

Break: 11:00 - 11:15

Plenary Address: 11:15 - 12:15, Plaza M205

Geoffrey Spedding, *University of Southern California*
The Aerodynamics of Everything

Lunch: 12:15 - 1:00

Afternoon Session I - Room NC1605
1:00 - 3:25

1:00 - 1:20	Kye M. Taylor *University of Colorado, Boulder*	A Geometric Perspective for Time Series Analysis
1:25 - 1:45	Matt Kaspari *University of Colorado, Denver*	Global Programming Model for Assignments
1:50 - 2:10	Ryan Croke *Colorado State University*	New Traveling Wave Solutions of the Novikov-Veselov Equations and a Word Regarding Some of its Symmetries
2:15 - 2:35	Timothy Dunn, Ignas Satkauskas *University of Colorado, Boulder*	Comparing Gaits via Dynamic Stability
2:40 - 3:00	Peizhen Zhu *University of Colorado, Denver*	Rayleigh-Ritz Majorization Error Bounds of the Mixed Type
3:05 - 3:25	Toni Klopfenstein *University of Colorado, Boulder*	Analysis of the Immune Complement System

Afternoon Session II - Room NC1603
1:00 - 3:25

1:00 - 1:20	Taylor Carlson, Jewell Anne Hartman, Connor Wood *University of Colorado, Colo. Springs*	*Modeling Contest, Problem B* Criminology and Geographical Profiling as an Aid to Prevent Serial Crimes
1:25 - 1:45	Lee Rosenberg, Michelle Rendon, Manuchehr Aminian *University of Colorado, Denver*	*Modeling Contest, Problem B* Vector-Centroid Method of Tracking Wayfaring Serial Killers

1:50 - 2:10	Cody Cichowitz *University of Colorado, Boulder*	Adjoint-based Probabilistic Characterization of Contaminant Sources in Water Distribution Systems under Transient Flow Conditions
2:15 - 2:35	C. Travis Hunter *University of Colorado, Colo. Springs*	Linear and Nonlinear Schrodinger Equations on Simple Networks
2:40 - 3:00	Nathan Halko *University of Colorado, Boulder*	Randomized Linear Algebra in a Quantum Computer
3:05 - 3:25	Kannanut Chamsri *University of Colorado, Denver*	Modeling the Cilia and Mucus of Lungs

Plenary Speaker

11:15 - 12:15, PLAZA M205

The Aerodynamics of Everything

Geoffrey Spedding, University of Southern California

Although we rarely pause to consider it, our life on earth is one where we are surrounded by aerodynamics puzzles and problems. The history of aviation has seen 100 years of spectacular successes in large-scale transport, the Airbus A380 being the recent most notable example. But aerodynamics involves much more than just large and fast transport aircraft, and while all kinds of cases of objects moving through air, or air moving past objects, are easily counted in large number, they are not always so easy to investigate using our standard mathematical tools and examples.

A case in point is the current research in designing and building small-scale flying machines, about the size of a human hand. They can carry a camera and transmit information from inaccessible and/or dangerous places, maneuvering through complex environments. Unfortunately, we now find that our usual analysis methods break down for the aerodynamics of even simple objects at this size and speed range. Overall, the specification sounds a lot like that of a bird, and perhaps we can learn from nature, where such problems have apparently been solved, at least to the satisfaction of the flyers themselves. This talk encourages basic questions about all flying things, and answers some of them.

Geoffrey Spedding is a Professor of Aerospace and Mechanical Engineering at the University of Southern California. He has a mixed background in both biology and engineering and enjoys working on problems that contain a bit of both. He also works on the detection of submarine tracks in work sponsored by the US Navy.

MORNING SESSION I

DERIVATIVE-FREE OPTIMIZATION USING A TRUST REGION FRAMEWORK

Jeffrey Larson
University of Colorado, Denver

Optimization problems involving function which have no (or expensive) derivatives are frequently found in applied mathematics. The unavailability (or high cost) of derivatives can arise from a variety of problems: sophisticated and time-intensive simulations, black-box functions, and unsupported legacy code are frequently sources. As if these problems weren't daunting enough in their own right, numerical and stochastic noise can result in spurious derivatives which only hinder progress towards an optimum. Nevertheless, these problems underlie countless problems in applied mathematics.

In this talk we present examples where derivative-free optimization is needed, as well as methods currently used to solve these problems. Lastly, we propose our own method for derivative-free optimization using weighted least squares regression models within a trust region framework.

AN ILL-POSED PROBLEM IN FLUID FLOW THROUGH POROUS MEDIA

Eric Sullivan
University of Colorado, Denver

A porous material is a porous solid saturated with one or more fluids. In this talk we consider the case in which *Darcy's Law* applies: a Newtonian fluid moving slowly through a saturated porous solid. Darcy's Law, first stated in 1856, states that the flux through a porous medium is proportional to the pressure gradient across the domain and yields an elliptic equation. The constant of proportionality, called the hydraulic conductivity, may vary up to five orders of magnitude across a given domain when modeling fluid flow in hydrological applications. It can be shown that this problem is ill-posed under certain geometric considerations and when the hydraulic conductivity jump is arbitrarily large. Such a situation may occur when modeling flow through a domain containing a void. We will present numerical experiments which demonstrate the ill posedness of the problem and determine when it may be safe to solve this problem despite the ill-posedness. These experiments are compared to similar well-known, well-posed geometries such as flow around a large impermeable object such as a rock.

ROLE OF NETWORK TOPOLOGY IN THE DYNAMIC RANGE OF COUPLED EXCITABLE SYSTEMS

Daniel B. Larremore
University of Colorado, Boulder

We study the effect of network structure on the dynamical response of networks of coupled discrete-state excitable elements which are stochastically stimulated by an external source. Such systems have been used as toy models for the dynamics of some human sensory neuronal networks and neuron cultures. An important characteristic of these systems is the "dynamic range", the range of stimulus strength over which the network response varies significantly. There has been much recent interest in explaining the large dynamic range of brain tissue. It has been previously argued, by using a mean-field approach, that the dynamic range is maximized when the product of mean network degree and transmission probability is unity. Here we show more generally that for a large class of networks, the dynamic range is maximized when the largest eigenvalue of certain matrix Q is unity. The entries of matrix Q are given by $Q_{ij} = A_{ij}p_{ij}$, where matrix A is the network adjacency matrix and p_{ij} is the probability of excitation transmission from node $j$to node i. In addition, by studying various approximations to a nonlinear model of the excitable dynamics, we find analytical expressions for the dynamic range in terms of eigenvectors of matrix Q. Using these approximations, we study analytically and numerically the effect of network topology on the optimum dynamic range. These results provide a better understanding of the sources of enhanced dynamic range of neuronal networks and may be applicable to the study of other systems that can be modeled as a network of coupled excitable elements (e.g., epidemic propagation).

HIGH-ORDER NUMERICAL SCHEME FOR SOLVING A NONLINEAR VOLTERRA PARTIAL INTEGRO-DIFFERENTIAL EQUATION MODELING A SWELLING POROUS MATERIAL ON A POLAR GEOMETRY

Keith J. Wojciechowski
University of Colorado, Denver

In this talk we will study a nonlinear Volterra partial integrodifferential equation derived using hybrid mixture theory and used to model swelling porous materials. The dependent variable is the liquid volume fraction and the problem domain is a unit disk. The model application is an immersed material imbibing fluid through the circle's exterior boundary implying constant Dirichlet boundary conditions at the exterior and a no-flux boundary condition at the center. We show that well-posedness is established under a given set of assumptions and we introduce a novel approach to constructing pseudospectral (PS) differentiation matrices in a polar geometry to compute the spatial derivatives. This new approach maintains eigenvalues that are $\mathcal{O}(N^2)$ even when the number of nodes grows arbitrarily thus avoiding the instability pointed out by Trefethen, Trummer, and Fornberg. An exponential time-differencing scheme using fourth-order Runge-Kutta parameters (ETDRK4) proposed by Cox and Matthews and stabilized by Kassam and Trefethen is employed for the time-stepping. After we show how to set up the equation and numerically solve it using our new PS differentiation matrices and the ETDRK4 time-stepper, we show and interpret results for a variety of diffusion coefficients and viscoelastic parameters.

COARSENING OF CALCIUM-DRIVEN ALTERNANS IN CARDIAC TISSUE

Per Sebastian Skardal
University of Colorado, Boulder

Cardiac alternans is a well-known but potentially fatal phenomenon defined by a beat-to-beat alternating pattern of action potential duration (APD) and calcium concentration ($[Ca^{2+}]_i$) in cardiac tissue. Several studies have shown that the onset of alternans can be mapped to a period-doubling bifurcation in the beat-to-beat APD and peak $[Ca^{2+}]_i$. Furthermore, depending on the choice of parameters in a given model alternans can either be voltage- or calcium-driven. In voltage-driven alternans the APD and peak $[Ca^{2+}]_i$ are always positively-coupled, whereas in calcium-driven alternans the APD and peak $[Ca^{2+}]_i$ can be either positively- or negatively-coupled depending on the model's parameters. We define positive coupling as large (small) APD values and large (small) $[Ca^{2+}]_i$ values occuring at the same beat and negative coupling as large (small) APD values and small (large) $[Ca^{2+}]_i$ values occuring at the same beat.

Previous work has studied the spatiotemporal dynamics of alternans taking into account only voltage alternans, but the effect of calcium on such dynamics is largely unknown. We introduce a beat-to-beat map of the coupled dynamics of APD and $[Ca^{2+}]_i$ on a spatial domain that includes a few parameters including a diffusive voltage parameter σ, a bifurcation parameter r, and later a conduction velocity (CV) restituion parameter Λ that accounts for variations in the finite CV of signals from the stimulation site.

First, we study the dynamics and analytically compute the characteristics of the map on a simple infinite one-dimensional region of tissue that is divided into two regions of in-phase alternans. Second, we simulate the map on a finite one-dimensional region of tissue with random initial conditions and no-flux boundary conditions, comparing to the analytics of the simple case and study the coarsening of alternans on in-phase regions. Finally, we introduce the CV parameter and study the spontaneous formation of alternan waves and the speed at which they propagate. Throughout the project we study the competition between the bifurcation in calcium and the smoothing of voltage and how it affects the coursening of in-phase regions.

MORNING SESSION II

SELF-AFFINE FRACTAL SETS

Marshall Carpenter
University of Colorado, Boulder

The de Rahm-Chaikin curve-smoothing algorithm is an iterative process that cuts corners to transform a polygon into a C^1 curve. The algorithm functions on a parameter which varies between 0 to 0.5. The same iterative process with a parameter between 0.5 and 1 becomes a corner creating algorithm. Iterating this process converges to a self-affine fractal. The fractal is a self-intersecting curve of infinite length, no where differentiable, and contains distorted copies of itself. What may be more interesting are the many ways that this fractal can be produced. Typically, we are used to fractals as the fixed point of iterated function systems. Well known fractals such as the Koch Curve, Sierpinski Gasket, Heighway's Dragon, Hilbert Curve, and many more. Additionally, the de Rahm-Chaikin fractal can also be produced as the fixed point of a seemingly unrelated iterated function system. The iterated function system employs two affine mappings from an equilateral triangle to the interior of the triangle.

Several mysteries still remain to be discovered about these fractals. An analytic result for the dimension has not been found. There is no proof of equivalence between the de Rahm-Chaikin curve and the iterated function system. Numerical results can support both of these claims but an analytic result still needs to be found.

TOWARDS AN EFFICIENT TILE MATRIX INVERSION OF SYMMETRIC POSITIVE DEFINITE MATRICES ON MULTICORE ARCHITECTURES

Henricus Bouwmeester
University of Colorado, Denver

The algorithms in the current sequential numerical linear algebra libraries (*e.g.* LAPACK) do not parallelize well on multicore architectures. A new family of algorithms, the *tile algorithms*, has recently been introduced. Previous research has shown that it is possible to write efficient and scalable tile algorithms for performing a Cholesky factorization, a (pseudo) LU factorization, and a QR factorization. In this extended abstract, we attack the problem of the computation of the inverse of a symmetric positive definite matrix. We observe that, using a dynamic task scheduler, it is relatively painless to translate existing LAPACK code to obtain a ready-to-be-executed tile algorithm. However we demonstrate that non trivial compiler techniques (array renaming, loop reversal and pipelining) need then to be applied to further increase the parallelism of our application. We present preliminary experimental results.

MODELING ANT COLONY BEHAVIOR

Erik Benzal, Connor Janowiak, Patrick O'Brien
University of Colorado, Bouder

Over the past twenty years researchers have uncovered a number of facts about the behavior of ant colonies, the most interesting of which is that ant colonies have no central control. The queen ant is deep inside the nest laying eggs for her entire life (about 20 years) and essentially has no knowledge of events in the upper levels of the nest, nor of events occurring above ground. With some notable exceptions, a colony is mostly composed of sterile female workers engaged in four major tasks: nest maintenance; patrolling; midden work; foraging; and a large reserve of idle ants. The lifetime of an individual ant is about one year, while the lifetime of the colony is tied to the 20-year lifetime of the queen. Over the lifetime of the colony, its population grows to about ten thousand ants in about ten years, and then levels off for the remainder of the colony lifetime. Yet given these apparent restrictions, a colony can survive and successfully respond to a variety of natural disturbances and stimuli. Furthermore, it has been observed that the response of young colonies is rather disorganized while that of a mature colony appears to be less chaotic.

It seems that the proportion of ants engaged in specific jobs actually depends on the current state of the nest and its surroundings. Ants engaged in specific jobs seem to emit distinct chemical signals coded to the job they are currently performing. As ants encounter each other, they touch antennae to determine the current job of the other ant. Apparently, ants react to high encounter frequency rates and often change from their current task to participate in an activity that occupies the attention of a large number of their fellow ants.

Our main objective is to collect, develop and evaluate promising elementary algorithms that represent the basic behaviors of specific ants, and yet result in the observed aggregate behaviors associated with the colony as a whole. In addition, we are interested in the task allocation and switching models that result in the colony successfully responding to disturbances to the nest. Finally, we are in the process of implementing reasonable algorithms on several existing software platform to determine if the models come close to the observed behavior of actual colonies.

OVERVIEW AND GENERALIZATION OF IMAGE SEGMENTATION ALGORITHMS

Manuchehr Aminian
University of Colorado, Denver

Two established and closely related methods for image partitioning are Spectral and N-cut (normalized-cut) segmentation, which involve treating the image as a weighted graph and solving for the Fiedler vector of either the graph Laplacian, in the case of Spectral, or the "normalized" graph Laplacian, in the case of N-cuts. If further partitions are desired, this process can be done recursively on each of the existing partitions as desired. We review some of these basics, provide some intuition of the eigenvectors as corresponding to vibrational modes of the corresponding mass-spring system, and where the results from these algorithms can go "wrong" if weights are assigned naively.

We then introduce our ongoing work into extending these methods into three dimensions; i.e., a sequence of images over time, as in frames in a movie, or true three-dimensional image, as in an MRI scan, and give a few examples of our results with test images.

TRANSITORY DYNAMICS AND TRANSPORT IN HAMILTONIAN SYSTEMS

Brock Mosovsky
University of Colorado, Boulder

Invariant manifolds have long been studied as important structures governing the flow of a dynamical system. Hyperbolic manifolds in particular, by their very definition, relate information about the exponential contraction and expansion of nearby trajectories within the flow, and so play crucial roles in the global dynamics of such systems. They form a skeleton of sorts for the underlying flow that can lend insight into the mechanisms by which mixing, transport, chaos, and other complex global phenomena within the system are produced. In the case in which these hyperbolic invariant manifolds intersect, lobes are formed containing packets of trajectories that remain coherent in the Lagrangian sense provided their bounding manifolds remain intact. Tracking these lobes provides a means for quantifying flux between coherent structures in the flow. While identifying the hyperbolic invariant manifolds of autonomous dynamical systems is generally well-understood, the problem is complicated by the introduction of aperiodic time-dependence. In the latter case, methods employing finite-time Lyapunov exponents (FTLE) or identifying so-called distinguished hyperbolic trajectories have recently gained popularity as ways of uncovering the global manifold structure of such flows. We present a new method for quantifying transport between coherent structures in the flow for a special set of Hamiltonian systems that are time-dependent on a compact interval in time. We reduce the information required to quantify this transport to knowing only the relevant heteroclinic orbits in the flow, and we compare our results for manifold computation to those involving FTLE, discussing the benefits and limitations of each method.

AFTERNOON SESSION I

A GEOMETRIC PERSPECTIVE FOR TIME SERIES ANALYSIS

Kye M. Taylor
University of Colorado, Boulder

Researchers in many different areas routinely analyze time series. Typically this analysis includes (i) separating signal and noise, (ii) detecting features such as trends or anomalies, and (iii) confirming models or making predictions. In the proposed approach, the time series is embedded in high dimensions, creating a space curve, or trajectory. The geometric properties of this trajectory are examined and exploited to obtain a new method for representing a time series that preserves and emphasizes its local properties. In addition to demonstrating how this representation can be used to achieve goals (i) – (iii), we'll discuss chaotic dynamics, random processes, and graphs with extremal commute times.

GLOBAL PROGRAMMING MODEL FOR ASSIGNMENTS

Matt Kaspari
University of Colorado, Denver

Many organizations and events require the work of volunteers in order to run properly. Assigning volunteers to tasks they prefer to do will increase the probability that they will volunteer in the future. We constructed a goal programming model that will make assignments in such a way that maximizes the volunteers preferences. Simulation experiments were conducted so that we could determine what happens to the volunteer pool over time. Our work will show volunteer coordinators the importance of assigning volunteers to tasks they prefer to do. We will also show them how we can help assist in making those assignments.

NEW TRAVELING WAVE SOLUTIONS OF THE NOVIKOV-VESELOV EQUATIONS AND A WORD REGARDING SOME OF ITS SYMMETRIES

Ryan Croke
Colorado State University

The study of nonlinear evolution equations (NLEE's) is important in many branches of applied sciences such as optics, imaging, biochemistry and communications, and are also of theoretical interest in partial differential equations (PDE), geometry and analysis. My research centers around a specific NLEE, the Novikov - Veselov (NV) equation, a $(2 + 1)$ generalization of the ubiquitous Korteweg De-Vries (KdV) equation. I am investigating both it's applications and theoretical curiosities. It is more well known as a soliton equation, an equation which contains soliton solutions. In exploring this equation I have been using established techniques to find new solutions and have begun to develop my own schemes for new traveling wave solutions.

There is numerical evidence this may have applications in laser imaging, with the hope of finding an application in medial imaging. Starting from the work of Konopelchenko and Moro, ultimately my works aims to show the NV equation governs a medium whose index of refraction has the Cole-Cole dependency. As with any soliton equation one can explore many properties of the equation; Traveling wave solutions, conservation laws, line soliton solutions and symmetries are such properties. In this talk I will show some new traveling wave solutions, the techniques used to derive them, and say a few words about its 3-fold symmetry.

COMPARING GAITS VIA DYNAMIC STABILITY

Timothy Dunn, Ignas Satkauskas
University of Colorado, Boulder

Human gait, whether it be walking or running, can be characterized as a nonlinear dynamical system. By using ideas from non-linear dynamics to analyze the movement patterns of the body over many gait cycles, we can infer the role of stability and control across gait. To this end, we are collecting motion capture and force data on humans walking at approximate preferred and transition speeds, and running at typical and transition speeds, where transition speed is the speed at which humans switch from walking to running. We then use two ideas from non-linear dynamics to analyze the appropriate biomechanical and/or kinematic markers. We use Floquet analysis to describe how the system responds to perturbations across the periodic cycles with a state space consisting of joint angles. We are also exploring the use of Lyapunov exponents as a means of measuring local stability.

Floquet analysis requires the presence of a distinct limit cycle for the perturbation to be quantified. However, gait does not have a specific limit cycle, but an area in which gait is considered to be stable. The approach taken here is to build a statistically bounded region within which gait is considered to be stable. This bounded region is created by dividing the periodic gait cycle into small, equi-spaced partitions and calculating minima and maxima for those regions in two dimensions. Each set of minima and maxima are then connected and projected toroidally around the cycle producing the bounded region. Sensitivity analysis and other statistical methods will be used to verify the potential encapsulation of a limit cycle within the constructed bounding region. This idea will then be compared to a previously used idea in which cycles are averaged to find a "limit cycle" from which perturbations are measured.

Lyapunov exponents involve producing time-delayed copies of a scalar measure in order to unfold the underlying attractor. They are used to assess the exponential divergence or convergence between nearest neighbor trajectories and can be estimated from the slope of the linear region in the logarithmic divergence curve. However, when dealing with experimental data, this linear region is not always easy to determine. Though this measure has been used previously, we are unsure of its appropriateness in this case. In order to test this measure, we are presently performing multiple sensitivity analysis tests. If Lyapunov exponents prove to be inadequate measure of stability (in human gait case), we will not be able to perform comparative analysis, and hence, we will redirect our research to searching for a different stability measure.

RAYLEIGH-RITZ MAJORIZATION ERROR BOUNDS OF THE MIXED TYPE

Peizhen Zhu
University of Colorado, Denver

If we perturb the trial subspace in the Rayleigh-Ritz method, how do the Ritz values change? In the case, where the initial subspace is A-invariant, the change in the Ritz values represents the eigenvalue approximation error. We use majorization to bound the change in terms of the angles between the perturbed subspaces in a priori error bounds or the singular values of the matrix residual in a posteriori error bounds, correspondingly. We conjecture a novel error bound of the mixed type, which uses both terms simultaneously.

ANALYSIS OF THE IMMUNE COMPLEMENT SYSTEM

Toni Klopfenstein
University of Colorado, Boulder

The Human Immune Complement System is a complex and dynamic system that, despite its importance in human physiology, few mathematical tools exist to help investigate this system. This talk will demonstrate some of the mathematical tools being developed in order to accurately model and analyze this system, as well as evaluate how information is propagated through this network through the use of Fourier Transforms.

AFTERNOON SESSION II

Modeling Contest, Problem B
CRIMINOLOGY AND GEOGRAPHICAL PROFILING AS AN AID TO PREVENT SERIAL CRIMES
Taylor Carlson, Jewell Anne Hartman, Connor Wood
University of Colorado, Colo. Springs

Serial crimes, terrorism, and their fusion are a threatening chimera in today's world. In an attempt to increase accuracy, repeatability, and range of data of geographical profiling with increased precision, we have prepared a tool with 9 schemes, as follows:

- Scheme Zero: Date of Next Crime
- Scheme One: Time of Day of the crime
- Scheme Two: Average position of the Crime Scene
- Scheme Three: Travel Time Between Crime Scenes
- Scheme Four: Proximity of the Crime to Anchors
- Scheme Five: Crime Scene Demographics
- Scheme Six: Path Prediction
- Scheme Seven: Online Social Networking Profiles
- Scheme Eight: Criminal Methodology

A combination of these schemes yields a result combination technique that we developed to aid in the prediction of future serial crimes. In addition, we designed an equation for reliability, a probability distribution function, and a sensitivity analysis to design a tool that is more robust than traditional methods of geographical profiling such as center of mass. Our result combination technique yields a total probability distribution map to aid in the accurate prediction of serial crimes and terrorism, due to the implementation of reliability variables to prevent weak distributions from greatly affecting the total. Our final probability estimate can guide law enforcement to the time, location, and identity of the next possible victim and/or location and identity of the potential suspect, with greater accuracy than the traditional methods. The result combination technique was then tested on the Peter Sutcliffe case to predict the last crime scene in the case of the Yorkshire Ripper. In our presentation, we will discuss the derivation and implementation of the equations for each scheme, and examine the specifications for the utilization of the result combining technique for geographical profiling of serial crimes. This is a presentation of the result combining technique tool that we designed and submitted for the MCM 2010 Contest Problem B.

Modeling Contest, Problem B
VECTOR-CENTROID METHOD OF TRACKING WAYFARING SERIAL KILLERS
Lee Rosenberg, Michelle Rendon, Manuchehr Aminian
University of Colorado, Denver

At any given moment there could be 20-50 unidentified active serial killers in the United States. Should just one of these killers be prolific, many lives could possibly be taken: this concept of tracking and apprehending serial killers, indeed, becomes increasingly important. Through research and in the problem posed, it was found that a centroid-based method can be used to forecast future murder locations in the efforts to catch a serial killer in the act of his/her next murder. In the model used herein, a combination of linear algebra, graph theory, and centroid calculations is utilized to create and refine a global search area based upon past known data points, given by latitude and longitude. Average vector direction and magnitude, and the additional idea of a DAG (Directed Acyclic Graph) formed a foundation for the model, which we have dubbed the Vector-Centroid Method of Serial Killer Apprehension" or VCMSKA. The primary assumption was that at least one or more murders would take place after the manhunt had begun, and that the killer would not kill randomly in locations centered about their home (in contrast to that which was mentioned in the centroid portion of the problem description) after beginning the streak. It was assumed that he/she killed only one person at a time in roughly regular time intervals, as well as had a history of at least three previous murders in the same series, with the same motivation" or rationalization"-that is, there is some sort of innate similarities in victims. VCMSKA was also not designed for use with multiple killers such as with partners and large-group-based serial killers. When VCMSKA was run on the murders of Ted Bundy, more specifically with his six-teenth murder, his seventeenth murder was well-predicted inside a 68% confidence sector based on ten runs of the simulator. This was promising, as Ted Bundy's murders were relatively widespread and seemingly random. Although VCMSKA works well for serial killers who tend to travel or stay within a certain comfort zone (called travelling" and local" respectively), it was not developed to predict serial killers who abduct victims and kill them all in one common location (place-specific).

ADJOINT-BASED PROBABILISTIC CHARACTERIZATION OF CONTAMINANT SOURCES IN WATER DISTRIBUTION SYSTEMS UNDER TRANSIENT FLOW CONDITIONS

Cody Cichowitz
University of Colorado, Boulder

The threat of accidental or deliberate releases of contaminants into water distribu- tion systems is of serious concern. If a contaminant is released into a water system, sensors placed throughout the distribution network relay information about the trans- port of the contaminants through the pipes, pumps, valves, and storage tanks that comprise the network. The purpose of this ongoing research is to determine an ef- ficient and accurate method for characterizing the source. Specifically, the goal of the project is to identify properties of the contaminant, the location and time of the injection, and the sensitivity of the system to various parameters.

The developed methods analyze the advective-dispersive-reactive transport process, described by a partial differential equation, by employing an adjoint-based modeling approach. This approach was utilized to direct calculate information that characterized the source. The spacial and temporal variability was reversed in the adjoint model. Information from the backward model was then used to obtain a probability density function that described the possible times that a contaminant could have been released from any node in the system.

The theoretical results were tested and verified using a hypothetical distribution network modeled by an engineering software, EPANET 2.0. In EPANET 2.0, the time and location of a contaminant release was successfully identified. Furthermore, these results built upon previous work by extending the approach to networks with transient flow conditions, pumps, valves, and storage tanks.

LINEAR AND NONLINEAR SCHRODINGER EQUATIONS ON SIMPLE NETWORKS

C. Travis Hunter
University of Colorado, Colo. Springs

Recent theoretical developments in the study of initial-boundary value problems for linear and nonlinear equations have motivated further studies of interface problems for PDEs posed on networks. We investigate the scattering (transmission and reflection) of pulses at interfaces and at bifurcations for the nonlinear Schrodinger (NLS) equation, as a prototype model for bidirectional wave propagation in physical media. NLS equation belongs to an entire class of nonlinear models, called integrable models, for which an intimate relationship exists between their solutions and the compatibility of a linear system (known as the scattering problem). Numerical simulations of such models posed on networks indicate that, even when the underlying equations are genuinely nonlinear, scattering at junctions still occurs in a linear fashion. This is consistent with similar behavior observed in other nonlinear systems.

RANDOMIZED LINEAR ALGEBRA IN A QUANTUM COMPUTER

Nathan Halko
University of Colorado, Boulder

In this talk we will explore randomized linear algebra techniques in a quantum computing environment. Given a matrix A, our task is to find a k-dimensional approximation of its range. This would optimally be given by the first k left singular vectors, however, this is an expensive computation if A is very large. Our next step would be to give up on optimality and construct a good approximation that we achieve by randomized sampling of A. Use of randomization then allows us to take advantage of the probabilistic and parallel features of quantum computing. The talk will consist of equal portions of randomized sampling, quantum computing, and how we can merge the two.

MODELING THE CILIA AND MUCUS OF LUNGS

Kannanut Chamsri
University of Colorado, Denver

Cilia are the small hairs which line lungs and, along with coughing, are responsible for moving mucus. In this talk we present preliminary results on modeling the flow of the liquid below the mucous layer, PCL, due to the movement of cilia. We consider the fluid to be incompressible, and we treat the cilia/PCL system as a porous material in which the solid phase moves the liquid (in usual models the liquid phase induces the movement of the solid). We introduce homogenization and explain how it will be used to obtain a model that will need to be solved numerically to obtain system characteristics at the macroscale. The numerical approach will also be discussed.