11^{th} Annual Front Range Applied Mathematics Student Conference

February 28, 2015

Registration: 8:30 - 9:00

Morning Session I - Room NC1323
9:00 - 11:35

9:00 - 9:20	Axel Brandt *University of Colorado, Denver*	Local Gap Colorings from Edge Labelings
9:25 - 9:45	Brent R. Davis *Colorado State University*	Numerical Algebraic Geometry for Analysis of Phylogenetic Trees
9:50 - 10:10	Luke Nelsen *University of Colorado, Denver*	A Look at Forcing Monochromatic Subgraphs in Arbitrarily Colored Graphs
10:10 - 10:25	15 Minute Break	
10:25 - 10:45	Eric Sullivan *University of Colorado, Denver*	Minimum saturated subgraphs of tripartite graphs
10:50 - 11:10	Brent Moran *University of Colorado, Denver*	Ramsey-Minimal Saturation Numbers for Sets of Stars
11:15 - 11:35	Devon Sigler *University of Colorado, Denver*	The Max-Cut Problem and Semidefinite Programming

Morning Session II - Room NC1324
9:00 - 11:35

9:00 - 9:20	Bradley McCaskill *University of Wyoming*	A Multiscale Domain Decomposition Method for Flow and Transport Problems
9:25 - 9:45	Louie Long & Derek Driggs *University of Colorado, Boulder*	Quasi-Geostrophic Convection in the Rotating Cylindrical Annulus
9:50 - 10:10	Meredith Plumley *University of Colorado, Boulder*	Ekman Boundaries in Rotating Rayleigh-Bénard Convection
10:10 - 10:25	15 Minute Break	

10:25 - 10:45	Ahmad Alyoubi *Colorado School of Mines*	Parallel simulation of a class of evolutionary systems
10:50 - 11:10	Marika Schubert & Weiliang Sun *University of Colorado, Boulder*	The Determination of the Diffusion Coefficient between Diluted and Pure Corn Syrup
11:15 - 11:35	Michelle Maiden *University of Colorado, Boulder*	Applied Mathematics of Viscous Fluid Conduit Experiments

Morning Session III - Room NC1325
9:00 - 11:35

9:00 - 9:20	Christian Parkinson *Colorado School of Mines*	In-Host Modeling of the Spatial Aspects of HIV
9:25 - 9:45	Farrah Sadre-Marandi *Colorado State University*	Comparison of Models for HIV-1 Nucleation
9:50 - 10:10	Deborah Shutt *Colorado School of Mines*	Bridging the Gap between Simplistic and Complex Models of HIV Dynamics
10:10 - 10:25	15 Minute Break	
10:25 - 10:45	Tyson Loudon *Colorado School of Mines*	Active Subspace Methods Applied to HIV Modeling
10:50 - 11:10	George Borleske *Colorado State University*	Modeling the Deformation of Proteins: From Coarse-Grained to Continuum
11:15 - 11:35	Mike Mikucki *Colorado State University*	The important role of proteins in vesicle budding

Morning Session IV - Room NC1326
9:00 - 11:35

9:00 - 9:20	Paul Diaz *Colorado School of Mines*	The Empirical Interpolation Method
9:25 - 9:45	Scott Walsh *University of Colorado, Denver*	Optimizing Quantities of Interest in High Dimensions to Improve Solutions to Inverse Problems

9:50 - 10:10	Wes Dyk *University of Colorado, Denver*	Optimization Methods for Liquids Hauling and Inventory
10:10 - 10:25	15 Minute Break	
10:25 - 10:45	Bradley Dworzak *Colorado School of Mines*	Inverse modeling of a class multiple scattering parameters
10:50 - 11:10	Anzhelika Lyubenko *University of Colorado, Denver*	Unbounded Trade-offs in Revenue Maximization Under Uncertain Consumer Demand
11:15 - 11:35	Minqi Liu *Colorado College*	A three species-model with predator-prey, competition, and mutualistic interactions

Lunch: 11:45 - 12:25

Plenary Address: 12:30 - 1:30, Room NC1130

Dr. Harvey Segur
Department of Applied Mathematics
University of Colorado, Boulder

Tsunami

Group Photographs at 1:30

Afternoon Session I - Room NC1322
1:45 - 3:20

1:45 - 2:05	Alexander Charlesworth *Colorado School of Mines*	Approximations and Analysis for a Class of Computational Time-Domain Electromagnetics
2:10 - 2:30	Tommy McDowell *University of Colorado, Colorado Springs*	Numerical studies of the KP line solitons
2:35 - 2:55	Charles Morgenstern *Colorado School of Mines*	A Non-standard FEM for Acoustic Wave Propagation
3:00 - 3:20	Kirill Golubnichiy *University of North Calorina, Charlotte*	About One Theorem for the Nonlinear Transport Equation in $H_\infty(D) \times L_\infty(G \times V)$

Afternoon Session II - Room NC1323
1:45 - 3:45

1:45 - 2:05	Miguel Carrasco *University of Colorado, Denver*	Optimal Operation of Power Systems Integrated with Distributed Generation
2:10 - 2:30	Bahaudin Hashmi *Colorado State University*	Modeling of Atmospherically Important Vapor-to-Particle Reactions
2:35 - 2:55	Rachel Neville *Colorado State University*	Persistence Images: A Look at Persistent Homology
3:00 - 3:20	Farhad Pourkamali-Anaraki *University of Colorado, Boulder*	Signal Processing and Learning for Big Data via Random Projections
3:25 - 3:45	Chad Waddington *Colorado State University*	Bistatic Synthetic Aperture Radar Imaging with Applications to Passive Sensing

Afternoon Session III - Room NC1324
1:45 - 3:45

1:45 - 2:05	Rayna Ben-Zeev *Colorado College*	The Vulnerability of California Amphibian Species to Climate Change
2:10 - 2:30	Kraig Thomas *University of Colorado, Denver*	Incorporating Relatedness in Gene Based Case-Only Analysis of Mendelian Traits

2:35 - 2:55	Melissa Jay *Colorado College*	Determining the Top All-Time College Coaches Through Markov Chain-Based Rank Aggregation
3:00 - 3:20	Denis Kazakov & Derek Driggs *University of Colorado, Boulder*	Tackling the outbreak at its core
3:25 - 3:45	Thomas Gebhardt, Conrad Hougen & Pawel Janas *University of Colorado, Boulder*	Eradicating Ebola: A Technique for a Quick Response to Infectious Diseases

Afternoon Session IV - Room NC1325
1:45 - 3:20

1:45 - 2:05	Ana Kenney *University of Colorado, Denver*	Predicting Random and Rather Erratic Road Conditions
2:10 - 2:30	Kaitlyn Martinez *Colorado College*	Epidemiological Methods for Examining Bullying
2:35 - 2:55	Branden Olson *University of Colorado, Boulder*	Simulation of Local Temperature and Precipitation Occurrence Using Approximate Bayesian Inference
3:00 - 3:20	Tony Wong *University of Colorado, Boulder*	Optimization of modeled land-atmosphere exchanges by Bayesian parameter calibratoin

Afternoon Session V - Room NC1326
1:45 - 3:20

1:45 - 2:05	Anna Johnsen *University of Colorado, Denver*	Multilayer Networks and their Applications to Human Resource Modeling
2:10 - 2:30	Christina S. Burris *Colorado State University*	Construction and Optimality of Unoriented de Bruijn Sequences
2:35 - 2:55	Michael Pilosov *University of Colorado, Denver*	Moving Pictures: Animating Still Images
3:00 - 3:20	Nathan Graber *University of Colorado, Denver*	Linear Turan numbers of Linear Cycles

Plenary Speaker

12:30 - 1:30, NC1130

Tsunami

Dr. Harvey Segur

Department of Applied Mathematics, University of Colorado, Boulder

Tsunami have gained worldwide attention over the past decade, primarily because of the destruction caused by two tsunami: one that killed more than 200,000 people in coastal regions surrounding the Indian Ocean in December 2004; and another that killed 15,000 more and triggered a severe nuclear accident in Japan in March 2011. This talk has three parts. It begins with a description of how tsunami work: how they are created, how they propagate and why they are dangerous. This part involves almost no mathematics, and should be understandable by everyone. The second part of the talk is about the operational models now being used to provide tsunami warnings and forecasts. These models predict some features of tsunami accurately, and other features less accurately, as will be discussed. The last part of the talk is more subjective: what public policies could be enacted to mitigate some of the dangers of tsunami? Much of the material in this talk appeared in a paper by Arcas and Segur, Phil. Trans. Royal Soc. London, 370, 2012.

About the Speaker

Dr. Harvey Segur is a professor of applied mathematics at the University of Colorado Boulder, where he helped initiate a new Department of Applied Mathematics in 1989. Dr. Segur has been the recipient of many awards for his contributions in teaching and research, including the 2011 Hazel Barnes Prize (the highest faculty recognition for teaching and research awarded by CU-Boulder) and the honor of becoming a CU President's Teaching Scholar in 1998. Before coming to CU-Boulder, he was a research fellow at the California Institute of Technology, an associate professor at Clarkson College of Technology in Potsdam, N.J., a professor at State University of New York, Buffalo, and has worked extensively in industry. Dr. Segur's research is highly cited, consisting of numerous journal articles and a book, and focuses on fluid dynamics and wave phenomenon. In particular, his research investigates nonlinear waves and the problems of dissipation and propagation of waves, as well as mathematical models of waves in shallow and deep water. Dr. Segur's contributions to the Department of Applied Mathematics at CU-Boulder also include teaching and curriculum enhancements, such as incorporating reflective discourse in lower-division calculus courses through oral assessments and offering a two-semester alternative to the typically one-semester Calculus 1 course. These reforms are now being adopted by several other universities across the United States.

MORNING SESSION I

LOCAL GAP COLORINGS FROM EDGE LABELINGS

Axel Brandt
Collaborators: Brent Moran, Kapil Nepal, Florian Pfender & Devon Sigler
University of Colorado, Denver

Graph coloring has a variety of applications, most notably to scheduling and register allocation problems. The significance and versatility of results have motivated a broad interest in variations of graph colorings. In this talk, we discuss a coloring in which vertices of a graph receive their color based on labels assigned to the edges of the graph. Specifically, this derived coloring is a local version of gap vertex–distinguishing edge coloring presented by Tahraoui, Duchêne, and Kheddouci in 2012. From an edge labeling $f\colon E \to \{1,\ldots,k\}$ of a graph G, an induced vertex coloring c is obtained by coloring the vertices with the greatest difference between incident edge labels. The local gap chromatic number of G, $\ell gap(G)$, is the minimum k for which there exists an edge coloring such that $c(u) \neq c(v)$ for all edges uv. Improving a result of Scheidweiler and Triesch, we prove that $\chi(G) \leq \ell gap(G) \leq \chi(G) + 1$ for all graphs G, where $\chi(G)$ denotes the chromatic number of G. We also provide families of graphs that meet both bounds.

NUMERICAL ALGEBRAIC GEOMETRY FOR ANALYSIS OF PHYLOGENETIC TREES

Brent R. Davis[1]
Collaborator: Joseph Rusinko[2]
[1] ***Colorado State University***
[2] ***Wintrop University***

Using tools from numerical algebraic geometry, we propose a phylogenetic reconstruction algorithm which uses the Euclidean distance to the nearest point on the Jukes Cantor quartet model to select the tree of best fit. This method allows for the reconstruction of the rates of nucleotide change over each edge of the model tree. In addition, the method can be used for hypothesis testing. We define and analyze two schemes (relative distance and p-value) for excluding quartets that lead to false positive reconstruction. This technique may be applied to exclude faulty data along quartets in the reconstruction of supertrees or species trees.

A LOOK AT FORCING MONOCHROMATIC SUBGRAPHS IN ARBITRARILY COLORED GRAPHS

Luke Nelsen[1]
Advisor: Louis DeBiasio[2]
[1] ***University of Colorado, Denver***
[2] ***Miami University, Ohio***

This talk will peek at the results and techniques of a submitted paper, "Monochromatic cycle partitions of graphs with large minimum degree," by Louis DeBiasio and myself. I will present a background of the problem in question and paint broad strokes of the approaches in our proof.

Lehel conjectured that for all n, any 2-edge-coloring of K_n admits a partition of the vertex set into a red cycle and a blue cycle. This conjecture led to a significant amount of work on related questions and was eventually proven for all n by Bessy and Thomassé. Balogh, Barát, Gerbner, Gyárfás, and Sárközy conjectured a stronger statement for large n: that if $\delta(G) > 3n/4$, then any 2-edge-coloring of G admits such a partition. Balogh, et al. use regularity and blow-up techniques to cover all but γn vertices if $\delta(G) > (\frac{3}{4}+\gamma)n$. DeBiasio and Nelsen use the absorbing method to prove their conjecture.

The submitted paper is available to read at http://arxiv.org/pdf/1409.1874v1.pdf and a related exposition on the techniques is available at http://math.ucdenver.edu/ nelsenl/hostedfiles/ LukeNelsenMastersThesis.pdf.

MINIMUM SATURATED SUBGRAPHS OF TRIPARTITE GRAPHS

Eric Sullivan[1]
Advisor: Paul S. Wenger[2]
[1] ***University of Colorado, Denver***
[2] ***Rochester Institute of Technology***

Let F and H be graphs, a subgraph G of H is an *F-saturated subgraph of H* if F is not a subgraph of G and F is a subgraph of $G + e$ for any edge $e \in E(H) \setminus E(G)$. The *saturation number of F in H*, is the minimum number of edges in a F-saturated subgraph of H.

In this presentation we briefly review the history of saturated subgraphs, and discuss the saturation number tripartite graphs in tripartite graphs. In particular, for $\ell \geq 1$ and n_1, n_2, and n_3 sufficiently large, we discus what the saturation number of $K_{\ell,\ell,\ell}$ in K_{n_1,n_2,n_3} is, and present a specific case of the proof.

RAMSEY-MINIMAL SATURATION NUMBERS FOR SETS OF STARS

Brent Moran
Collaborators: M. Ferrara & M. Mowrey
University of Colorado, Denver

A graph G is *$\mathcal{F}$-saturated* for a family $\mathcal{F}$ of graphs if G contains no member of $\mathcal{F}$ as a subgraph, but for any edge $e \in E(\overline{G})$, some member of $\mathcal{F}$ is a subgraph of $G+e$. The *saturation number* $\mathrm{sat}(n, \mathcal{F})$ is the minimum number of edges in an $\mathcal{F}$-saturated graph of order n. If $\mathcal{F} = \{F\}$ for a single graph F, we say G is *F-saturated*, denoted $\mathrm{sat}(n, F)$.

Given a set $\{H_1, \ldots, H_k\}$ of graphs, a graph G is called *$(H_1, \ldots, H_k)$-Ramsey-minimal* if every k-coloring of $E(G)$ contains some H_i in color i, but for any edge $e \in E(G)$, some k-coloring of $G - e$ does not. We denote the family of $(H_1, \ldots, H_k)$-Ramsey-minimal graphs by $\mathcal{R}_{\min}(H_1, \ldots, H_k)$.

Motivated in part by a 1987 conjecture of Hanson and Toft, we prove a number of results about Ramsey-minimal saturation numbers for sets of stars. In particular, we give an upper bound on $\mathrm{sat}\big(n, \mathcal{R}_{\min}(K_{1,t_1}, \ldots, k_{1,t_p})\big)$ for arbitrary $t_1, \ldots, t_p$, and show that it is sharp when $p = 2$ and in several other cases.

THE MAX-CUT PROBLEM AND SEMIDEFINITE PROGRAMMING

Devon Sigler
Advisor: Alexander Engau
University of Colorado, Denver

This talk will introduce the max-cut problem as well as semidefinite programming, and explain how semidefinite programming can be used to find good suboptimal solutions to the max-cut problem using the method developed by Goemans and Williamson. Solving the max-cut problem for a graph is a NP-hard combinatorial optimization problem. The difficulty of solving the max-cut problem has lead researchers to look for ways to find suboptimal solutions which are computationally efficient and guaranteed to be close to the optimal value. One such method for finding suboptimal solutions uses semidefinite programming relaxations of the max-cut problem to deliver solutions of expected value .87856 times the optimal value. In this talk computational experiments, which verify the effectiveness of this method, will be presented and compared to results obtained from a linear programming relaxation of the max-cut problem.

MORNING SESSION II

A MULTISCALE DOMAIN DECOMPOSITION METHOD FOR FLOW AND TRANSPORT PROBLEMS

Bradley McCaskill
Advisor: Victor Ginting
University of Wyoming

We develop a multiscale method in the framework of domain decomposition techniques, which can potentially take advantage of recent developments in the computational power and availability of heterogeneous processing units. In this method, the original global problem is divided into a set of local subdomain problems that can be solved quickly with parallel implementation. Specifically, we create a set of multiscale basis functions associated to each subdomain and represent our subdomain solution as a linear combination of these functions. The global solution is extracted from these basis functions by imposing Robin Boundary Conditions at the interface of each subdomain. A set of numerical examples is presented to illustrate the performance of the method.

QUASI-GEOSTROPHIC CONVECTION IN THE ROTATING CYLINDRICAL ANNULUS

Louie Long & Derek Driggs
Advisors: Keith Julien, Philippe Marti & Michael Calkins
University of Colorado, Boulder

Spherical fluid systems exist throughout nature, and although the equations dictating their behavior are well known, they are often impossible to solve. The Earth's magnetic field, for example, is sustained by convectively-driven turbulence in the liquid outer core, and so are characterized by a vast range of spatio-temporal scales that cannot be resolved using direct numerical simulations of the complete set of governing equations. We are using a cylindrical annulus geometry as an approximation to a spherical geometry, consisting of a "slice" that is coaxial to the rotation axis of the sphere, to simulate fluid flow in rapidly rotating spherical bodies.

We use VAPOR, a visualization and analysis platform, to visualize the results of simulations of fluid flow generated by the simulation program constructed by Calkins, Julien, and Marti. With Rayleigh numbers below a certain critical value, the fluid velocity should decay to zero, and when Rayleigh numbers surpass a certain critical value, the system should continue to flow and reach a non-zero equilibrium in velocity, vorticity, and buoyancy. We initialize our simulations with extreme Rayleigh numbers to find where the simulations fail to yield accurate results.

To determine the critical Rayleigh number for a system as a function of wavenumber, a generalized eigenvalue problem is solved. Using the eigenvalues and corresponding wave numbers, secant and bisection methods are used to determine the curve on which the critical Rayleigh numbers lie. While MATLAB documentation already exists for solving this problem, we seek to understand the code and thus the larger problem at hand; eventually, we will port the code into Python.

EKMAN BOUNDARIES IN ROTATING RAYLEIGH-BÉNARD CONVECTION

Meredith Plumley
Advisor: Keith Julien
University of Colorado, Boulder

The study of convection in rotating layers of fluid is relevant for understanding the flow in Earth's atmosphere and oceans as well as planetary interiors. The nature of the flow, with the combination of turbulent motion and rotation, leads to small boundary layers and fast waves, which makes numerical simulation costly. In particular, the rapid rotation of these flows results in low values of the Rossby number (Ro), which further restricts the temporal and spatial resolutions. Employing asymptotic techniques on the governing equations in the limit of small Ro results in a reduced model that is valid in the limit of strong rotation. This model benefits from being less computationally expensive and has been successful in characterizing possible fluid states. However, in the case of rigid boundaries, there are some discrepancies with experimental results and direct numerical simulations because of the effect of Ekman pumping. In this talk, I will describe the effect of the boundary layers and Ekman pumping and explain the resulting changes to the asymptotic model.

PARALLEL SIMULATION OF A CLASS OF EVOLUTIONARY SYSTEMS

Ahmad Alyoubi
Advisor: Mahadevan Ganesh
Colorado School of Mines

Single- and multi-phase flow models are essential to characterize physical processes that occur in vast number of applications. In various cases, such processes are best modeled using nonlocal in-time fractional derivative partial differential equations (FPDEs). Understanding long-time behavior of these processes require efficient algorithms to simulate the FPDEs. However, long-time simulation of large scale meshes using standard time-stepping methods leads to a computational bottleneck. In this work, we develop a parallel framework to simulate anomalous-in-time single-phase flow models. Our framework overcomes time-stepping computational bottleneck as well as facilitates efficient memory usage for long-time simulation of large scale meshes.

THE DETERMINATION OF THE DIFFUSION COEFFICIENT BETWEEN DILUTED AND PURE CORN SYRUP

Marika Schubert & Weiliang Sun
Advisors: Mark Hoefer & Michelle Maiden
University of Colorado, Boulder

The Dispersive Hydrodynamics research group at CU Boulder is investigating a nonlinear interfacial wave experiment that involves passing diluted corn syrup through a column of pure corn syrup. The validity of this experiment relies on significant momentum diffusion and very little mass diffusion between the two corn syrup concentrations. In our experiment, we seek to measure the mass diffusion coefficient between 100% corn syrup and water-diluted corn syrup of differing concentrations. Pure light Karo brand corn syrup is placed into a cuvette with a layer of diluted corn syrup on top, yielding a clear interface between the two. Corn syrup fluoresceses under UV light at an intensity proportional to its concentration. This light intensity can therefore be used to determine concentration at any given point in the cuvette. Multiple digital images of the cuvette are taken over a twelve hour period and corn syrup vertical intensity profiles are extracted as a function of time. Fick's law of diffusion, $u_t = Du_{xx}$, describes the concentration u as a function of time t and position length x where D is the diffusion constant. This equation can be solved to obtain a self similar solution in the form $u(x,t) = f(x/\sqrt{Dt})$ for our specific boundary conditions. We use a nonlinear least squares procedure to fit this model profile to the measured intensity profiles in order to extract D from the data. For 70% corn syrup and 30% water, we estimate $D = 1.3 \pm 0.3 * 10^{-6}\text{cm}^2/\text{s}$, affirming the validity of the main experiment. This experiment is a generalization of that presented in the paper by E. Ray, P. Bunton, and J.A. Pojman entitled "Determination of the diffusion coefficient between corn syrup and water using a digital camera", published 2007 in the American Journal of Physics.

APPLIED MATHEMATICS OF VISCOUS FLUID CONDUIT EXPERIMENTS

Michelle Maiden
Advisor: Mark Hoefer
Collaborator: Gennady El
University of Colorado, Boulder

Viscous fluid conduits provide an ideal system for the study of dissipationless, dispersive hydrodynamic systems. The conduit equation models the interface between two viscous fluids, where the interior fluid is less viscous and less dense than the exterior fluid. Thus the interior fluid buoyantly rises, and if it is continuously injected into the exterior fluid, a pipe-like structure forms.

Here, we discuss an experimental setup for which the conduit equation is a model. This setup allows for unprecedented control over the boundary conditions of a nonlinear system with nearly elastic interactions between solitary waves and no measurable dissipation. Structures at multiple length scales are observed, including solitary waves and shock waves. Challenges faced while working in a physical experimental setting are discussed, as well as the methods used to overcome them. The conclusion of this talk is a discussion of preliminary experimental results. Excellent agreement with Poiseuille flow was found for the constant-rate conduit. Finally, comparisons will be made between dispersive shock waves in theory, numerics, and experiments.

MORNING SESSION III

IN-HOST MODELING OF THE SPATIAL ASPECTS OF HIV

Christian Parkinson
Colorado School of Mines

There is a simple and canonical dynamical system which models the spatially homogeneous dynamics of a HIV in-vivo. We adapt this model to account for spatial heterogeneity by considering diffusion. The new system of three parabolic PDEs is analyzed in detail and results regarding existence, uniqueness and regularity of solutions are discussed. We also attempt to decide some of the asymptotic behavior of the model and compare our findings with the analogous results for the spatially homogeneous model. Finally, the system is simulated in MATLAB to verify the analysis.

COMPARISON OF MODELS FOR HIV-1 NUCLEATION

Farrah Sadre-Marandi
Advisors: Drs. James Liu & Simon Tavener
Colorado State University

The capsid is a strong shell made from CA proteins inside the virus that protects the genetic material (DNA or RNA). It is known that the viral capsid assembly consists of two stages: nucleation and elongation. There have been kinetic models for viral capsid (protein) assembly but these models consider a simplified pathway that only allows association or dissociation of one protein, called a monomer, at a time as well as combining the two stages into one model. There is new biological indication that non-monomer subunits can assemble with each other and also strong evidence that dimers (two joined proteins) are important intermediates to capsid formation.

This presented research explores an inexpensive approach for modeling and simulations. We examine mathematical models developed specifically for the nucleation of HIV-1 capsid. Biological assumptions and results from a sensitivity analysis are used to reduce the model. Sensitivity analysis of CA multiuser concentrations to the association and dissociation rates further reveals the influence of CA dimers in the nucleation stage of viral capsid self-assembly.

BRIDGING THE GAP BETWEEN SIMPLISTIC AND COMPLEX MODELS OF HIV DYNAMICS

Deborah Shutt
Advisor: Dr. Stephen Pankavich
Colorado School of Mines

The Human Immunodeficiency Virus (HIV) disables many components of the body's immune system and, without antiretroviral treatment, leads to the onset of Acquired Immune Deficiency Syndrome (AIDS) and subsequently death. The infection progresses through three stages: initial or acute infection, an asymptomatic or latent period, and finally AIDS. Modeling the entire time course of HIV within the body can be difficult as many models have oversimplified its biological dynamics in the effort to gain mathematical insight but fail to capture the three stages of infection. Only one model has been able to describe the entire time course by including so many biological components and fitting parameters to clinical data that preserving the mathematical understanding of the model is infeasible. In this talk, we reduce the complexity of the descriptive long term model while retaining its biologically relevant aspects to investigate the complex underlying mathematical dynamics and biological implications.

ACTIVE SUBSPACE METHODS APPLIED TO HIV MODELING

Tyson Loudon
Advisor: Dr. Stephen Pankavich
Colorado School of Mines

The Human Immunodeficiency Virus (HIV) disables many components of the body's immune system and, without antiretroviral treatment, leads to the onset of Acquired Immune Deficiency Syndrome (AIDS) and subsequently death. The infection progresses through three stages: initial or acute infection, an asymptomatic or latent period, and finally AIDS. Modeling the entire time course of HIV within the body can be difficult as many models have oversimplified its biological dynamics in the effort to gain mathematical insight but fail to capture the three stages of infection. Only one HIV model has been able to describe the entire time course, but this model is large and is expensive to simulate. In this talk, I'll present a reduced order model for the T-cell count 2000 days after initial infection using Active Subspace methods.

MODELING THE DEFORMATION OF PROTEINS: FROM COARSE-GRAINED TO CONTINUUM

George Borleske
Advisor: Yongcheng Zhou
Colorado State University

There has been much research in the area of mathematically modeling of protein complexes using coarse-grained models or continuum models. We are proposing a new approach that will combine the potential energy found in elastic network model or residual based coarse-grained models, and stress/strain components to produce a stiffness matrix. This matrix will have the proteins anisotropic properties encoded within it. The computed anisotropic elastic moduli will be then used for simulating the deformation of protein-complexes.

THE IMPORTANT ROLE OF PROTEINS IN VESICLE BUDDING

Mike Mikucki
Advisor: Yongcheng Zhou
Colorado State University

Understanding the biological process of vesicle budding is a growing area of research. Mathematical models involving a diffusive interface allow for the treatment of topological changes to vesicle membranes, such as those that occur in vesicle budding. These models account for the mechanical bending energy of the membrane, but have so far not yet included the role of membrane-bound proteins. However, membrane-bound proteins have been shown to be a necessary component in vesicle budding. In this talk, a diffuse interface approach will be derived that includes the effect of membrane-bound proteins in budding.

MORNING SESSION IV

THE EMPIRICAL INTERPOLATION METHOD

Paul Diaz
Advisor: Dr. Mahadevan Ganesh
Colorado School of Mines

Analytic solutions to partial differential equations and ordinary differential equations, though rare, often are parameter dependent functions. The Empirical Interpolation Method is a powerful method of interpolation which seeks to strip the solving of parameter dependent functions of their parameter dependence in such a way that they can be quickly and efficiently solved for multiple parameter values. This is hugely beneficial in solving problems where analytic solutions are not possible, and thus numerical solutions are the best option, because a wide variety of parameter values may be evaluated without the same use of computational resources required to solve the initial numerical solution. Additionally, because the method by construction separates the parameter dependence from the independent variable in solving the problem, the process is split into one computationally expensive (offline step), and an inexpensive repeated step (online step), making the method ideal for cloud based scientific computing.

OPTIMIZING QUANTITIES OF INTEREST IN HIGH DIMENSIONS TO IMPROVE SOLUTIONS TO INVERSE PROBLEMS

Scott Walsh
Advisor: Troy Butler
University of Colorado, Denver

The predictive capabilities of physics-based models are improved by reliably decreasing the size of the sets defining the uncertain input parameters. These sets are often inferred by solution to an inverse problem. We explore techniques for identifying the optimal quantities of interest within a high dimensional output data set for use in the inverse problem to improve the predictive capabilities of a model. Numerical results on physically relevant models are provided.

OPTIMIZATION METHODS FOR LIQUIDS HAULING AND INVENTORY

Wes Dyk
Advisor: Alexander Engau
University of Colorado, Denver

Crude oil and waste water are two liquid products of the petroleum exploration and production sector which are distributed using trucked transportation. Managing resources to handle inventory, transportation and disposition of the products is a highly complex task. Seeking operational efficiency is aided by the use of optimization models. Initial approaches to solving these models have resulted in some preliminary success and opened up several remaining questions for research. This work discusses the ongoing development and application of improved models and updated solution methods.

INVERSE MODELING OF A CLASS MULTIPLE SCATTERING PARAMETERS

Bradley Dworzak
Advisor: Mahadevan Ganesh
Colorado School of Mines

We consider several parameters based sound wave propagation configurations comprising multiple particles with various material properties such as sound-soft, sound-hard, or penetrable. For a given incident wave, the material properties, shape, size, location and orientation of particles in the configuration dictate the intensity of the far-field. We develop and demonstrate tools for the nonlinear ill-posed inverse problem of simulating key parameters for a class of wave scattering configurations subject to the constraint of using the far-field data from a single incident wave.

UNBOUNDED TRADE-OFFS IN REVENUE MAXIMIZATION UNDER UNCERTAIN CONSUMER DEMAND

Anzhelika Lyubenko
Advisor: Alexander Engau
University of Colorado, Denver

We consider the problem of total revenue maximization under uncertain consumer demand. We model revenue by a quadratic function under two possible uncertainty realizations and examine the trade-offs associated with each scenario. We also develop conditions under which these trade-offs become unbounded using the theory of proper efficiency.

A THREE SPECIES-MODEL WITH PREDATOR PREY, COMPETITION, AND MUTUALISTIC INTERACTIONS

Minqi Liu
Advisor: Andrea Bruder
Colorado College

This research is inspired by Brown, Bruder and Kummel's research project on the predator-prey interaction of aphids and ladybugs on yucca plants. An important feature of this study system is that it contains ants as a third species. Therefore, this ecological system is composed of a predator-prey relationship between the ladybugs and aphids, a competitive relationship between the ladybugs and ants, and a mutualistic relationship between the aphids and ants.

Most existing mathematical models study one type of interaction, or they focus on three species and study a tri-trophic food chain. We develop and analyze a new mathematical model that includes the predator-prey interaction as well as the competitive and mutualistic aspects of the system. The predator-prey interaction is described by a Rosenzweig-MacArthur model, which assumes logistic growth of the predator. To build a mathematical model for the competitive and mutualistic relationships, we use a modified Lotka-Volterra model and include terms representing competition and mutualism.

Since the three-species model is substantially harder to analyze, we first study the three submodels, i.e. the predator-prey, competition, and mutualism model. Then we use the submodel results to explore the three-species model and the significance of its parameter values. With the help of Mathematica and MATLAB, we construct phase planes and time series plots, find the equilibria of the systems, determine the stability of each equilibrium and conduct a bifurcation analysis.

AFTERNOON SESSION I

APPROXIMATIONS AND ANALYSIS FOR A CLASS OF COMPUTATIONAL TIME-DOMAIN ELECTROMAGNETICS

Alexander Charlesworth
Advisor: Mahadevan Ganesh
Colorado School of Mines

Simulation of electromagnetic wave propagation in two dimensional space is considered using the Maxwell model in the case of conductive, homogeneous, nondispersive, isotropic, and linear media. Discretization is based on using second order approximations in time and various finite difference approximations in space on a staggered grid with a stencil equivalent to that obtained using a fourth order operator, known as the (2, 4) class. Since wave propagation is considered, the primary concern of this work is analysis of error in the transmission of electromagnetic waves by the discrete system, known as the dispersion error. The finite difference techniques developed are compared to results obtained by the standard (2, 2) scheme of Yee.

NUMERICAL STUDIES OF THE KP LINE SOLITONS

Tommy McDowell
Advisor: Dr. Sarbarish Chakravarty
Collaborator: Michelle Osborne
University of Colorado, Colorado Springs

The Kadomntsev-Petviashvilli (KP) equation admits an important class of solitary wave solutions that are regular, non-decaying, and localized along distinct lines in the xy-plane. The line-soliton solutions of KP have been studied extensively in recent years. These solutions consist of an arbitrary number of line solitons in the far-field region and a complex interaction pattern of intermediate solitons resembling web-like patterns in the near-field region. Such wave patterns arise in nature as beach waves, and in laboratory settings in water tank experiments. We have numerically investigated the interaction properties of the line-soliton solutions corresponding to V-shape and trapezoidal initial conditions. By choosing initial data that are far from line-soliton solutions, we observe that they evolve to exact line-soliton solutions plus dispersive waves which separate from the line solitons. Our work provides preliminary numerical evidence of the stability of such line-soliton solutions of the KP equation.

A NON-STANDARD FEM FOR ACOUSTIC WAVE PROPAGATION

Charles Morgenstern
Advisor: Mahadevan Ganesh
Colorado School of Mines

We consider time-harmonic acoustic wave propagation in heterogenous media. The standard Galerkin variational formulation of the Helmholtz model and the associated finite element method (FEM) discretization provide a robust computational framework for simulation of acoustic wave propagation in general media. However, these techniques impose various constraints on the continuous and discrete model. We develop a nonstandard FEM computer model to avoid some of the key constraints. We demonstrate the efficiency of the approach compared to the standard formulation for media with curved and nonsmooth boundaries.

ABOUT ONE THEOREM FOR THE NONLINEAR TRANSPORT EQUATION IN $H_\infty(D) \times L_\infty(G \times V)$

Kirill Golubnichiy
University of North Carolina, Charlotte

We prove local unique solvability in $H_\infty(D) \times L_\infty(G \times V)$ of the inverse problem with final overdetermination for the modified nonlinear

transport equation in the case
$J(x,v',t,v) = j(x,v)\, g(x,v',t,v) + h(x,v',t,v)$.

In this paper the local unique solvability inverse problem with final overdetermination modified equation for nonlinear Transport. These tasks can be viewed as the problem of controllability, which management is, for instance, the multiplier on the right side, or in any other factors, depending only on spatial variables in the case of the final overdetermination and independent only occasionally in the case of integral overdetermination. However, this article is devoted to the final overdetermination.

AFTERNOON SESSION II

OPTIMAL OPERATION OF POWER SYSTEMS INTEGRATED WITH DISTRIBUTED GENERATION

Miguel Carrasco
University of Colorado, Denver

Small-scale generators connected to medium and low voltage distribution systems, also called distributed generators (DGs), are primed to play a central role in future power systems. If properly integrated, DGs present two main advantages. First, they increase the efficiency of the system by avoiding transmitting power over long distances. Second, emissions are reduced since most DGs are based on renewables like wind and solar. However, they introduce uncertainty and variability into the system, and require current power distribution management practices to be redesigned. Traditionally, these practices were based on the discrete control of breakers, switches, capacitor banks, and tap changers. However, these techniques do not allow for frequent switching actions, and are therefore not suitable to deal with the intermittent nature of renewables. On the other hand, power electronic devices interfacing DGs with the grid can provide the required system level control flexibility to enhance the operation of the system. Their fast and continuous control capabilities may be leveraged by making use of suitable real–time optimization algorithms. In this talk, the challenges in formulating and solving the resulting optimization problem will be addressed, and current approaches to overcome them will be discussed.

MODELING OF ATMOSPHERICALLY IMPORTANT VAPOR-TO-PARTICLE REACTIONS

Bahaudin Hashmi
Advisors: Patrick Shipman & Jiangguo Liu
Colorado State University

Liesegang ring formation is a special type of chemical pattern formation in which a spatial order is formed by density fluctuations of a weakly soluble salt. The Vapor-to-Particle nucleation process that is believed to produce these Liesegang rings is theorized to be the cause of mini-tornadoes and mini-hurricanes developed in a lab. In this thesis, we develop a one-dimensional finite element scheme for modeling laboratory experiments in which ammonia and hydrogen chloride vapor sources are presented to either end of the tubes. In these experiments, a reaction zone develops and propagates along the tube. Both numerical simulations and the laboratory experiments find an increasing amplitude of oscillations at the reaction front.

PERSISTENCE IMAGES: A LOOK AT PERSISTENT HOMOLOGY

Rachel Neville
Advisor: Dr. Patrick Shipman
Colorado State University

Given a discrete data set, one might be interested in reconstructing the underlying geometric object, discovering topological features or in some other way examine geometric patterns that arise in your data. It is useful not only to have a notion of for example, holes in your data, but also to have a quantitative understanding of the size of these holes. Are they prominent or is it likely they arise due to noise or some distortion or bias in sampling?

Persistent homology is a technique in computational topology that performs multiscale analysis and gives information regarding the size of topological features of a data set. As a computational tool, persistent homology is still a fairly novel technique. There remains much to be said and developed in this theory. With the use of carefully developed notions of distance, persistence opens the door to "seeing" a wide array of features of very different data sets. Persistence has been used to understand structure and patterns in applications as varied as chaotic dynamical systems, brain artery trees, image processing and neural networks.

The topological information from persistent homology is encoded in a barcode. Currently there are a few notions of distances between barcodes, however there are some drawbacks to each of these methods. The Topological Data Analysis (TDA) research group at CSU is developing a way to treat these barcodes as images. This opens the door for machine learning techniques to be used to classify and compare barcodes.

SIGNAL PROCESSING AND LEARNING FOR BIG DATA VIA RANDOM PROJECTIONS

Farhad Pourkamali-Anaraki
Advisors: Profs. Stephen Becker & Shannon Hughes
University of Colorado, Boulder

The term "Big Data" refers to the recent phenomenon of exponential growth of data in our modern world and its resulting challenges for data analysis. Modern data acquisition capabilities have increased massively in recent years, which can lead to a wealth of rapidly changing high-dimensional data. Moreover, in applications such as sensor networks and surveillance, data is typically distributed over many sensors. Drawing insights from large and complex data has the potential to bring significant advancements in various fields such as content retrieval, image and video processing, and natural language processing.

However, for many key signal processing and learning algorithms such as principal component analysis (PCA), Gaussian mixture model (GMM) estimation, clustering, and dictionary learning, run-time depends linearly, polynomially, or even exponentially on the dimension of the data, which makes the processing of big data intractable in practice. Moreover, classical learning tools are not designed for processing of streaming, decentralized, and online data. Therefore, this era of "data deluge" creates large challenges for researchers who must develop scalable statistical learning tools to gain insights from massive amounts of high-dimensional data.

One promising strategy to solve the problem of processing and learning from big data is to use random projections. The main idea behind this approach is to provide a simple low-dimensional representation of the data that preserves key properties of the original data. The work of learning is then done using the lower-dimensional sketches, instead of the original high-dimensional data, causing substantial savings of both memory and computation time.

In this talk, we introduce new algorithms for signal processing and learning tasks using several types of random projections. We provide a theoretical analysis of the performance of these algorithms for both the easy-to-work-with Gaussian random projections and the more practically useful database-friendly sparse random projections. Given these results, we can then choose to tune the sparsity of the random projections deliberately to achieve a desired point on the tradeoff between reducing memory and computation on the one hand and maintaining estimation accuracy on the other. We hope that our work will provide valuable mathematical insights into the possibility of efficient learning via low-dimensional random projections and that these methods can be employed in many fields where highly-efficient processing of the data is crucial.

BISTATIC SYNTHETIC APERTURE RADAR IMAGING WITH APPLICATIONS TO PASSIVE SENSING

Chad Waddington[1]
Advisor: Dr. Margaret Cheney[1]
Collaborator: Dr. Jim Given[2]
[1] ***Colorado State University***
[2] ***US Naval Research Lab***

In this talk we consider an analytic model for Bistatic Synthetic Aperture Radar imaging with two moving platforms, one transmitting, one receiving, using a filtered back projection approach. We assume that the platforms have independent arbitrary but known flight paths and that the ground topography is also arbitrary but known. We will assume a single scattering approximation and focus on the imaging operator for received data. We will consider how to appropriately choose a filter for the kernel of the imaging operator so that the FBP becomes a pseudodifferential operator and therefore amenable to microlocal analysis. This allows us to correctly reconstruct both the location and orientation of any singularities in the scene. We will then briefly discuss the open problem of using a similar model to detect and geolocate low probability of intercept signals in a target scene.

AFTERNOON SESSION III

THE VULNERABILITY OF CALIFORNIA AMPHIBIAN SPECIES TO CLIMATE CHANGE

Rayna Ben-Zeev
Advisors: Drs. Miroslav Kummel & David Brown
Collaborator: Dr. Barry Sinervo
Colorado College

Amphibians are declining on a global scale, faster than any other taxonomic group. Although we are still unsure of the causes of many local declines, we have evidence that on a larger scale temperature and precipitation changes caused by climate change directly relate to broader amphibian disappearances. We aim to use past temperature and precipitation trends and amphibian distributions in California to predict future amphibian distributions. We use the Biomod2 package in R, along with CMIP5 climate layers and emissions scenarios to correlate amphibian distributions to climate, and predict a range of future possibilities for amphibians under different carbon emission scenarios. We hope to identify which species are most in danger of extirpation to hopefully direct future management initiatives to these species.

INCORPORATING RELATEDNESS IN GENE BASED CASE-ONLY ANALYSIS OF MENDELIAN TRAITS

Kraig Thomas
Advisor: Dr. Audrey Hendricks
University of Colorado, Denver

Genome sequencing, a technology that provides complete genetic information within a focused area or genome-wide, can identify mutations related to simple (i.e. Mendelian) or complex traits. Statistical methods exist for detecting association between a gene-region and a disease, including a case-only test that uses only diseased individuals without the need for a matched set of unaffected individuals. In this project, we extend the case-only method to incorporate related subjects. This is motivated by the observation that rare Mendelian diseases often appear and are thus studied in families, but the existing case-only method used to study rare mutations within a gene region uses only unrelated subjects. The case-only test statistic is the number of subjects who have a mutation within a certain gene. As we compare the observed number of subjects to the expected number of subjects, the test statistic has a binomial distribution. The expected number of subjects having a mutation within a certain gene is estimated from the large number of genes across the genome (20000) most of which we expect not to be associated with disease status. To incorporate the relatedness framework to the case-only model, we consider related pairs of subjects, and calculate the total number of pairs who share a mutation within a gene. We consider the effective number of mutations of a related pair: for instance, a pair of siblings shares approximately half of their genetic information. A pair of siblings contributes less unique genetic information than a pair of unrelated subjects, and thus, their effective number of mutations is less than two (i.e. the number of mutations contributed by a pair of unrelated subjects). To extend the case only analysis we replace the number of subjects with one mutation with the effective number of pairs of related subjects who share a mutation, yielding a new test statistic with a binomial distribution. Future work includes theoretical and empirical verification of the combined model.

DETERMINING THE TOP ALL-TIME COLLEGE COACHES THROUGH MARKOV CHAIN-BASED RANK AGGREGATION

Melissa Jay
Collaborators: V. Ganesh Karapakula & Emma Krakoff
Colorado College

We develop a mathematical model that determines the best all-time college coach(es) of the past century in a given sport. We propose ranking college coaches through Markov chain-based aggregation of ranked lists using holistic criteria. Our model synthesizes four full or partial ranked lists based on win percentages, victories, career durations, and effort levels to produce the final comprehensive rankings. This model is applicable not only across all possible sports but also to both male and female coaches. As a demonstration, we rank the top NCAA Division I men's ice hockey coaches of the past century.

TACKLING THE OUTBREAK AT ITS CORE

Denis Kazakov & Derek Driggs
University of Colorado, Boulder

The spread of infection causes exponentially more damage if it is not contained and treated in a timely and isolative manner. As a sad proof of that, recent outbreak of Ebola is the worst in history. Thus far, it has topped at 30,000 known cases. To aid in fighting the current outbreak and any other infectious deceases, we have developed three models, which act like a toolbox for predicting behavior of the infected system and its most infectious regions.

For our first model, we used differential equations to model how much vaccine we would need to stop Ebola in a given community with respect to the number of people in latency for that area. Next, we moved to a network model and used a Markov matrix in order to model which territory was the most likely to spread disease to other territories. Such approach allows to identify the most infectious regions of the system and to predict its behavior.

A measure to prevent a virus outbreak from growing is to detect it early and respond to it as fast as possible with containment, treatment and isolation. Our approach tackles that task with dignity.

ERADICATING EBOLA: A TECHNIQUE FOR A QUICK RESPONSE TO INFECTIOUS DISEASES

Thomas Gebhardt, Conrad Hougen & Pawel Janas
Advisors: Drs. Anne Dougherty & Bengt Fornberg
University of Colorado, Boulder

The Ebola epidemic of 2014, continuing into 2015, is the largest and deadliest outbreak since the discovery of the virus in 1976, and critical measures must be taken to prevent the current epidemic from growing any larger. Experimental drugs and vaccines have been proposed to combat the spread of Ebola, but it is unclear how effective these medications may be. Assuming that an effective medication exists, our objectives are to model the most cost-effective strategies for medicine delivery, and determine how different delivery locations might affect the death toll of the West African population.

Using major results from network science, we develop a stochastic model for the spread of Ebola virus disease in connected communities that depends on the medical approach taken. We then calibrate the model to fit the characteristics of the 2014 Ebola outbreak. In particular, our model focuses on the following aspects:

- **Spread of disease:** We create an interaction network based on the Block Two-Level Erdös-Rényi Model where each community in the network corresponds to a city in West Africa. We then estimate the spread of disease through the interaction network with a probabilistic breadth-first-search algorithm known as Forest-Fire Sampling. The overall structure of the model is an extended version the well-known Susceptible - Infected - Removed (SIR) model from epidemiology.

- **Quantity and availability of medicine:** We analyze the effects of delivering different quantities of medicine, with knowledge of practical limits on the manufacturing rate of such a drug or vaccine. These limits stem from the procedures currently being used to manufacture the experimental drug, ZMapp.

- **Location of medicine delivery:** We make use of city and airport location data to weigh the costs of medicine delivery against the Google PageRank of people in each particular city. Because cities are well-connected, leading to higher rankings of the people within each city, and because airports tend to be near large cities, we find that delivering medicine in these locations reduces the number of expected deaths while also reducing costs.

- **Construction and location of hospitals:** Also important for fighting Ebola, we consider the financial costs of building and maintaining hospitals with a fixed number of beds. These hospitals are assumed to provide quarantine services for those infected, thereby decreasing the rate at which Ebola spreads in the network.

AFTERNOON SESSION IV

PREDICTING RANDOM AND RATHER ERRATIC ROAD CONDITIONS

Ana Kenney
Advisor: Dr. Alexander Engau
University of Colorado, Denver

We present current research that improves the methodological use of stochastic model predictive control (SMPC) on various applications. Specifically, this talk will focus on the optimal operation of hybrid vehicles under uncertain road conditions. To improve the performance as well as applicability of SMPC in this context, it is important to limit its assumption of priori knowledge and attempt to estimate road conditions more dynamically, thus providing immediate benefits for its potential use in practice. We present and analyze our newly developed prediction method and validate its performance on several numerical experiments.

EPIDEMIOLOGICAL METHODS FOR EXAMINING BULLYING

Kaitlyn Martinez
Advisor: Andrea Bruder
Colorado College

Bullying is known to result in significant psychological damage in both the victim and the bully, but despite this reality bullying research has hit a standstill in the last few decades, resulting in a lack of change and action going towards the prevention of this destructive phenomenon. In contrast mathematics research has become more influential and groundbreaking in many fields of research. Harnessing the progress that has been made in the field of epidemiology we explore the idea that the social phenomenon of bullying should be modeled like an infectious disease, especially in the ways a bully interacts with a susceptible population. Using an existing differential equations compartmental model that describes the dynamics of influenza as a template, we introduce an altered differential equation model for bullying, perform numerical simulations and parameter analysis and find the reproductive value, R0. Then we introduce a intervention model that can be altered to reflect interventions that schools today use to respond to bullying. Through numerical simulations on the intervention model we are able to show that the method most commonly used to quench bullying, the Traditional Disciplinary Approach, has the least amount of impact on the population affected by bullying whereas the less traditional approaches are able to better reduce the effects of bullying, either more quickly, or via less impact on the population.

SIMULATION OF LOCAL TEMPERATURE AND PRECIPITATION OCCURRENCE USING APPROXIMATE BAYESIAN INFERENCE

Branden Olson
University of Colorado, Boulder

Weather impacts the daily lives of humans and plays an important role in many models for scientific fields such as ecology, hydrology, and agriculture. Stochastic weather generators (SWGs) produce infinitely long series of synthetic weather for use in such models. Observations of time series of temperature and precipitation suggest that their statistical characteristics oscillate throughout the year, and whose heterogeneous characteristics make modeling and simulation difficult. We propose a statistical model that captures annual patterns, seasonal heteroskedasticity, and unusual but important patterns like dry and wet spells. Estimation of model parameters would optimally follow a Bayesian route to capture parametric uncertainty, however inference on datasets with a large number of dependent observations is difficult or impossible to implement. We are developing an estimation technique that relies on matching statistics of simulated weather to observed patterns, known as Approximate Bayesian Computation (ABC). ABC is a desirable approach as estimation is tied to simulation and no explicit likelihoods are ever required.

For temperature, we minimize the absolute error of the mean and standard deviation between the simulations and observations with respect to all four seasons. For precipitation occurrences, we instead minimize the error with respect to a catalog of wet and dry spells in the observations. Using a numerical minimization function, we illustrate that the estimated model produces realistic simulated behavior seen in the observations at a meteorological site in Glenwood Springs, Colorado.

OPTIMIZATION OF MODELED LAND-ATMOSPHERE EXCHANGES BY BAYESIAN PARAMETER CALIBRATION

Tony Wong
Advisors: William Kleiber & David Noone
University of Colorado, Boulder

The single largest uncertainty in climate model energy balance is the surface latent heating over tropical land. Furthermore, the partitioning of total latent heat flux into contributions from surface evaporation and plant transpiration is of critical importance, but notoriously poorly constrained. Resolving this issue requires better exploiting information which lies at the interface between observations and advanced modeling tools, both of which are imperfect. There are remarkably few observations which can constrain these fluxes, placing strict requirements on developing statistical methods to maximize the use of limited information to best improve models.

We utilize an approach to calibrating select model parameters to observational data in a Bayesian estimation framework, requiring Markov chain Monte Carlo sampling of the posterior distribution. Our Bayesian calibration approach is applied to a state-of-the-art land surface model and is shown to constrain uncertain parameters as well as inform relevant values for operational use. Finally, this approach is shown to constrain uncertain ecosystem processes such as evapotranspiration partitioning.

AFTERNOON SESSION V

MULTILAYER NETWORKS AND THEIR APPLICATIONS TO HUMAN RESOURCE MODELING

Anna Johnsen
Advisor: Gary Olson, Collaborators: Brent Moran & Mike Murphy
University of Colorado, Denver

Organizational churn has been frequently studied by sociologists. While numerous definitions for churn exist in the literature, for this presentation we define the employee churn rate, or simply churn, to be the ratio of the number of employees who leave an organization in a year to the total number of positions in that organization. In this presentation, we develop a Human Capital network model and use it to analyze both the productivity and churn within a fictional organization, ICM.

One common way to represent a network model is through the use of a graph. Such a graph might consist of a node set representing people, organizations, or other structures which are connected to each other by edges. Based upon previous research, we find that analyzing the dynamic relationships between people at ICM is a good way to predict churn within the company. Churn in any company is related to multiple factors including hierarchy, friendships, and other types of relationships between employees. Thus, we utilize an object presented by Mikko Kivelä, Alexandre Arenas, Marc Barthelemy, James P. Gleeson, Yamir Moreno, and Mason A. Porter called a multilayer network, which is a way of representing how "sets of entities interact with each other" with respect to considerations like relationships, time, and "other complications."

For the purposes of our presentation, we define a multilayer network as a set of layers, where each layer holds a directed or undirected graph. Constructing a network with multiple layers allows us to represent different types of connections between nodes on different layers. This means we can assign various types of relationships between positions and employees at ICM to different layers of the network, thereby representing the structure of the organization.

Using the software package called the *Multilayer Networks Library*, we develop a data structure where we treat each layer of a multilayer network as a graph representing a different type of relationship within the company. The computer representation of these networks is comprised of a multidimensional array, or tensor. We take an object oriented approach to simulating interactions between employees, interactions between positions in the hierarchy, and interactions between employees and their positions within the hierarchy.

Using this framework, we develop a model of human capital flow throughout the organization.

CONSTRUCTION AND OPTIMALITY OF UNORIENTED DE BRUIJN SEQUENCES

Christina S. Burris[1]
Advisor: Patrick D. Shipman[1]
Collaborator: Francis C. Motta[2]
[1]***Colorado State University***
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For positive integers k, n, a de Bruijn sequence $B(k, n)$ is a finite sequence with elements drawn from k characters whose subwords of length n are exactly the k^n words of length n on k characters. This paper introduces the unoriented de Bruijn sequence $uB(k, n)$, an analog to de Bruijn sequences, but for which the sequence is read both forwards and backwards to determine the set of subwords of length n. We show that unoriented de Bruijn sequences of optimal length exist if and only if both k and n are less than 3. Unoriented de Bruijn sequences for any k, n may be constructed from certain Eulerian paths in Eulerizations of unoriented de Bruijn graphs.

MOVING PICTURES: ANIMATING STILL IMAGES

Michael Pilosov
Advisor: Dr. Douglas Baldwin
University of Colorado, Denver

We present a means of developing digital image transformations that allow a still image to be turned into a short and visually pleasing animation. Rather than manually altering successive frames to create the illusion of motion, the method presented here requires only the input of a few parameters for each transformation. We developed a mathematical framework wherein we defined animations as sequences of still images, and transformations as composable functions on such sequences.
To implement this work, we have built a MATLAB library of composable functions that streamline the process of turning still images into novel animations. Examples include manipulation of contrast, intensity, and colors of pixels, as well as warps of contours, positions, and size of select regions. The transformations allow for easy animation of regions of interest, giving some semblance of life to still images by turning them into animated GIFs.

LINEAR TURÁN NUMBERS OF LINEAR CYCLES

Nathan Graber[1]
Collaborators: Clayton Collier-Cartaino[2] **& Tao Jiang**[2]
[1] ***University of Colorado, Denver***
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An r-unifrom hypergraph is called an r-graph. A hypergraph is linear if every two edges intersect in at most one vertex. Given a linear r-graph H and a positive integer n, the linear Turán number, $ex_L(n, H)$ is the maximum number of edges in a linear r-graph on n vertices that does not contain H as a subgraph.

An r-uniform linear cycle of length k, deonted C_k^r is a linear r-graph consisting of k edges $E_1, \ldots, E_k$ such that E_i and E_j if and only if $i = j + 1$ modulo k.

In this talk we will discuss the history of Turán numbers for hypergraphs and discuss applications these numbers have to other problems. We will also share a new result answering a question of Kostochka, Mubayi, and Verstaëte for linear cycles. Namely that for all $r \geq 3$, $m \geq m$ there exist constants $c_{m,r}$ and $c'_{m,r}$ depending only on m and r such that $ex_L(n, C_{2m}^r) \leq c_{m,r} n^{1+\frac{1}{n}}$ and $ex_L(n, C_{2m+1}^r) \leq c'_{m,r} n^{1+\frac{1}{n}}$. If time permits we will give a brief description of the proof techniques used.