

First ACES Workshop 2006

Emory University, Atlanta, GA, December 2-3, 2006

Students from Auburn, Clemson, Emory, South Carolina, and NC State

Schedule: Saturday, December 2, 2006

10:00-11:00 Breakfast and check in

11:00-11:05 Welcome and opening address

11:05-12:20 Student presentations: **Image analysis and inverse problems**

1. Daniel Fan (E): *Inpainting and denoising through fractal image encoding*
2. Wei Feng (A): *Image registration using mean square optimization*
3. Julianne Chung (E): *HyBR: A hybrid bidiagonalization regularization method for solving ill-posed inverse problems*

12:20-1:00 Lunch break (ordered sandwiches, pizza)

1:00-2:15 Student presentations: **Partial differential equations**

1. Necibe Tuncer (A): *A novel finite element discretization of domains with spherical geometry*
2. John Chrispell (C): *A fractional step θ -method for convection-diffusion equations*
3. Luke Owens (S): *A W -cycle algorithm for a weakly over-penalized nonsymmetric interior penalty method*

2:15-2:45 Coffee break

2:45-4:00 Student presentations: **Networks and graph theory**

1. Samuel J. Lyle (C): *Assignments of social networks*
2. Andrzej Dudek (E): *On the vertex connectivity of Kneser graphs*
3. Robert A. Beeler (C): *The $\{K_{1,s}, K_{1,t}\}$ -spectrum of stars and caterpillars*

4:00-5:00 Drive to Atlanta CNN Studio

5:00-6:00 Atlanta CNN Studio Tour

6:00-8:00 Dinner (in planning)

8:00-x:yz Social activities

First ACES Workshop 2006

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Schedule: Sunday, December 3, 2006

8:00-9:00 Breakfast

9:00-9:50 Student presentations: **Distributed collaborative computing systems**

1. Pawel Jurczyk (E): *P2P metacomputing system based on H2O and JXTA*
2. James Gardner (E): *NNexus: Overview of an automatic linker for a massively-distributed collaborative corpus*

9:50-10:05 Coffee break

10:05-11:20 Student presentations: **Math programming, probability, and statistics**

1. Christine R. Kraft (C): *Developing reusable final examination timetables*
2. Anjela Y. Govan (NC State): *Applying theory of Markov chains to the problem of ranking*
3. Chinthaka N. Kuruwita (C): *A Bayesian approach for bandwidth selection in kernel density estimation with censored data*

11:20-11:40 Coffee break

11:40-12:55 Student presentations: **Algebra and group theory**

1. Audrey Malagon (E): *Lie algebras*
2. Fred Helenius (E): *Finiteness of the class group à la Dedekind*
3. Mari Castle (E): *Everything you've ever wanted to know about Pólya's Theorem (but were afraid to ask)*

12:55-1:00 Closing address and farewell

Thanks to all ACES sponsors

- The Emory University SIAM Student Chapter
- The Department of Mathematics and Computer Science at Emory University
- The Clemson University SIAM Student Chapter

Abstracts: Image analysis and inverse problems

Inpainting and Denoising through Fractal Image Encoding

Ying Wai (Daniel) Fan E yfan@emory.edu

Digital image inpainting is a technique to recover missing pixels of an image. Many different approaches have been proposed for digital image inpainting. The original approach by Bertalmio et al is based on continuation of isophotes into the inpainting regions, while Chan and Shen use curvature-driven diffusion techniques. We propose a novel approach to inpainting based on fractal image encoding.

Fractal image encoding, more widely known as fractal image compression, is a lossy image compression method that represents an image as a set of Iterated Function Systems (IFS). First, the image is partitioned into range blocks. Then for each range block, we search for a larger portion of the image, a domain block, which after shrinking and an affine transformation, closely resembles the range block. These matches of range blocks and domain blocks and the corresponding affine transformations form the IFS, or the fractal code, of the image. To decode the fractal code, we start with a random initial image and repeatedly apply the IFS obtained in the encoding process, and this iterative process converges to the decoded image.

In this talk we describe an inpainting approach that is based on fractal image encoding. In particular, we modify the encoding process by skipping the missing pixels from the inpainting regions. After this modified encoding is complete, we decode in the normal way, and the iterative process converges to an image with the missing pixels filled in. Several examples will be presented to illustrate the effectiveness of our inpainting method.

Image registration using mean square optimization

Wei Feng A fengwe1@auburn.edu

Image registration is a major tool in medical image analysis because multiple images obtained for one tissue are generally not well aligned, while many functional analysis about the tissue will be based on well aligned images. In this talk we present a registration technique based on minimizing mean square error between two images. It's an inverse problem and many iterative optimization methods can be applied. Registration of human heart images results will be presented.

HyBR: A Hybrid Bidiagonalization Regularization Method for Solving Ill-posed Inverse Problems

Julianne Chung E jmchung@emory.edu

Lanczos hybrid regularization methods have been proposed as effective approaches to solve large-scale ill-posed inverse problems. Regularization parameters must be chosen at each iteration, and numerical experiments show that a modified GCV method is effective at choosing these regularization parameters.

Abstracts: Partial differential equations

A novel finite element discretization of domains with spherical geometry

Necibe Tuncer A tuncene@auburn.edu

We develop and analyze finite element discretizations for domains with spherical geometry. In particular, we describe the method used to approximate solutions (as well as eigenvalues and eigenvectors) of partial differential equations posed on the sphere, ellipsoidal shell, and cylindrical shell. These novel, so-called, "radially projected finite elements" are particularly attractive for numerical simulations since the resulting finite element discretization is "logically rectangular" and may be easily implemented in existing finite element codes.

A fractional step θ -method for convection-diffusion equations

John Chrispell C jchrisp@clemson.edu

The accurate numerical approximation of viscoelastic fluid flow poses two difficulties: the large number of unknowns in the approximating algebraic system (corresponding to velocity, pressure, and stress), and the different mathematical types of the modeling equations. An appealing approximation approach is to use an operator splitting method which decouples the conservation of momentum equation from the constitutive equation. This split reduces the size of the linear systems that need to be solved and separates the parabolic and hyperbolic equations into different substeps. Motivated by the viscoelastic fluid flow problem, we analyze an operator splitting fractional step θ -scheme for the numerical approximation of a convection-diffusion problem. In this presentation, we describe the approximation scheme and present both theoretical and numerical results.

A W -Cycle Algorithm for a Weakly Over-penalized Nonsymmetric Interior Penalty Method

Luke Owens S owensl@math.sc.edu

We introduce a weakly over-penalized nonsymmetric interior penalty (WOPNIP) method for solving elliptic boundary value problems. The WOPNIP method introduced has h -optimal error estimates in both the energy norm and L_2 norm. Also, although the resulting global stiffness matrix has a condition number of order h^{-4} , there is a simple preconditioner that reduces the condition number to h^{-2} . This is a significant advantage when designing a good smoothing procedure for multigrid algorithms. We then prove that there is a bound (< 1) for the contraction number of the W -cycle algorithm, which is independent of the mesh level, for an appropriately chosen number of smoothing steps.

Abstracts: Networks and graph theory

Role Assignments of Social Networks

Samuel J. Lyle C slyle@clemson.edu

A role graph R is a representation of interactions between societal roles. A *role assignment* is a mapping from a social network onto a role graph, assigning each individual a role. The problem of determining if a given network is R -role assignable is very difficult, with the dichotomy settled by Fiala and Paulusma. Since the general problem of determining if a given network is R -role assignable for a fixed graph R with more than one edge is NP complete, we instead fix a graph class S and attempt to determine the role graphs R for which S is R -role assignable. In this presentation, we will consider the methods for attempting this, as well as the results and consequences of the results.

On the Vertex Connectivity of Kneser Graphs

Andrzej Dudek E adudek@emory.edu

The Kneser graph $K(m, n)$, for $n \geq 1$ and $m \geq 2n$, is a graph with the set of vertices consisting of all n -element subset of m -element set, i.e., it is equal to $\binom{[m]}{n}$. Two vertices are adjacent if and only if the corresponding n -subsets are disjoint. Kneser graphs have been studied very widely. For instance, the chromatic number, the independent number and the diameter of the Kneser graph $K(m, n)$ are well-known parameters. In this talk we will give a partial characterization of the vertex connectivity of the Kneser graphs.

The $\{K_{1,s}, K_{1,t}\}$ -Spectrum of Stars and Caterpillars

Robert A. Beeler C rbeeler@clemson.edu

Let \mathcal{K} be a collection of graphs. We say that \mathcal{D} is a \mathcal{K} -decomposition of H if the edges of H can be partitioned such that the subgraph induced by each part of the partition is isomorphic to an element of \mathcal{K} . In this case, we refer to H as the *host* of the decomposition and the elements of \mathcal{K} as *blocks* or *prototypes*.

The *chromatic index* of the decomposition, denoted $\chi'(\mathcal{D})$ is the minimum number of colors required to color the blocks of a decomposition, such that if two blocks share a common vertex in H then those blocks receive different colors. The \mathcal{K} -spectrum of H , denoted $Spec_{\mathcal{K}}(H)$, is the set of all possible values of $\chi'(\mathcal{D})$.

Mendelsohn and Jamison showed that every n element set of positive integers is the \mathcal{K} -spectrum of a tree when \mathcal{K} is a family of n trees. In this presentation, we will look at ways of improving this result. In particular, we examine the problem of whether any n element subset of the natural numbers is the spectrum of a star when decomposing into other stars, as well as whether any n element subset of the natural numbers is the spectrum of a tree when decomposing into a family of $k < n$ trees.

Abstracts: Distributed collaborative computing systems

P2P metacomputing system based on H2O and JXTA

Pawel Jurczyk E pjuri@interia.pl

The main goal of this work is to build a uniform global metacomputing system using H2O distributed computing framework and JXTA P2P technology. H2O is a Java-based, component-oriented, lightweight resource sharing platform for metacomputing. It allows deployment of services into container not only by container owners, but by any authorized clients or third parties. As a communication mechanism, H2O uses RMIX that is interoperable and extensible communication library. JXTA technology is a set of open protocols that allows any connected device on a network to communicate and collaborate in a P2P manner.

This P2P computational network will give users new possibilities in building and utilizing of distributed computing systems, namely H2O kernels behind firewalls will be accessible. Group management in JXTA will bring a possibility of creating virtual groups of kernels, which enables dynamic ad-hoc created collaborations. We present that the integration of the RMIX library with the JXTA technology leads to development of a remote method invocation framework that can take benefits from acting in pure P2P environments.

NNexus: Overview of an Automatic Linker for a Massively-Distributed Collaborative Corpus

James Gardner E jgardn3@emory.edu

Collaborative online encyclopedias such as Wikipedia and PlanetMath are becoming increasingly popular. In order to understand an article in a corpus a user must understand the related and underlying concepts through linked articles. In this talk, I introduce NNexus, a generalization of the automatic linking component of PlanetMath.org and the first system that automates the process of linking encyclopedia entries into a semantic network of concepts. I will discuss the challenges, present the conceptual models as well as specific mechanisms of the NNexus system, and discuss some of our ongoing and completed works.

Abstracts: Math programming, probability, and statistics

Developing Reusable Final Examination Timetables

Christine R. Kraft C cstemm@clemson.edu

Two procedures for creating reusable university final examination timetables are developed and compared. Course times, rather than individual courses, are used as the unit of measurement since the demand for course times remains relatively constant despite changes to course schedules. The first procedure employs a multi-criteria quadratic integer program formulation. The other procedure splits the problem into two phases: a clustering phase, utilizing either a hierarchical or a partitioning method, and a sequencing phase. Results are compared using enrollment data from Clemson University.

Applying Theory of Markov Chains to the Problem of Ranking

Anjela Y. Govan NC State aygovan@math.ncsu.edu

The search engine Google uses the basic theory of the discrete-time Markov chains, with finite sample space, to rank web pages. With some modifications these techniques can also be used to rank weekly performances of the National Football League teams. The beauty of the resulting algorithm is in its flexibility. This flexibility can be summarized in a question: What are the aspects of the given applications that contribute the most to the rank? In case of ranking football teams this translates to: Which weekly statistics of each team should be included in the ranking process?

A Bayesian Approach for Bandwidth Selection in Kernel Density Estimation with Censored Data

Chinthaka N. Kuruwita C ckuruwi@clemson.edu

Estimating an unknown probability density function is a common problem arising in statistics and in many fields of studies including engineering, economics, social sciences etc. Over the years many methods have been developed for density estimation and among those the kernel method is widely used. However, the regular kernel method has an inherent problem. It assigns positive weights for values outside the support when estimating a density with a bounded support. This problem is commonly known as the 'Spill-over' effect. We propose a modification to the kernel method to circumvent this problem in a Bayesian framework.

We derive a density estimator using an asymmetric kernel as opposed to the symmetric kernels which are used with the regular method and establish the strong convergence of this estimator to the underlying density. Furthermore, we explore the possibility of finding a local bandwidth calculation procedure which is depending upon the data only and devise methods to utilize the data efficiently even with the presence of censoring.

Abstracts: Algebra and group theory

Lie Algebras

Audrey Malagon E amalago@emory.edu

In this talk, we introduce Lie Algebras over an arbitrary field of characteristic zero and discuss their killing forms.

Finiteness of the Class Group à la Dedekind

Fred Helenius E fheleni@emory.edu

Many modern texts prove the finiteness of the class group of a number field by using the machinery of Minkowski's theorem on geometric lattices. Here we present a more direct approach based on the original proof by Dedekind.

Everything you've ever wanted to know about Pólya's Theorem (but were afraid to ask)

Mari Castle E mfcastl@emory.edu

Let $\mathbb{R}[\bar{X}] = \mathbb{R}[x_1, \dots, x_n]$ and let Δ_n denote the simplex $\{(x_1, \dots, x_n) \mid x_i \geq 0, \sum_i x_i = 1\}$. Pólya's Theorem says that if a form (homogeneous polynomial) $f \in \mathbb{R}[\bar{X}]$ is positive on Δ_n , then for sufficiently large $N \in \mathbb{N}$ all the coefficients of

$$(x_1 + \dots + x_n)^N \cdot f(x_1, \dots, x_n)$$

are positive. This talk will present recently published explicit bounds for N , both for strictly positive polynomials on the simplex and polynomials with simple zeros on the corners of the simplex. Additionally, several characterizations of polynomials (not necessarily forms) that satisfy Pólya's Theorem will be presented.

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