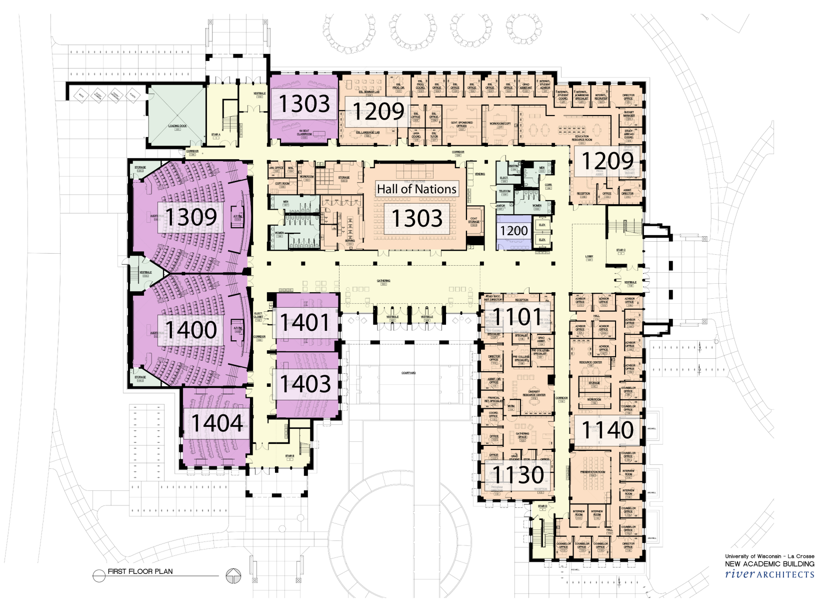
Event Schedule

Centennial Hall 1404	
7:30 –8:15 am	Registration and Refreshment (1st Floor Centennial Hall)
8:20 – 8:30 am	Welcome by Dean Bruce Riley
8:30 – 9:30 am	**Dr. Chi-Wang Shu, Brown University** High Order Numerical Methods for Convection Dominated Problems
9:45 – 11: 00 am	Contributed Talk Session I (Room 1404, 1401, 1403, 1303)
11:00 – 11:15 am	Refreshment (coffee and snacks)
11:15 – 12:15 pm	**Dr. Douglas Arnold, University of Minnesota** Computing Spectra without Solving Eigenvalue Problems
12:30 – 1:30 pm	Lunch break
1:45 – 2:35 pm	Contributed Talk Session II (Room 1404, 1401, 1403, 1303)
2:45 – 3:45 pm	**Dr. Hailiang Liu, Iowa State University** Structure Preserving DG methods for Kokker-Planck-type Equations
3:45 – 4:00 pm	Refreshment
4:00 – 5:00 pm	**Drs. Chi-Wang Shu, Douglas Arnold and Hailiang Liu** Panel Discussion: Future Direction in Research
End of event	River boat dinner (optional)



Contributed Talk Session I

All presenters please preload your talk 10 minutes before each session starts.

Room 1404	
9:45 – 10:05	**Theoretical and Numerical Approximations of the Singularly Perturbed Convection-Diffusion Equations** Youngjoon Hong, University of Illinois at Chicago
10:10 – 10:30	**Spectrum Slicing by Polynomial and Rational Function Filtering** Yuanzhe Xi, University of Minnesota
10:35 – 10:55	**Domain Decomposition Methods for Symmetric Eigenvalue Problems,** Vasileios Kalantzis, University of Minnesota

Room 1401	
9:45 – 10:05	**A High-Order and Energy-Conserving Local Discontinuous Galerkin Method for the Sine-Gordon Equation** Mahboub Baccouch, University of Nebraska at Omaha
10:10 – 10:30	**A Family of Regionally Implicit Discontinuous Galerkin Methods with Applications to Solving the Relativistic Vlasov-Maxwell System** Pierson Guthrey, Iowa State University
10:35 – 10:55	**A Lyapunov Exponents Based Stability Theory for Runge-Kutta Methods** Andrew Steyer, University of Kansas

Room 1403	
9:45 – 10:05	**An ETD Real Distinct Poles L-Stable Scheme** Bruce Wade, University of Wisconsin - Milwaukee
10:10 – 10:30	**A Fast Multi-Rank Update to the Symmetric Eigenvalue Problem** Jimmy Vogel, Purdue University
10:35 – 10:55	**Third Order Maximum-Principle-Satisfying Direct DG Methods for Convection Diffusion Equations on Unstructured Triangular Meshes** Jue Yan, Iowa State University

Room 1303	
9:45 – 10:05	**An efficient adaptive rescaling scheme for computing Hele-Shaw problems** Meng Zhao, Illinois Institute of Technology
10:10 – 10:30	**On common diagonal Lyapunov solutions** Mehmet Gumus, Southern Illinois University Carbondale
10:35 – 10:55	**Sensitivity and computation of a defective eigenvalue** Zhonggang Zeng, Northeastern Illinois University

Contributed Talk Session II

All presenters please preload your talk 10 minutes before each session starts.

Room 1404	
1:45 – 2:05	**Energy-Conserving Numerical Scheme for the Poisson-Nerst-Plank Equations** Julienne Kabre, Illinois Institute of Technology
2:10 – 2:30	**The Lanczos Alternative to the Singular Value Decomposition** Enyinda Onunwor, Stark State College

Room 1401	
1:45 – 2:05	**A Fast Treecode Algorithm for Stokes Flow in 3D** Lei Wang, University of Wisconsin - Milwaukee
2:10 – 2:30	**High-Order DG-FEM for Micro-Macro Partitioned Kinetic Models** James Rossmanith, Iowa State University

Room 1403	
1:45 – 2:05	**A New Finite Element and Finite Difference Hybrid Method for a Class of Nonlinear Interface Problems** Dexuan Xie, University of Wisconsin-Milwaukee
2:10 – 2:30	**Domain Decomposition Methods for Symmetric Eigenvalue Problems** Vasileios Kalantzis, University of Minnesota

Room 1303	
1:45 – 2:05	**Adomian Solutions of the Higher Order Sawada-Kotera and Lax Equations** Mohamed El-Houssieny, The University of Toledo
2:10 – 2:30	**Wavelet Regularized Solution for the Dirichlet Problem in an Arbitrary Shaped Domain** Vani Cheruvu, The University of Toledo

Contributed Talk

Room 1404

Theoretical and Numerical Approximations of the Singularly Perturbed Convection-Diffusion Equations

Youngjoon Hong, University of Illinois at Chicago

Abstract: We explore singularly perturbed convection-diffusion equations in a circular domain. Considering boundary layer analysis of the singularly perturbed equations and we show convergence results. In view of numerical analysis, we discuss approximation schemes, error estimates and numerical computations. To resolve the oscillations of classical numerical solutions due to the stiffness of our problem, we construct, via boundary layer analysis, the so-called boundary layer elements which absorb the boundary layer singularities. Using a P1 classical finite element space enriched with the boundary layer elements, we obtain an accurate numerical scheme in a quasi-uniform mesh.

Spectrum Slicing by Polynomial and Rational Function Filtering

Yuanzhe Xi, University of Minnesota

Abstract: Two filtering techniques are presented for solving large eigenvalue problems by spectrum slicing. In the first approach, the filter is constructed as the least-squares approximation to an appropriately centered Dirac distribution. In the second approach, a least-squares rational filter is designed for matrices whose spectrum is contained in a large interval and generalized eigenvalue problems.

Domain Decomposition Methods for Symmetric Eigenvalue Problems

Vasileios Kalantzis, University of Minnesota

Abstract: In this talk we will discuss Domain-Decomposition (DD) type methods for large Hermitian eigenvalue problems. This class of techniques rely on spectral Schur complements combined with Newtons iteration. The eigenvalues of the spectral Schur complement appear in the form of branches of some functions, the roots of which are eigenvalues of the original matrix. It is possible to extract these roots by a number of methods which range from a form or approximate Rayleigh iteration to an approximate inverse iteration, in which a Domain Decomposition framework is used. Numerical experiments in parallel environments will illustrate the numerical properties and efficiency of the method.

Energy-Conserving Numerical Scheme for the Poisson-Nerst-Plank Equations

Julienne Kabre, Illinois Institute of Technology

Abstract: The Poisson-Nernst-Planck equations are a system of nonlinear partial differential equations that describe flow of charged particles in solution. In particular, we are interested in the transport of ions in the biological membrane proteins (ion channels). This work is about the design of numerical schemes that preserve exactly (up to round off error) a discretized form of the energy dynamics of the system. We will present a scheme that achieves the conservation of energy law, and the numerical results.

The Lanczos Alternative to the Singular Value Decomposition

Enyinda Onunwor, Stark State College

Abstract: The symmetric Lanczos method is commonly applied to reduce large-scale symmetric linear discrete ill-posed problems to small ones with a symmetric tridiagonal matrix. How quickly the nonnegative subdiagonal entries of this matrix decay to zero will be investigated. Their fast decay to zero suggests that there is little benefit in expressing the solution of the discrete ill-posed problems in terms of the eigenvectors of the matrix compared with using a basis of Lanczos vectors, which are cheaper to compute. Similarly, the solution subspace determined by the LSQR method when applied to the solution of linear discrete ill-posed problems with a nonsymmetric matrix often can be used instead of the solution subspace determined by the singular value decomposition without significant, if any, reduction of the quality of the computed solution.

Room 1401

High-Order DG-FEM for Micro-Macro Partitioned Kinetic Models

James Rossmanith, Iowa State University

Abstract: The dynamics of gases can be simulated using kinetic or fluid models. Kinetic models are valid over most of the spatial and temporal scales that are of physical relevance in many application problems; however, they are computationally expensive due to the high-dimensionality of phase space. Fluid models have a more limited range of validity, but are generally computationally more tractable than kinetic models. One critical aspect of fluid models is the question of what assumptions to make in order to close the fluid model.

The approach we consider in this work for handling the fluid closure problem is the micro-macro partition approach of [Bennoune, Lemou, and Mieussens, J. Comp. Pays., 2008]. In particular, we develop a high-order extension of their method using discontinuous Galerkin finite element methods (DG-FEMs) in conjunction with semi-Lagrangian time-stepping. Several numerical examples are shown to demonstrate the viability, efficiency, and accuracy of the proposed numerical method.

A Family of Regionally Implicit Discontinuous Galerkin Methods with Applications to Solving the Relativistic Vlasov-Maxwell System

Pierson Guthrey, Iowa State University

Abstract: In the relativistic limit, the Vlasov-Maxwell system introduces numerical difficulties as explained in [2]. We develop an efficient solver for the relativistic Vlasov-Maxwell (RVM) system in order to model laser-plasma interactions; and in particular, the acceleration of electrons or ions to relativistic energies. In doing so we expand on the so called Locally Implicit Discontinuous Galerkin method (LIDG) developed in [1] by defining Regionally Implicit Discontinuous Galerkin Methods. These methods are parametrized by the region parameter r. For a given cell, the region parameter determines how many neighboring cells (this collection of cells known as the region) will provide information to the prediction step of the method. We use a Rusanov Riemann solver on the interior of said region and the interior cell values on the boundary of the region. We show that these methods allow a much larger CFL number when compared to the LIDG method, and thus offer a vastly improved efficiency over the LIDG method. Here we introduce the methods applied to the 1D, 2D, and 3D advection equations.

[1] Jianxian Qiu, Michael Dumbser, and Chi Wang Shu. The discontinuous Galerkin method with Lax-Wendroff type time discretizations. Computer Methods in Applied Me- chanics and Engineering, 194(42-44):45284543, 2005.

[2] Akihiro Suzuki and Toshikazu Shigeyama. A conservative scheme for the relativistic Vlasov-Maxwell system. Journal of Computational Physics, 229(5):16431660, 2010.

A Lyapunov exponents based stability theory for Runge-Kutta methods

Andrew Steyer, University of Kansas

Abstract: In this talk we consider the stability of variable step-size Runge-Kutta methods approximating bounded and time-dependent solutions of ordinary differential equation initial value problems. We use Lyapunov exponent theory to determine conditions on the maxi- mum allowable step-size that guarantees the discrete Lyapunov exponents of the numerical solution of a time-dependent linear problem with an integral separation structure approxi- mate the Lyapunov exponents of the exact solution with the same order of accuracy as the Runge-Kutta method that is used. This result is used to justify using a one-dimensional asymptotically contracting real-valued nonautonomous linear test problem to characterize the stability of a Runge-Kutta method approximating a time-dependent problem. The linear stability result is applied to show the stability of the numerical solution of stable nonlinear problems through an application of the discrete variation of constants formula. We conclude the talk by showing how these results extend to strictly stable linear multistep methods and discussing applications in the computation of integral manifolds and step-size selection. This is a joint work with Erik Van Vleck from University of Kansas.

A High-Order and Energy-Conserving Local Discontinuous Galerkin Method for the Sine-Gordon Equation

Mahboub Baccouch, University of Nebraska at Omaha

Abstract: The sine-Gordon equation is one of the basic equations in modern nonlinear wave theory. It has applications in many areas of physics and mathematics. Developing efficient, stable, energy-conserving, and accurate numerical schemes to solve the sine-Gordon nonlinear hyperbolic equation is of fundamental importance to the simulation of waves and solitons. It is well-known that energy-conserving schemes are very suitable for long time simulations. They are also important when dealing with coarse grids and large time steps. In this talk, we develop and analyze a high-order and energy-conserving local discontinuous Galerkin method for solving the sine-Gordon nonlinear hyperbolic equation. We prove the L^2 stability, the energy conserving property, and optimal error estimates for the proposed LDG scheme. More precisely, we identify special numerical fluxes and a suitable projection of the initial conditions for the LDG scheme to achieve $p + 1$ order of convergence for both the potential and its gradient in the L^2-norm, when piecewise polynomials of degree at most p are used. These results are also valid for the two-dimensional sine-Gordon equation on Cartesian grids, when tensor product polynomials of degree at most p are used. We present several numerical examples to validate the theoretical results.

A Fast Treecode Algorithm for Stokes Flow in 3D

Lei Wang, University of Wisconsin - Milwaukee

Abstract: A large number of problems in fluid dynamics are modeled as many-particle interactions in Stokes flows, for example, simulations of falling jets of particles in viscous fluids, microfluidic crystals, and vesicle flows. The formulation is often based on fundamental solutions. The Stokeslet and the Stresslet are the kernels in the single and double layer potentials, respectively. Many situations (e.g., through superposition or discretization of boundary integrals) involve sums of Stokeslets and Stresslets, which is an example of an N- body problem and the direct sum requires $O(N^2)$ operations. This can make the numerical calculation prohibitively expensive. A Barnes-Hut tree treecode algorithm is developed for speeding up the computation. The particles are restructured recursively into a tree, and the particle-particle interactions are replaced with particle-cluster interactions computed by either a far-field expansion or a direct summation. Numerical results exhibit the promising performance of the algorithm.

An ETD Real Distinct Poles L-Stable Scheme

Bruce Wade, University of Wisconsin - Milwaukee

Abstract: A second order Exponential Time Differencing (ETD) scheme for advection-diffusion-reaction equations which uses a real distinct poles discretization is developed. It is demonstrated to be robust for problems involving non-smooth initial and boundary conditions due to its favorable L-stability property.

A Fast Multi-Rank Update to the Symmetric Eigenvalue Problem

Jimmy Vogel, Purdue University

Abstract: For over 20 years, there have existed algorithms to update the eigenvalues of a symmetric matrix plus a rank-one perturbation in linear time (O(n) complexity). This has become a key subroutine in many areas of scientific computing. However if, one seeks to analogously perform a rank-k perturbation, where 1 ¡ k ¡¡ n, either the complexity increases dramatically or it must be done as a sequence of rank-one updates. The latter leads to poor data locality, thus unsuitable for high performance computing. We present a novel approach for the rank-k update to the symmetric eigenvalue problem, which is a hybrid of traditional, iterative, hierarchical, and inverse eigenvalue techniques. The algorithm is stable, robust, has O(kn log n) complexity, and has great data locality. As an immediate consequence, we show how this algorithm can be used in high performance divide-and-conquer eigensolvers for structured matrices, and particularly how the fast rank-k update leads to an elegant approach for dealing with the pathological case of clustered eigenvalues. We support our claims with theoretical complexity, stability, and convergence analysis, as well as numerical examples from practical applications such as optimal control and kinetic simulations.

Third Order Maximum-Principle-Satisfying Direct DG Methods for Convection Diffusion Equations on Unstructured Triangular Meshes

Jue Yan, Iowa State University

Abstract: We develop 3rd order maximum-principle-satisfying direct discontinuous Galerkin methods for convection diffusion equations on unstructured triangular mesh. We carefully calculate the normal derivative numerical ux across element edges and prove that, with proper choice of parameter pair (0, 1) in the numerical ux formula, the quadratic polynomial solution satises strict maximum principle. The polynomial solution is bounded within the given range and third order accuracy is maintained. There is no geometric restriction on the meshes and obtuse triangles are allowed in the partition. A sequence of numerical examples are carried out to demonstrate the accuracy and capability of the maximum-principle- satisfying limiter.

A New Finite Element and Finite Difference Hybrid Method for a Class of Nonlinear Interface Problems

Dexuan Xie, University of Wisconsin-Milwaukee

Abstract: In this talk, I will introduce a hybrid method that we developed recently by techniques of domain decomposition, finite element, and finite difference to solve a class of nonlinear interface problems. As an application, it has led to a new hybrid algorithm for solving the nonlinear Poisson-Boltzmann equation — a commonly used dielectric continuum model for predicting an electrostatic field induced by a protein in an ionic solvent. Numerical results demonstrate that our new hybrid scheme can significantly improve the performance of a PBE finite element solver (reported in Journal of Computational Physics, Vol. 275, pages 294-309, 2014). This project is a joined work with my student, Jinyong Ying, under the support by NSF award DMS-1226259.

Domain Decomposition Methods for Symmetric Eigenvalue Problems

Vasileios Kalantzis University of Minnesota

Abstract: In this talk we will discuss Domain-Decomposition (DD) type methods for large Hermitian eigenvalue problems. This class of techniques rely on spectral Schur complements combined with Newtons iteration. The eigenvalues of the spectral Schur complement appear in the form of branches of some functions, the roots of which are eigenvalues of the original matrix. It is possible to extract these roots by a number of methods which range from a form or approximate Rayleigh iteration to an approximate inverse iteration, in which a Domain Decomposition framework is used. Numerical experiments in parallel environments will illustrate the numerical properties and efficiency of the method.

Room 1303

An Efficient Adaptive Rescaling Scheme for Computing Hele-Shaw Problems

Meng Zhao, Illinois Institute of Technology

Abstract: In this talk, we present an efficient rescaling scheme for computing the long-time dynamics of expanding interfaces. The idea is to design an adaptive time-space mapping such that in the new time scale, the interfaces evolves logarithmically fast at early growth stage and exponentially fast at later times. The new spatial scale guarantees the conservation of the area/volume enclosed by the interface. Compared with the original rescaling method in [J. Comput. Phys. 225(1) (2007) 554567], this adaptive scheme dramatically improves the slow evolution at early times when the size of the interface is small. Our results show that the original three-week computation in [J. Comput. Phys. 225(1) (2007) 554567] can be reproduced in about one day using the adaptive scheme. We then present the largest and most complicated Hele-Shaw simulation up to date.

On Common Diagonal Lyapunov Solutions

Mehmet Gumus, Southern Illinois University Carbondale

Abstract: Several recent results regarding common diagonal Lyapunov solutions are further explored here. The first one, attributed to Redheffer and revisited by Shorten and Narendra, reduces the diagonal stability of a matrix to common diagonal Lyapunov solutions on two matrices of order one less. We present a shorter, purely matrix-theoretic proof of this result along with its extensions. The second one concerns two different necessary and sufficient conditions, due to Oleng, Narendra, and Shorten, for a pair of 2 x 2 matrices to share a common diagonal Lyapunov solution. We show that these two conditions are connected directly to each other.

Sensitivity and Computation of a Defective Eigenvalue

Zhonggang Zeng, Northeastern Illinois University

Abstract: A defective eigenvalues is well documented to be hypersensitive to data perturbations and round-off errors, making it a formidable challenge in numerical computation particularly when the matrix is known through approximate data. In this work we establish a finitely bounded sensitivity of a defective eigenvalue with respect to perturbations that preserve the geometric multiplicity and the smallest Jordan block size. Based on this perturbation theory, numerical computation of a defective eigenvalue is regularized as a well-posed least squares problem so that it can be accurately carried out using floating point arithmetic even if the matrix is perturbed.

Adomian Solutions of the Higher Order Sawada-Kotera and Lax Equations

Mohamed El-Houssieny, University of Toledo

Abstract: Nonlinear partial differential equations with higher order like Sawada-Kotera and Lax are considered. A domain decomposition method is implemented to approximate the solution of these equations. In the solution procedure, all the nonlinear terms are dealt as one nonlinear operator instead of dealing with each term separately. We compare the numerical results with the exact solution and demonstrate the accuracy of our solution. In this talk I will present the methodology and the numerical solution of these equations.

Wavelet Regularized Solution for the Dirichlet Problem in an Arbitrary Shaped Domain

Vani Cheruvu, University of Toledo

Abstract: Interior Dirichlet problem for the two-dimensional Laplace equation in an arbitrary shaped domain is considered. Analytic continuation is used to embed the arbitrary shaped domain into a circular domain. This implementation leads to an inverse problem for the unknown boundary function on the circular domain. The resulting ill-conditioned system is solved using wavelet regularization. In this talk, we present the idea and conclude with couple of numerical results.