Midwest Numerical Analysis Day 2015
Wright State University, Dayton, Ohio
April 25, 2015 Schedule
Morning 7:30am-12:10pm
Room 160, Rike Hall (RK on the map)

Organizers: Dr. Weiqun Zhang (weiqun.zhang@wright.edu)
Dr. Mohamed Sulman (mohamed.sulman@wright.edu)

7:30-8:20	Registration and Refreshment		
8:20-8:25	Welcome by Dr. Yi Li, Dean of College of Science and Math, Wright State University		
8:25-8:30	MWNADAY Executive Committee Dr. Fasshauer and Dr. Wade		
8:30-9:10	**Dr. Weizhang Huang, University of Kansas, 160 Rike Hall** Geometric discretization and simple implementation for variational adaptive moving mesh methods		
9:15-9:55	**Dr. Weimin Han, University of Iowa, 160 Rike Hall** Hemivariational Inequalities: Modeling, Analysis and Numerical Solution		
9:55-10:10	Break and Coffee		
10:10-10:50	**Dr. D.A. French, University of Cincinnati, 160 Rike Hall** Error Analyses of Stabilized MLS Methods with Pseudo-Derivatives		
	158 Rike Hall	**160 Rike Hall**	**166 Rike Hall**
	The 1st speaker (*) in each room is the session chair. Please stay until your session is over. Thanks!		
11-11:20	**Xu Zhang*** Purdue University Discontinuous immersed Finite Element Methods for Elliptic Interface Problems	**Fatih Celiker*** Wayne State University Nonlocal theories derived from local theories	**Mahboub Baccouch*** Univ. of Nebraska, Omaha Superconvergence and recovery type *a posteriori* error estimators for the Discontinuous Galerkin method for hyperbolic problems
11:25-11:45	**Kenneth Czuprynski** University of Iowa Energy discretizations of the Radiative Transfer Equation	**Yuliang Wang** Purdue Univeristy INVERSE ELASTIC SURFACE SCATTERING WITH NEAR-FIELD DATA	**Cheng Wang** Tongji University, China A SPACE CASCADIC MULTI-GRID METHOD FOR THE RADIATIVE TRANSFER EQUATION
11:50-12:10	**Alia Khurram** Adrian College Reconstruction of Univariate Discrete Function from the Magnitude of its Fourier Transform	**Fritz Keinert** Iowa State University Rank Minimization and Semidefinite Programming	**Yongyong Cai** Purdue University, Error estimates of numerical methods for nonlinear Schroedinger equation with wave operator
1210-110	**Free lunch provided at Student Union**. Please find “SU” on the map attached to this schedule.		

Midwest Numerical Analysis Day 2015
Wright State University, Dayton, Ohio
April 25, 2015 Schedule
Afternoon 1:15pm-6:00pm
Room160, Rike Hall (RK on the map)

Organizers: Dr. Weiqun Zhang (weiqun.zhang@wright.edu)
Dr. Mohamed Sulman (mohamed.sulman@wright.edu)

1:15-1:55	**Dr. Yanqiu Wang, Oklahoma State University, 160 Rike Hall** H(curl) and H(div) elements on polygonal and polyhedral meshes		
2:00-2:40	**Dr. Ching-Shan Chou, Ohio State University, 160 Rike Hall** Optimal energy conserving local discontinuous Galerkin methods for second-order wave equation in heterogeneous media		
2:40-2:55	Break and Coffee		
3:00-3:40	**Dr. Anil Hirani, University of Illinois Urbana-Champaign, 160 Rike Hall** Anticipating Topology with Eigenvalues		
	158 Rike Hall	**160 Rike Hall**	**166 Rike Hall**
	The 1st speaker (*) in each room is the session chair. Please stay until your session is over. Thanks!		
3:45-4:05	**Rongfang Gong*** University of Iowa A new Kohn-Vogelius type formulation for inverse source problems	**Hengguang Li*** Wayne State University Optimal Quadrilateral Finite Elements on Polygonal Domains	**Arunasalam Rahunanthan*** Central State University Forecasting Porous Media Flows Using GPUs
4:10-4:30	**Jimm Vogel** Purdue University A Superfast Divide-and-Conquer Method for the Structured Singular Value Decomposition	**Alan, Liddell** University of Notre Dame, Numerically Certifying the Completeness of Real Solution Sets of Polynomial Systems	**Yingwei Wang** Purdue University FAST STRUCTURED SPECTRAL METHODS
4:35-4:55	**Sangwoo Chung** University of Cincinnati Finding Ground States for Quantum Systems in a 1D Continuum via Variational Matrix-Products Ansaetze	**Leopold Matamba Messi** Ohio State University (BV;L2) Multiscale Decomposition: Modes and Rate of Convergence	**Yibing Lv** Yangtze University, China An equilibrium point approach for solving the linear bilevel multiobjective programming problem
5:00-5:20		**Vani Cheruvu** University of Toledo Numerical Methods, Grids on a Sphere	
5:30-8:00	**Dinner, cost and location TBA.**		

Invited Talks

Optimal energy conserving local discontinuous Galerkin methods for second-order wave equation in heterogeneous media
Dr. Ching-Shan Chou, Department of Mathematics, Ohio State University, Columbus, OH

Abstract: Solving wave propagation problems within heterogeneous media has been of great interest and has a wide range of applications in physics and engineering. The design of numerical methods for such general wave propagation problems is challenging because the energy conserving property has to be incorporated in the numerical algorithms in order to minimize the phase or shape errors after long time integration. In this talk, we will discuss multi-dimensional wave problems and consider linear second-order wave equation in heterogeneous media. We will present an LDG method, in which numerical fluxes are carefully designed to maintain the energy preserving property and accuracy. We propose compatible high order energy conserving time integrators and prove the optimal error estimates and the energy conserving property for the semi-discrete methods. Our numerical experiments demonstrate optimal rates of convergence, and show that the errors of the numerical solution do not grow significantly in time due to the energy conserving property.

Error Analyses of Stabilized MLS Methods with Pseudo-Derivatives
Dr. D.A. French, Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH

Abstract: Moving least square (MLS) methods are a popular type of meshfree approximation scheme. These MLS schemes when combined with pseudo or diffuse derivatives (PDs) are simpler to work with, retain a similar structure to the MLS methods themselves and appear to be advantageous for enrichment schemes. They have been developed and implemented in both Galerkin and least squares method frameworks for elasticity and fluids problems (See Krongauz & Belytschko (1997), Vidal et al (2003), Lee & Yoon (2004), Kim & Liu (2006) and many more). Our computations and others (including Krongauz & Belytschko (1997)) suggest that Galerkin MLS/PD implementation has low accuracy. Also, all of these studies of this MLS/PD method approach have been computational.
A stabilization approach for these MLS/PD schemes that improves the Galerkin accuracy and will be provided in this talk. Error analysis and computational results for these stabilized MLS/PD Galerkin and least squares schemes will be given on a range of ordinary and partial differential equation as well as basic fractional derivative problems.

Hemivariational Inequalities: Modeling, Analysis and Numerical Solution
Dr. Weimin Han, Department of Mathematics University of Iowa, Iowa City, IA

Abstract: Hemivariational inequalities (HVIs) and variational inequalities (VIs) are closely related. In the context of applications in mechanics, VIs are concerned with convex energy functionals, whereas HVIs are concerned with nonsmooth and nonconvex energy functionals. The notion of HVI was first introduced by Panagiotopoulos in early 1980s. During the last three decades, HVIs were shown to be very useful across a wide variety of subjects, ranging from nonsmooth mechanics, physics, engineering, to economics. This talk is devoted to the modeling of some contact problems as HVIs, well-posedness analysis and numerical solutions of the HVIs.

Anticipating Topology with Eigenvalues
Dr. Anil Hirani, Department of Mathematics, University of Illinois at Urbana-Champaign

Abstract: It is well-known that when a planar domain or a surface is deformed (pinched) in such a way that would make it split into two or more connected components this pinching can be detected by observing the small nonzero eigenvalues of the scalar Laplacian. This is a consequence of Cheeger's 1970 result on a lower bound for the smallest nonzero eigenvalue of the Laplacian. We show (for a specific solid domain) that it may be possible to anticipate the appearance of a hole by observing the small eigenvalues of the Laplacian on 1-forms (also known as the vector Laplacian). This is joint work with D. Arnold, V. de Silva, S. Mukherjee, and M. Schubel.

Geometric discretization and simple implementation for variational adaptive moving mesh methods
Dr. Weizhang Huang, Department of Mathematics, University of Kansas, Lawrence, KS

Abstract: A simple direct discretization and implementation is presented for variational adaptive moving mesh methods for the numerical solution of partial differential equations. Meshing functionals are discretized on simplicial meshes and the Jacobian matrix of the continuous coordinate transformation is approximated by the Jacobian matrices of affine mappings between elements. The advantage of this direct discretization is that it preserves the basic geometric structure of the continuous functional, which is useful in preventing strong decoupling or loss of integral constraints satisfied by the functional. Moreover, the discretized functional is a function of the coordinates of mesh vertices and its derivatives have a simple analytical form, which allows a simple implementation of variational adaptive moving mesh methods on computer. Application of the developed implementation of adaptive moving mesh methods in the numerical solution of partial differential equations and in mesh generation (mesh quality improvement) is discussed.

H(curl) and H(div) elements on polygonal and polyhedral meshes
Dr. Yanqiu Wang, Department of Mathematics Oklahoma State University

Abstract: We construct H(curl) and H(div) finite elements on convex polygons and polyhedra. These elements can be viewed as extensions of the lowest order Nedelec-Raviart-Thomas elements, from simplices to general convex polytopes. The construction is based on generalized barycentric coordinates and the Whitney forms. In 3D, it currently requires the faces of the polyhedron be either triangles or parallelograms. Unified formula for computing basis functions are given.The finite elements satisfy discrete de Rham sequences in analogy to the well-known ones on simplices. Moreover, they reproduce existing H(curl) and H(div) elements on simplices,parallelograms, parallelepipeds, pyramids and triangular prisms. Approximation property of the constructed elements is obtained on arbitrary convex polygons and certain polyhedra.

Contributed Talks

Nonlocal theories derived from local theories
Fatih Celiker, Wayne State University

We study nonlocal equations from the area of peridynamics on bounded domains. We prove that in $\mathbb{R}^n$, the governing operator in peridynamics, which involves a convolution, is a bounded function of the classical (local) governing operator. Building on this, we define an abstract convolution operator on bounded domains which is a generalization of the standard convolution based on integrals. The abstract convolution operator is a function of the classical operator, defined by a Hilbert basis available due to the purely discrete spectrum of the latter. As governing operator of the nonlocal equation we use a function of the classical operator, this allows us to incorporate local boundary conditions into nonlocal theories.

We present a numerical study of the solutions of the wave equation. For discretization, we employ a weak formulation based on a Galerkin projection and use piecewise polynomials on each element which allows discontinuities of the approximate solution at the element borders. We study convergence order of solutions with respect to polynomial order and observe optimal convergence. We depict the solutions for each boundary condition.

This is joint work with H. Beyer and B. Aksoylu.

FAST STRUCTURED SPECTRAL METHODS
Yingwei Wang, Purdue University

JIE SHEN_, YINGWEI WANG_ AND JIANLIN XIA_
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Spectral methods have been used extensively in numerical approximation of partial di_erential equations due to their bigger accuracy when compared to Finite Di_erences (FD) and Finite Elements (FE) methods. However, FD and FE usually lead to a sparse linear system while spectral methods often su_er from the huge computational complexity caused by dense matrices. Fortunately, although the matrices arising from spectral methods are dense, they enjoy a hidden nice property, named low-rank structure[1], i.e. their o_-diagonal blocks have small numerical ranks for a given tolerance which is nearly bounded or grows slowly with the sizes of matrices. This property could be exploited to dramatically reduce the computational cost and give birth to direct spectral solvers with nearly optimal complexity and memory, thanks to the hierarchically semiseparable (HSS) representation for structured matrices [2]. The Fast Structured Spectral Methods presented here include fast structured Jacobi transforms, fast structured spectral Galerkin methods for di_erential equations with variable coe_cients, and fast structured spectral collocation methods. Our methods are very attractive for spectral approximations of problems with variable coe_cients, especially when the coe_cients have steep gradients and/or large variations or are degenerate, and when only matrix-vector products are available.

REFERENCES
[1] S. Chandrasekaran, M. Gu, X. Sun, J. Xia, and J. Zhu, A superfast algorithm for Toeplitz systems of linear equations, SIAM J. Matrix Anal. Appl., 29 (2007), pp. 1247{1266.
[2] J. Xia, S. Chandrasekaran, M. Gu, and X. S. Li, Fast algorithms for hierarchically semiseparable matrices, Numer. Linear Algebra Appl, 17 (2010), pp. 953{976.

Numerically Certifying the Completeness of Real Solution Sets of Polynomial Systems
Alan Liddell, Applied and Computational Mathematics and Statistics, University of Notre Dame

The computation of real solutions to a system of polynomial equations presents unique challenges. Since real solutions are often the solutions sought after in applications, one may wish to know if one has computed the complete set of solutions for a given system. Con_dence in numerical methods would be greatly boosted if the completeness of such sets could be readily guaranteed. In this work, we develop an algorithm certifying that a given set of solutions, including real isolated and positive-dimensional solution components, constitutes a complete real solution set.

Optimal Quadrilateral Finite Elements on Polygonal Domains
Hengguang Li, Math, Wayne State University

We propose three quadrilateral mesh refinement algorithms to improve the convergence of the finite element method approximating the singular solutions of elliptic equations, which are due to the non-smoothness of the domain. These algorithms result in graded meshes consisting of convex and shape-regular quadrilaterals. With rigorous analysis in weighted spaces, we provide the selection criteria for the grading parameter, such that the optimal convergence rate can be recovered for the associated finite element approximation. Various numerical tests verify the theory.

Finding Ground States for Quantum Systems in a 1D Continuum via Variational Matrix-Products Ansaetze
Sangwoo Chung, Dept of Physics, University of Cincinnati

The continuous matrix product states (cMPS) is a variational ansatz for a computational treatment of low energy quantum states for strongly correlated systems in a one-dimensional continuum. Using the cMPS formalism, the system energy can be expressed as a matrix functional. We have computed the ground state properties of interacting fermions via (free) energy minimization. Graphical processing units were used to facilitate the necessary computational power. We have validated our calculations and tested their precision by checking against the results obtained from other numerical schemes available for the treatment of special cases.

Discontinuous immersed Finite Element Methods for Elliptic Interface Problems
Xu Zhang, Math, Purdue University

In this presentation, we discuss a class of discontinuous immersed finite element (IFE) methods for a second order elliptic interface problem. The proposed methods can be used on Cartesian meshes regardless of the interface geometry. A priori error estimation shows that the discontinuous IFE methods can converge optimally in a mesh-dependent energy norm. The combination of IFE functions and discontinuous Galerkin formulation in these methods allows local mesh refinement in the structure of Cartesian meshes. Finally, we will present some numerical results to demonstrate features of these discontinuous IFE methods.

INVERSE ELASTIC SURFACE SCATTERING WITH NEAR-FIELD DATA
Yuliang Wang, Math, Purdue Univeristy

PEIJUN LI, YULIANG WANG, AND YUE ZHAO

Consider the scattering of a time-harmonic plane wave by a one-dimensional periodic surface. A novel computational method is proposed for solving the inverse elastic surface scattering problem by using the near-_eld data. Above the surface, the space is _lled with a homogeneous and isotropic elastic medium, while the space below the surface is assumed to be elastically rigid. Given an incident _eld, the inverse problem is to reconstruct the surface from the displacement of the wave _eld at a horizontal line above the surface. This paper is a nontrivial extension of the authors' recent work on near-_eld imaging of the Helmholtz equation and the Maxwell equation to the more complicated Navier equation due to coexistence of the compressional and shear waves that propagate at di_erent speed. Based on the Helmholtz decomposition, the wave _eld is decomposed into its compressional and shear parts by using two scalar potential functions. The transformed _eld expansion is then applied to each component and a coupled recurrence relation is obtained for their power series expansions. By solving the coupled system in the frequency domain, simple and explicit reconstruction formulas are derived for two types of measurement data. The method requires only a single illumination with a _xed frequency and incident angle. Numerical experiments show that it is simple, e_ective, and e_cient to reconstruct the scattering surfaces with subwavelength resolution.

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Key words and phrases. inverse elastic surface scattering, near-_eld imaging, transformed _eld expansion, subwave-length resolution.

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A Superfast Divide-and-Conquer Method for the Structured Singular Value Decomposition
Jimmy Vogel, Math, Purdue University

We present a superfast (nearly linear time) algorithm for finding all the singular values as well as all the singular vectors (in a structured form) of a class of rank structured matrices (HSS). This class of matrices is often encountered in practical applications such as Toeplitz systems and certain discretized problems. We discuss the fundamental ideas of the algorithm such as the divide-and-conquer strategy, HSS operations, and rank-one updates and downdates to the symmetric eigenproblem. We also discuss the important numerical analysis algorithms used as subroutines, including the fast multipole method (FMM), inverse eigenvalue problem, and rational interpolation. The use of these tools ensures the algorithm's respective efficiency, stability, and accuracy. Numerical results are given to support our theoretical claims.

Forecasting Porous Media Flows Using GPUs
Arunasalam Rahunanthan, Math and Computer Science, Central State University

In many applications in flows through porous media one needs to determine properties of subsurface to detect, monitor, or forecast the actions of natural or induced forces. Here we consider the problem of forecasting flows in porous media. Our strategy consists of establishing a complete statistical description of subsurface properties, such as rock permeability and porosity that are conditioned to existing dynamic data. A Bayesian approach using a Markov Chain Monte Carlo (MCMC) algorithm is well suited for reconstructing the spatial distribution of permeability and porosity. A crucial step in this approach is the computation of a likelihood function, which involves solving a nonlinear system of partial differential equations. The computation time for the likelihood function and the sequential nature of MCMC simulation limit the posterior exploration in a practical period of time. In this talk we consider two approaches to speed-up the posterior exploration. The first approach relies on the use of surrogate models that capture general trend of the quantities of interest in the original model. In the second approach we parallelize the MCMC algorithm using a pre-fetching technique. We then compare both approaches on GPUs for forecasting production in an oil reservoir.

A new Kohn-Vogelius type formulation for inverse source problems
Rongfang Gong, Math, University of Iowa

Rongfang Gong1;2
1 Department of Mathematics
Nanjing University of Aeronautics and Astronautics, China
2 Department of Mathematics, University of Iowa, U.S.A.

In this talk we propose a Kohn-Vogelius type formulation for an inverse source problem of partial differential equations. The unknown source term is to be determined from both Dirichlet and Neumann boundary conditions. We introduce two different boundary value problems, which depend on two different positive real numbers _ and _, and both of them incorporate the Dirichlet and Neumann data into a single Robin boundary condition. This allows both boundary data to have noise simultaneously. By using the Kohn-Vogelius type Tikhonov regularization, data to be fitted is transferred from boundary into the whole domain, which makes resolving of the problem more robust. More importantly, with the formulation proposed here, satisfactory reconstruction could be achieved for rather small regularization parameter through choosing properly the values of _ and _. This is a desirable property to have since the smaller the regularization parameter, the better the approximation of the regularized problem to the original one. Some theoretical results are also delivered. Two numerical examples are provided to show the usefulness of the proposed method.

This is a joint work with Prof. Xiaoliang Cheng of Zhejiang University, China, and Prof. Weimin Han of the University of Iowa, U.S.A.

(BV;L2) Multiscale Decomposition: Modes and Rate of Convergence
Leopold Matamba Messi, Mathematical Biosciences Institute, Ohio State University

Ming-Jun Lai1 and Leopold Matamba Messi2,*
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Tadmor, Nezzar and Vese [Eitan Tadmor, Suzanne Nezzar, and Luminita Vese. A multiscale image representation using hierarchical (BV;L2) decompositions. Multiscale Model. Simul., 2(4):554{579, 2004.] developed a total variation multiscale method for decomposing a function f 2 BV into a countable set of features fuk: k = 0; 1; 2 : : :g associated with a sequence of dyadic scales f_k = _02□k: k = 0; 1; 2; : : :g. In this talk, we will establish a geometric convergence rate for this decomposition and formulate separate necessary and su_cient conditions for its convergence in the space of functions with bounded variation.

Energy discretizations of the Radiative Transfer Equation
Kenneth Czuprynski, Applied Mathematical and Computational Science, University of Iowa

The Radiative Transfer Equation (RTE) arises in a wide variety of disciplines such as neutron transport, heat transfer, bio-medical optics, and radiation therapy. Due to the integro-di_erential form of the equation, the high dimension and the numerical singularity of the kernel function of the integral operator in applications, it is challenging to solve the RTE e_ciently. In most of the relevant references, only the energy independent RTE is studied. In this talk, we consider the more general energy dependent RTE, focusing on the discretization of the energy variable and related error estimates.

Optimal Quadrilateral Finite Elements on Polygonal Domains
Hengguang Li, Math, Wayne State University

We propose three quadrilateral mesh refinement algorithms to improve the convergence of the finite element method approximating the singular solutions of elliptic equations, which are due to the non-smoothness of the domain. These algorithms result in grade meshes consisting of convex and shape-regular quadrilaterals. With rigorous analysis in weighted spaces, we provide the selection criteria for the grading parameter, such that the optimal convergence rate can be recovered for the associated finite element approximation. Various numerical tests verify the theory.

A SPACE CASCADIC MULTI-GRID METHOD FOR THE RADIATIVE TRANSFER EQUATION

Cheng Wang, Tongji University, Department Department of Mathematics

CHENG WANGy, QIWEI SHENGz, AND WEIMIN HANx

Abstract.
The radiative transfer equation (RTE) arises in many different areas of science and engineering. In this talk, we propose and investigate a discrete-ordinate discontinuous-streamline diffusion (DODSD) method for solving the RTE. The numerical scheme is constructed in two steps. In the first step, the integral operator for the angular variable is discretized by the discrete ordinate technique and the RTE is reduced to a semi-discrete hyperbolic system. In the second step, a discontinuous-streamline diffusion method is employed to solve the semi-discrete hyperbolic system. We prove stability of the resulting DODSD method and derive error estimates for the numerical solutions in certain norms. Based on the DODSD method, we further study its source iteration and Gauss-Seidel iteration schemes, and present a space cascadic multigrid algorithm for solving the systems generated by the DODSD method. Under an assumption on the convergence rate of iteration schemes, we prove that the space cascadic multigrid algorithm is optimal in both accuracy and computational complexity. Numerical examples are provided to illustrate the performance of the space cascadic multigrid algorithm, with a particular attention paid on the numerical convergence orders.

Key words. radiative transfer equation, discrete-ordinate discontinuous-streamline diffusion method, cascadic multigrid method
AMS subject classifications. 65N30, 65R20

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Error estimates of numerical methods for nonlinear Schroedinger equation with wave operator

Yongyong Cai, Department of Mathematics , Purdue University

Abstract: The nonlinear Schroedinger equation (NLS) with wave operator (NLSW) is NLS perturbed by the wave operator with strength described by a dimensionless parameter " ∈ (0; 1]. NLSW appears in many physical applications, such as the Klein-Gordon equation in the nonrelativistic limit, Langmuir envelope approximation in plasma and modeling light bullets from sine-Gordon equation. As " → 0+, NLSW converges to NLS and for the small perturbation, i.e. 0 < " ≪ 1, the solution of NLSW differs from that of NLS with a function oscillating in time with O("2)-wavelength at O("2) and O("4) amplitudes for ill-prepared and well-prepared initial data, respectively. This rapid oscillation in time brings significant difficulties in designing and analyzing numerical methods with error bounds uniformly in ". I will start with the error analysis of finite difference methods for NLSW and the uniform bounds w.r.t. ". Then I will show the error analysis of an exponential wave integrator sine pseudospectral method for NLSW, with improved uniform error bounds.

Reconstruction of Univariate Discrete Function from the Magnitude of its Fourier Transform

Alia Khurram, Adrian College

Abstract:
Phase retrieval is an important problem in Physics and Engineering. This has been studies both for univariate and multivariate functions. I have studied this problem with functions that are univariate and discrete. I have applied Fienup's analysis and adapted the Gerchberg-Saxton algorithm to vectors of length N with only 0, 1 entries. In this talk I will be discussing the phase ambiguities that arise due to translations, reflections, etc. I will present error analysis and suggest ways to improve convergence of the algorithm.

Superconvergence and recovery type *a posteriori* error estimators for the Discontinuous Galerkin method for hyperbolic problems

Mahboub Baccouch, Associate Professor
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In this talk, we analyze the original discontinuous Galerkin (DG) method for linear and nonlinear conservation laws in one and two space dimensions. We prove several optimal $L2$ error estimates and super convergence results. We also provide a very simple derivative recovery formula which gives a super convergent approximation to the directional derivative. The element-by-element post processing of the derivative in the direction of the flow is shown to converge under mesh refinement with order $p + 1$, when piecewise polynomials of degree at most p are used. We use these results to construct robust recovery-based *a posteriori* error estimators. The proposed error estimators of the recovery-type are easy to implement, computationally simple, asymptotically exact, and are useful in adaptive computations. We further prove that the *a posteriori* DG error estimates converge to the true errors in the $L2$-norm under mesh refinement. The order of convergence is proved to be $p + 1$. Finally, we prove that the global effectivity index converges to unity at $O(h)$ rate. Several numerical examples are provided to support our theoretical results and to show the effectiveness of our recovery-based error estimates.

Rank Minimization and Semidefinite Programming

Fritz Keinert, Iowa State University

A rank minimization problem tries to find the matrix of lowest rank that satisfies some constraints. For example, some of the entries may be known. If the constraints are linear, this can be converted to a semidefinite program, a generalization of a linear program. I will give an overview of some connections between compressed sensing and rank minimization, and between algorithms for linear programming and semidefinite programming.

An equilibrium point approach for solving the linear bilevel multiobjective programming problem

**Yibing Lv, School of Information and Mathematics,
Yangtze University, Jingzhou 434023, China**

In this talk, a linear bilevel multiobjective programming (LBMP) problem is considered. Based on the optimality conditions of a lower level problem, we transform the LBMP problem into a corresponding linear multiobjective programming problem with complementary constraints. We append the complementary constraints to the upper level objectives with a penalty. Then, we construct a penalized problem and prove that the penalty function is exact. The concept of an equilibrium point of the penalized problem is introduced and its properties are analyzed. Thereafter, we propose an equilibrium point algorithm for the LBMP, which only requires solving a series of linear programming problems. Numerical results are presented, showing the usefulness of the equilibrium point approach.

Numerical Methods, Grids on a Sphere

Vani Cheruvu, University of Toledo

There is a considerable effort in using high-order methods to solve partial differential equations that model geophysical flow. In this talk, I would discuss three different high-order methods, their advantages and disadvantages. These methods are compared by applying to a PDE that model a physical phenomena in atmospheric/oceanic sciences. Several issues are involved in high-order solutions on a sphere for instance, suitability of a grid. I will conclude the talk with two suitable grids on a sphere.

Wright State University Main Campus Map

AL	Allyn Hall	**DP**	Dog Park, Wingerd Service	**LX**	Computer Services Library Annex	**RK**	Rike Hall	**UH**	University Hall
BS1	Biological Sciences I	**DL**	Dunbar Library, Paul Laurence	**MM**	Mathematical and Microbiological Sciences	**RSC**	Rinzler Student Sports Complex	**UP**	University Park Apartments
BS2	Biological Sciences II	**FH**	Fawcett Hall	**MS**	Medical Sciences	**RC**	Russ Engineering Center	**V**	The Village Apartments
BCH	Boston/Cedar/Hawthorn	**FB**	Fine Arts Building	**MH**	Millett Hall	**SC**	Student Success Center and Classroom Building	**VP**	Visitor Parking Booth
BL	Brehm Laboratory	**FL**	Forest Lane Apartments	**NC**	Nutter Center, Wright State	**SU**	Student Union	**WH**	White Hall (Boonshoft School of Medicine)
CC	Community Center	**G**	Garden for the Senses	**NE**	Neuroscience Engineering Collaboration Building	**SZ**	Setzer Pavilion/ Mills Morgan Center		
CM	Campus Ministry Center	**GL**	Geology Field Equipment Base	**OMP**	Oak/Maple/Pine	**TV**	Television Center		
CS	Campus Services Building	**HH**	Hamilton Hall	**OH**	Oelman Hall	**TS**	Transportation Services Center		
CD	Child Development Center	**HC**	Honors Community	**PB**	Wright State Physicians Health Center				
CP	College Park Apartments	**HS**	Health Sciences						
CA	Creative Arts Center	**JC**	Joshi Research Center						
DG	Diggs Laboratory	**LJH**	Laurel/Jacob/Hickory