Midwest Numerical Analysis Day 2017

Saturday, April 22, 2017 from 8:00 am – 6:00 pm

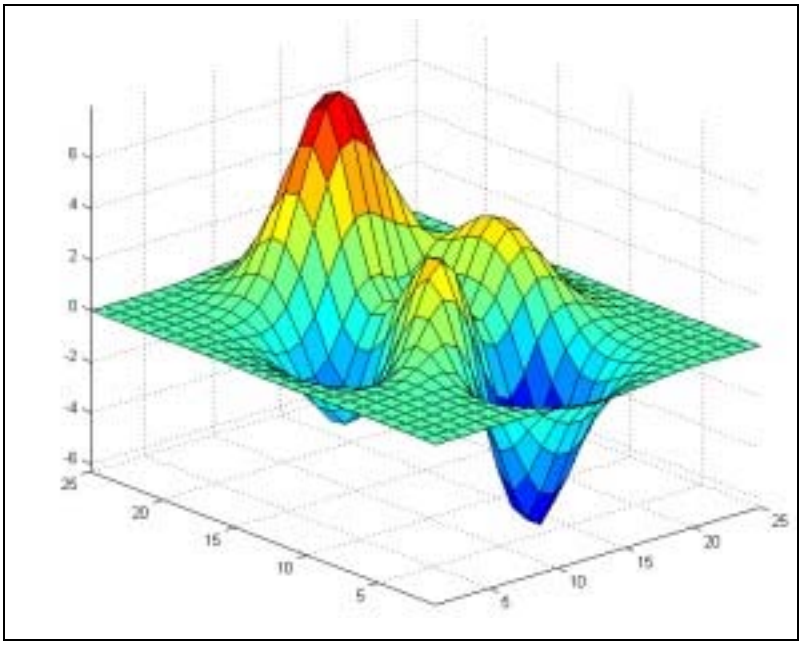
The meeting takes place at the Milo Bail Student Center

Dodge Room 302 (Third floor)

University of Nebraska at Omaha

6001 Dodge Street, Omaha, NE, 68182

Organizer: Mahboub Baccouch (mbaccouch@unomaha.edu)



The purpose of this conference is to provide a forum for researchers at all stages of their careers, mainly from the Midwest, to exchange ideas in numerical analysis, scientific computing and related application areas.

Sponsored by: Department of mathematics, University of Nebraska at Omaha.

Announcements

Welcome to UNO!

The Midwest Numerical Analysis Day (MWNADay) is a forum for researchers at all stages of their careers, mainly from the Midwest, to exchange ideas in numerical analysis, scientific computing and related application areas. Participation of graduate students is strongly encouraged. The conference has a rich history and has run for more than 20 years.

The 2017 MWNADay Conference will be held at the University of Nebraska at Omaha, April 22, 2017. Details regarding this meeting can be found on the MWNADay web page

http://people.uwm.edu/mwnaday/

When: Saturday, April 22, 2017, from 8:00am to 6:00pm.

Where: Milo Bail Student Center (3rd floor), Dodge Room 302, University of Nebraska at Omaha, 6001 Dodge Street, Omaha, NE, 68182.

Organizer: Prof. Mahboub Baccouch, Associate Professor, Department of Mathematics, University of Nebraska at Omaha, mbaccouch@unomaha.edu

Sponsor: The conference is sponsored by the department of mathematics, University of Nebraska at Omaha.

Parking: Parking for MWNADay 2017 will be in Lot D, E, F (see attached parking map). No permits are required.

Food: Refreshments (coffee and snacks) and lunch boxes will be provided with no charge.

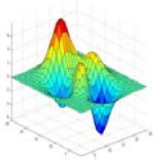
- Breakfast: Refreshment at registration from 8:00 am-8:25 am
- Lunch: We offer free lunch boxes from 12:50-1:50 pm.
- Coffee breaks: coffee and snacks are provided from 10:15-10:30 am and 3:40-4:00pm.

Wi-Fi: UNO offer free guest Wi-Fi "UNOGuest". No password is needed. You may also use "eduroam".

Computers: All presentation rooms are equipped with computers and projectors. You may also use your own laptop for presentation. However, we prefer using the computer available in the room for all presentations. Please copy your presentation on a Flash drive and preload your talk before session starts.

Travel: The closest airport is Eppley Airfield airport. Address: 4501 Abbott Dr, Omaha, NE 68110. It is 7.5 miles from the conference, 15 min driving.

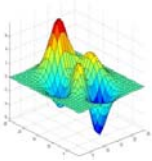
Lodging: The closest hotel is Sonesta ES Suites Omaha (3-star hotel). Address: 6990 Dodge St, Omaha, NE 68132. Phone: (402) 553-8898. It is 0.6 miles from the conference, 2 min driving Price: $84 per night. Code Group: **0422MIDWES.** Other options are listed on the 2017 MWNADay webpage.



Conference Schedule

April 22, 2017, 8:00am-6:00pm

Building: Milo Bail Student Center (MBSC), Dodge Room 302 (3rd floor)	
8:00 – 8:25 am	**Registration and Refreshments (3rd Floor Atrium):** Check-in/Name badge and conference handouts pick-up
8:25 – 8:30 am	**Welcome by Prof. Jim Rogers (Mathematics Department Chair), Dodge Room 302**
8:30 – 9:20 am	**Plenary Talk 1: Slimane Adjerid, Virginia Tech,** High Order Immersed Galerkin Methods for Interface Problems
9:25 – 10:15 am	**Plenary Talk 2: Jue Yan, Iowa State University** Recent developments on direct discontinuous Galerkin methods
10:15–10:30 am	**Coffee break (3rd Floor Atrium)**
10:30–12: 50 pm	**Contributed Talk Session I (Dodge Room 302)**
12:50 – 1:50 pm	**Lunch break (3rd Floor Atrium)**
1:50 – 2:40 pm	**Plenary Talk 3: Thomas Lewis, University of North Carolina at Greensboro** Finite Difference Methods for Approximating Fully Nonlinear Partial Differential Equations
2:45 – 3:35 pm	**Plenary Talk 4: Dexuan Xie, University of Wisconsin-Milwaukee** Recent Advances in Protein Electrostatic Modeling and Fast Finite Element Solvers
3:40 – 4:00 pm	**Coffee break (3rd Floor Atrium)**
4:00 – 6:00 pm	**Contributed Talk Session II (Dodge Room 302)**



Contributed Talk Session I, 10:30 – 12:50 pm

All presenters please preload your talk before session starts.

Dodge Room 302		
Time	**Speaker**	**Title**
10:30-10:50 am	Zhonggang Zeng, Northeastern Illinois University	Intuitive and efficient software design for numerical computation
10:50-11:10 am	Hailiang Liu, Iowa State University	A free energy satisfying DG method for Poisson--Nernst-Planck systems
11:10-11:30 am	Xiaoming He, Missouri University of Science and Technology	Dual-porosity- Stokes model and finite element method for coupling dual-porosity flow and free flow
11:30-11:50 am	Yangwen Zhang, Missouri University of Science and Technology	HDG-POD reduced models for convection dominated convection-diffusion-reaction equations
11:50-12:10 pm	Christopher Goodrich, Creighton Preparatory School	Monotonicity and Convexity Results for Discrete Fractional Operators
12:10-12:30 pm	Scott Gensler, PhD Student, University of Nebraska-Lincoln	Discrete Fractional Difference Equations
12:30-12:50 pm	Areeba Ikram, University of Nebraska-Lincoln	Lyapunov-Type Inequalities for Boundary Value Problems involving a Fractional Self-Adjoint Difference Equation

Contributed Talk Session II, 4:00 – 6:00 pm

All presenters please preload your talk before session starts.

Dodge Room 302		
Time	**Speaker**	**Title**
4:00- 4:20 pm	Peimeng Yin, Iowa State University	Error estimates for the Iterative Discontinuous Galerkin method to the nonlinear Poisson-Boltzmann equation
4:20-4:40 pm	Chengxin Qiu, Missouri University of Science and Technology	A Multi-Physics Domain Decomposition Method for Navier-Stokes-Darcy Model
4:40-5:00 pm	Avary Kolasinski, University of Kansas	A new functional for variational mesh generation and adaptation based on equidistribution and alignment
5:00-5:20 pm	Yufei Yu, University of Kansas	Selection of the regularization parameter in the Ambrosio-Tortorelli approximation of the Mumford-Shah functional for image segmentation
5:20-5:40 pm	Zhang Fei, Petroleum Engineering at China University of Petroleum Beijing	A study on moving mesh finite element solution of the phase-field models for brittle fracture
5:40-6:00 pm	Dongmi Luo, Xiamen University	A quasi-Lagrangian moving mesh discontinuous Galerkin method for hyperbolic conservation laws

Plenary Speakers and Abstracts

Plenary Speaker 1, 8:30 – 9:20 am, Dodge Room 302

Slimane Adjerid, Professor, Department of Mathematics, Virginia Tech
adjerids@math.vt.edu

Brief Bio: Slimane Adjerid is a professor of mathematics at Virginia Tech. He received his Ph.D. (1985) and M.Sc. (1982) degree in mathematics from Rensselaer Polytechnic Institute and his B.Sc. from Houari Boumedienne University of Sciences and Technology, Algeria. His area of expertise is numerical methods for solving partial differential equations originating from science and engineering.

Title: High Order Immersed Galerkin Methods for Interface Problems.

Abstract: We introduce and motivate the immersed finite element approach for solving interface problems modeled by partial differential equations with discontinuous coefficients. A brief historical review of immersed finite element methods will be presented. We will show how to construct higher-order immersed finite element spaces and weak Galerkin formulations for high accuracy computations. We will present computational results for several applications from acoustics, fluid dynamics and conclude with a list of open questions and future research projects.

Plenary Speaker 2, 9:25 – 10:15 am, Dodge Room 302

Jue Yan, Associate Professor, Department of Mathematics, Iowa State University, jyan@iastate.edu

Brief Bio: Jue Yan received her Ph.D. in 2002 from Brown University. She joined the faculty at ISU in 2006. Her research focuses on Fluid Dynamics, Numerical Analysis, and Partial Differential Equations

Title: Recent developments on direct discontinuous Galerkin methods

Abstract: We first introduce the direct discontinuous Galerkin (DDG) method and its variations, namely the DDGIC and symmetric DDG methods. Compared to the leading diffusion solver the interior penalty method (SIPG), we find out our diffusion solver the DDG methods have many advantages. While the SIPG method needs polynomial degree dependent large enough penalty coefficient to stabilize the scheme, numerically we observe small constant penalty coefficient is enough for the DDGIC method to obtain optimal convergence. Under the topic of maximum principle, DDG methods numerical solution can be proved to satisfy strict maximum principle even on unstructured triangular meshes with at least third order of accuracy. Recently we develop DDG methods to solve Keller-Segel Chemotaxis equations. Different to available numerical methods in literature, we introduce no extra variable to approximate the chemical density gradients and we solve the system directly. With Pk polynomial approximations, we observe no order loss for the density variable. The reason behind is that the DDGIC or the symmetric DDG methods have the hidden super convergence property on its approximation to the solution gradients. With Fourier (Von Neumann) analysis technique, we prove the DDG solution's spatial derivative is super convergent with at least (k+1)th order under moment format or in the weak sense. Notice that we do not have super convergence for the SIPG method. We show the cell density approximations are strictly positive with at least third order of accuracy. Blow up features are captured well for the density profile of the Keller-Segel chemotaxis model.

Plenary Speaker 3, 1:50 – 2:40 pm, Dodge Room 302

Thomas Lewis, Assistant Professor, Department of Mathematics and Statistics, University of North Carolina at Greensboro (UNCG), tllewis3@uncg.edu

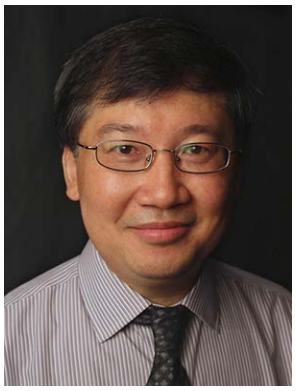
Brief Bio: Dr. Lewis earned a Ph.D. in 2013 from the University of Tennessee in Knoxville, and he joined the faculty at UNCG the same year. His research focuses on numerical PDEs and applied mathematics.

Title: Finite Difference Methods for Approximating Fully Nonlinear Partial Differential Equations

Abstract: We introduce a new narrow-stencil finite difference (FD) method for approximating the viscosity solution to second order fully nonlinear elliptic partial differential equations (PDEs). Historically, monotone FD methods that require wide-stencils are used for fully nonlinear second-order problems. The new FD method will use a stabilization technique that allows for narrow-stencils. The concept of viscosity solution theory for fully nonlinear PDEs will be introduced, and the new FD method will be motivated using approximation theory for first order Hamilton-Jacobi equations. The proposed method has applications to the Monge-Ampere equation and the Hamilton-Jacobi-Bellman equation. The new stabilization technique also has applications to designing higher-order FD methods for fully nonlinear first order PDEs. This talk is based on recent joint works with Xiaobing Feng at the University of Tennessee and Chiu-Yen Kao at Claremont McKenna College.

Plenary Speaker 4, 2:45 – 3:35 pm, Dodge Room 302

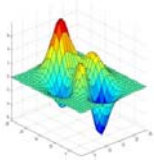
Dexuan Xie, Professor, Department of Mathematical Sciences, University of Wisconsin-Milwaukee, dxie@uwm.edu



Brief Bio: Dexuan Xie is a professor at the University of Wisconsin-Milwaukee. He received his PhD in Applied Mathematics from the University of Houston in 1995. His research interests include Numerical Analysis, Computational Mathematics, Mathematical Biology, numerical optimizations, and high performance scientific computing

Title: Recent Advances in Protein Electrostatic Modeling and Fast Finite Element Solvers

Abstract: Calculation of electrostatics for a protein (or other biomolecules) in an ionic solvent is a fundamental task in structural biology, computational biochemistry, biophysics, and mathematical biology. The Poisson-Boltzmann equation (PBE) is one commonly used dielectric continuum model for such calculation. It has been applied to protein study, rational drug design, and many other bioengineering applications. To reflect polarization correlation among water molecules and ionic size effects, size modified PBE, nonlocal PBE, and Poisson-Fermi models have been developed as variants of PBE. In this talk, I will report the recent advances that we made on these new models and their fast finite element solvers. I will also introduce our new SMPBS (Size Modified Poisson-Boltzmann Solvers) web server (smpbs.math.uwm.edu), which was published on the Journal of Computational Chemistry in the last month. SMPBS will be demonstrated as a useful tool for teaching numerical solution of nonlinear elliptic boundary value problems. Our research projects were partially supported by the National Science Foundation, USA, through grants DMS-0921004 and DMS-1226259.



Contributed Talks (Abstracts)

Title: Intuitive and efficient software design for numerical computation
Speaker: Zhonggang Zeng, Professor, Northeastern Illinois University, z-zeng@neiu.edu

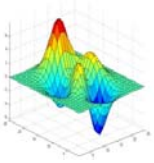
Abstract: Ultimately, numerical algorithms need to be implemented as software tools for practical scientific computing. It occurs often in research and classroom teaching when a particular linear or nonlinear equation needs to be solved only once but the technicalities are daunting. In such cases, the efficiency of an algorithm itself is secondary to how fast its implementation can be set up to produce immediate results. In this talk, we shall discuss the software designing issues for numerical computation on the importance of intuitiveness and the efficiency of the interface. We shall present our attempt to address those issues in our recent innovations in the software toolbox NAClab for numerical algebraic computation.

Title: A free energy satisfying DG method for Poisson--Nernst-Planck systems
Speaker: Hailiang Liu, Professor, Department of Mathematics, Iowa State University, hliu@iastate.edu

Abstract: We design an arbitrary-order free energy satisfying discontinuous Galerkin (DG) method for solving time-dependent Poisson-Nernst-Planck systems. The schemes are shown to satisfy the corresponding discrete free energy dissipation law and preserve the equilibrium states. Numerical examples are presented to demonstrate the high resolution of the numerical algorithm and illustrate the proven properties of mass conservation, free energy dissipation, as well as the preservation of steady states. This is a joint work with Zhongming Wang (Florida International University).

Title: Dual-porosity- Stokes model and finite element method for coupling dual-porosity flow and free flow
Speaker: Xiaoming He, Associate Professor, Missouri University of Science and Technology, hex@mst.edu

Abstract: We propose and numerically solve a new model considering confined flow in dual-porosity media coupled with free flow in embedded macro-fractures and conduits. Such situation arises, for example, for fluid flows in hydraulic fractured tight/shale oil/gas reservoirs. The flow in dual-porosity media, which consists of both matrix and micro-fractures, is described by a dual-porosity model. And the flow in the macro-fractures and conduits is governed by the Stokes equation. Then the two models are coupled through four physically valid interface conditions on the interface between dual-porosity media and macro-fractures/conduits, which play a key role in a physically faithful simulation with high accuracy. All the four interface conditions are constructed based on fundamental properties of the traditional dual-porosity model and the well-known Stokes-Darcy model. The weak formulation is derived for the proposed model and the well-posedness of the model is analyzed. A finite element semi-discretization in space is presented based on the weak formulation and four different schemes are then utilized for the full discretization. The convergence of the full discretization with backward Euler scheme is analyzed. Four numerical experiments are presented to validate the proposed model and demonstrate the features of both the model and numerical method, such as the optimal convergence rate of the numerical solution, the detail flow characteristics around macro-fractures and conduits, and the applicability to the real world problems.



Title: HDG-POD reduced models for convection dominated convection-diffusion-reaction equations.
Speaker: Yangwen Zhang, PhD student, Missouri University of Science and Technology, ywzfg4@mst.edu

Abstract: We propose a new hybrid discontinuous Galerkin reduced order modeling technique based on proper orthogonal decomposition (POD). For convection dominated problems, it is known that the standard CG-POD causes strong nonphysical oscillations; we demonstrate HDG-POD gives much better performance. Specifically, we investigate CG-POD constructed using both CG data and HDG data, and also HDG-POD with HDG data. Numerical results shows HDG-POD with HDG data works better than the other two approaches.

Title: Monotonicity and Convexity Results for Discrete Fractional Operators
Speaker: Christopher Goodrich, Teacher at Creighton Preparatory School and part time instructor at the University of Nebraska at Omaha, cgoodrich@uri.edu

Abstract: I will discuss the connections between the sign of a discrete fractional operator acting on a map f and the associated monotonicity and convexity of the map f. Some representative results in the area will be discussed, and, especially, the sharpness of the results will be mentioned. Finally, I will compare and contrast these results with those known for non-fractional difference operators, and it will be shown that in the fractional case there is considerably greater richness to the results and underlying mathematical complexity.

Title: Discrete Fractional Difference Equations
Speaker: Scott Gensler, PhD Student, University of Nebraska-Lincoln, scott.gensler@huskers.unl.edu

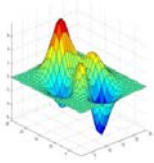
Abstract: We introduce and motivate a difference calculus for discrete domains, to include fractional difference operators on functions with such domains. These operators generalize the notion of an nth order difference and allow us to talk about half order or π-th order differences. With a fractional difference in hand, we then briefly discuss solving both initial and boundary value problems involving fractional difference equations using Cauchy and Green's functions. Finally, we will look at some recent developments in the field where research has yielded some interesting results.

Title: Lyapunov-Type Inequalities for Boundary Value Problems involving a Fractional Self-Adjoint Difference Equation
Speaker: Areeba Ikram, PhD student, University of Nebraska-Lincoln, areeba@huskers.unl.edu

Abstract: We will present background for the nabla fractional calculus. We will then discuss results about Green's functions for several boundary value problems involving a Caputo fractional self-adjoint difference equation. Finally, we will show Lyapunov-type inequalities for these boundary value problems.

Title: Error estimates for the Iterative Discontinuous Galerkin method to the nonlinear Poisson-Boltzmann equation
Speaker: Peimeng Yin, PhD student, Iowa State University, pemyin@iastate.edu

Abstract: I will present the error estimate for the iterative discontinuous Galerkin (IDG) method introduced in [P. Yin, Y. Huang and H. Liu. *Commun. Comput. Phys.* 16: 491--515, 2014] to the nonlinear Poisson-Boltzmann equation. The total error includes both the iteration error and the discretization error of the direct DG method to linear elliptic equations. For the DDG method, the energy error is obtained by a constructive approach through an explicit global projection satisfying interface



conditions dictated by the choice of numerical fluxes. The L^2 error of order $O(h^{m+1})$ for polynomials of degree m is further recovered. The bounding constant is also shown to be independent of the iteration times. Numerical tests are given to validate the established convergence theory.

Title: A Multi-Physics Domain Decomposition Method for Navier-Stokes-Darcy Model
Speaker: Chengxin Qiu, PhD student, Missouri University of Science and Technology, cqrg7@mst.edu

Abstract: In a karst aquifer, free flow and porous media flow are tightly coupled together, for which the Navier-Stokes-Darcy model has higher fidelity than either the Darcy or Navier-Stokes systems on their own. The Stokes-Darcy type model has attracted significant attention in the past ten years. However, coupling the two constituent models leads to a very complex system. This presentation discusses a multi-physics domain decomposition method for solving the Navier-Stokes-Darcy system. Computational results are presented to illustrate the features of the proposed method.

Title: A new functional for variational mesh generation and adaptation based on equidistribution and alignment
Speaker: Avary Kolasinski, PhD student, University of Kansas, avaryk@ku.edu

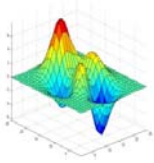
Abstract: We will introduce a new meshing functional for variational mesh generation and adaptation with minimal parameters based on the equidistribution and alignment conditions. We will discuss the theoretical properties of this functional including its coercivity and the nonsingularity and existence of limiting meshes. We will present a comparative numerical study of this new functional with one well known functional, which is also based on the equidistribution and alignment conditions.

Title: Selection of the regularization parameter in the Ambrosio-Tortorelli approximation of the Mumford-Shah functional for image segmentation
Speaker: Yufei Yu, PhD student, University of Kansas, y920y782@ku.edu

Abstract: Image segmentation is a process to find the boundary sets of a given image. In 1989, Mumford and Shah propose a functional whose minimization leads to optimal segmentation. However, the Mumford-Shah functional is inconvenient to carry out in practical computation due to its lack in regularity. Ambrosio and Tortorelli (1992) propose a phase-field regularization of the functional and show that it gamma-converges to the original functional as the regularization parameter goes to zero. On the other hand, in actual computation, people find that the regularization parameter has physical dimension and its choice can result in very different results. Even worse, the functional is found not to gamma-converge to the Mumford-Shah functional in some cases. In this talk we will present some theoretical explanations for this behavior. Moreover, we will present a strategy for choosing the regularization parameter for better segmentation effects. Numerical examples will be presented.

Title: A study on moving mesh finite element solution of the phase-field models for brittle fracture
Speaker: Zhang Fei,PhD student, Petroleum Engineering at China University of Petroleum Beijing, fzhang_cup@outlook.com

Abstract: In this talk, we present a moving mesh method for the numerical simulation of two dimensional fracture propagation in elastic media using the phase-field approach. A continuous phase-field variable is introduced to describe the unbroken or broken status of the material, which can model fractures without explicitly tracking discontinuous displacement fields. It has the advantages of being able to handle complex cracks, crack propagation, and creation of new cracks more easily. To avoid the requirement of fine meshes throughout the domain, we apply a moving mesh method that relocates the mesh nodes automatically to capture the fracture propagation. The method is based on the moving mesh



partial differential equation (MMPDE) approach. Moreover, we employ a new implementation of the MMPDE method, which has several advantages over the traditional one, including its simplicity in formulation, ease to program, and robustness in the sense that the mesh is guaranteed to stay nonsingular. The numerical results for 2D fracture propagation under quasi-static loads are presented, and the effectiveness of the moving mesh method together with phase-field model for fracture simulation is demonstrated.

Title: A quasi-Lagrangian moving mesh discontinuous Galerkin method for hyperbolic conservation laws
Speaker: Dongmi Luo, PhD Student, Xiamen University, dongmiluo@outlook.com

Abstract: A moving mesh discontinuous Galerkin method is developed for the numerical solution of hyperbolic conservation laws. The method is a combination of the discontinuous Galerkin method and the mesh movement strategy which is based on the moving mesh partial differential equation approach and moves the mesh continuously in time and orderly in space using a system of mesh partial differential equations. It not only can achieve the high order in smooth regions, but also capture shocks well in non-smooth regions. For the same number of grid points, the numerical solution with the moving mesh method is much better than ones with the uniform mesh method. Numerical examples are presented to show the accuracy and shock-capturing features of the method.

Other Graduate and Undergraduate Participants
Wunsch Donnie, Undergraduate student, Missouri University of Science and Technology, donaldcwunsch@gmail.com
Liangya Pi, Ggraduate student, Missouri University of Science and Technology, lpp4f@mst.edu
Wumaier Maimaitiyiming, graduate student, Iowa State University, wumaierm@iastate.edu
Jinjin Yang, Undergraduate student, Missouri University of Science and Technology

The Midwest Numerical Analysis Day 2018

The Midwest Numerical Analysis Day 2018 will take place at the University of Kansas. This event will be organized by Prof. Weizhang Huang, Department of Mathematics, University of Kansas, whuang@ku.edu

Future meetings

We are still looking for hosts for the Midwest Numerical Analysis Day 2019. Please contact any member of the Steering Committee (http://people.uwm.edu/mwnaday/) if you are interested in hosting a future meeting.

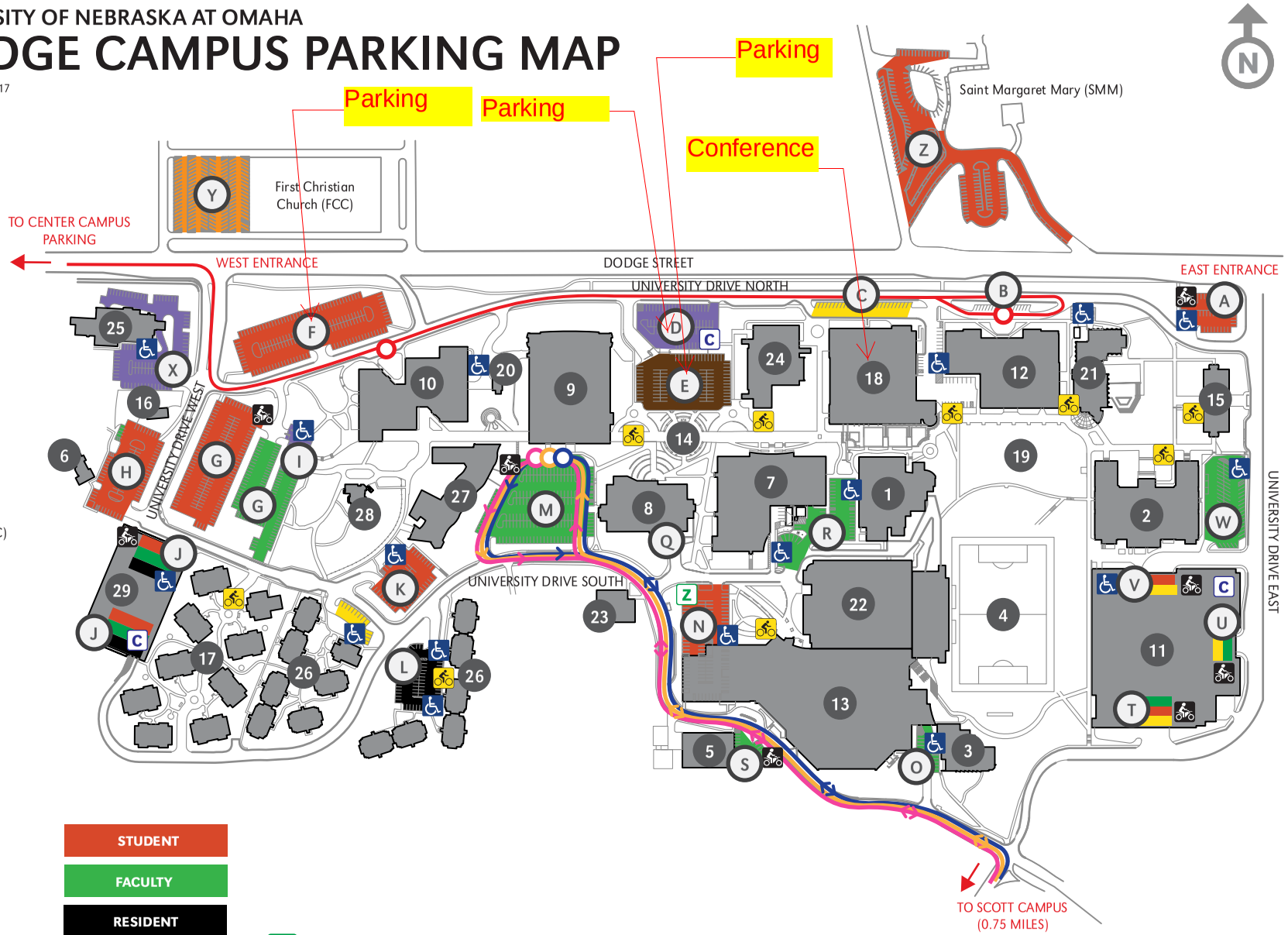
Thank you!

Thank you everyone for attending and participating. The organizer would like to thank each one of our speakers, participants, and sponsors. We could not make this happen without any of you. We hope everyone enjoyed the conference, and we encourage you to take part in this event in the upcoming years by organizing, presenting, or attending. We hope to see you next time.

UNIVERSITY OF NEBRASKA AT OMAHA

DODGE CAMPUS PARKING MAP

UPDATED 01/13/17



1 Allwine Hall (AH)
2 Arts & Sciences Hall (ASH)
3 Biomechanics Research Building (BRB)
4 Caniglia Field (CF)
5 Central Utilities Plant (CUP)
6 Child Care Center (CCC)
7 College of Public Affairs & Community Service (CPACS)
8 Barbara Weitz Community Engagement Center (Weitz CEC)
9 Criss Library (CL)
10 Durham Science Center (DSC)
11 East Parking Garage (EPG)
12 Eppley Administration Building (EAB)
13 Health, Physical Education & Recreation (HPER)
14 Henningson Memorial Campanile (HMC) (clock tower)
15 Kayser Hall (KH)
16 Landscape Services (LS)
17 Maverick Village (MV)
18 Milo Bail Student Center (MBSC)
19 Pep Bowl (open space)
20 Resource Conservation & Recovery Area (RCRA)
21 Roskens Hall (RH)
22 Sapp Fieldhouse (SFH)
23 Sculpture & Ceramics Studio (SCS)
24 Strauss Performing Arts Center (SPAC)
25 Thompson Alumni Center (TAC)
26 University Village (UV)
27 Weber Fine Arts Building (WFAB)
28 Welcome Center (WC)
29 West Parking Garage (WPG)

DODGE/SCOTT CAMPUS SHUTTLE

SCOTT RESIDENT EXPRESS SHUTTLE

DODGE/CENTER CAMPUS SHUTTE

NEWMAN CENTER/DODGE CAMPUS SHUTTLE

STUDENT
FACULTY
RESIDENT
CEC VISITOR
VISITOR
MULTIPURPOSE
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CLOSED LOTS

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HANDICAP PARKING
BICYCLE RACK
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