Abstract Book of EASIAM 2018

Plenary Talk (23, June)

Room 213 (Building No.2)

Title: Modeling by networks
Speaker: Martin Golubitsky (Ohio State University)
Abstract: Networks consist of nodes and unidirectional arrows and encode systems of differential equations. The arrows indicate which nodes are coupled to which. The nodes and arrows can be annotated to indicate which nodes are identical and which kinds of coupling are identical. We suggest that these types of annotated networks should be thought of as modeling assumptions. Mathematically we ask the question: What kinds of dynamics are typical in the class of differential equations that are associated to a given network? This project on network dynamics is joint work with Ian Stewart.
What distinguishes a coupled network of differential equations from a large system of differential equations in the desire to keep track of the output from each node individually. It is then possible to compare signals from different nodes (synchrony) and to keep track of singularities in individual nodes. This talk will illustrate these ideas with two biological applications: binocular rivalry (based on symmetry in Wilson networks) and homeostasis (in gene regulatory networks).
In binocular rivalry subjects are shown two different images - one to the right eye and one to the left eye. Typically, the subject perceives alternation between the two images. Sometimes, subjects perceive a more complicated set of images. We show how network modeling can help predict the set of possible percepts.
Homeostasis occurs when a certain feature of a family of equilibria remains approximately constant as an input parameter is varied. Again, we show how network modeling leads naturally to homeostasis and particularly to the possible existence of " housekeeper genes " in gene regulatory networks. Housekeeper genes are ones that keep the production of their associated proteins approximately constant and such genes are thought to be important in the regulation of gene networks.

Invited Talks

Room 213 (Building No.2)

Invited Talk 1 (23, June)

Title: Topological data analysis and materials science
Speaker: Yasuaki Hiraoka (Kyoto University / RIKEN)
Abstract: Topological data analysis is an emerging concept in applied mathematics in which we characterize " shape of data " using topological methods. In particular, the persistent homology and its persistence diagrams are nowadays applied to a wide variety of scientific and engineering problems including materials science, life science and social networks etc. In my talk, I will give a survey of these concepts both from mathematics and applications in materials science. If time is allowed, I will show several future challenges which deepen the mathematical understandings and possible applications.

Invited Talk 2 (23, June)

Title: Rare event studies in systems biology
Speaker: Tiejun Li (Peking University)
Abstract: As a research field to overcome the multiple time scale issues in noise induced transitions, the rare event study has attracted much attention in recent years. In this talk, I will review some recent results on the rare event study in systems biology done by our group. In theoretical aspect, I will introduce the so-called two-scale large deviation theory for chemical kinetic processes motivated by biophysical study for genetic switches. This will induce to different mean field limits and different chemical Langevin approximations when the involved two timescales has different magnitudes. I will also mention the mathematical theory of energy landscapes widely used in systems biology. In the application aspect, I will mention the rare events and energy landscape constructions for genetic switch, budding yeast cell cycle and S-phase checkpoint activation mechanism related to the most recent biological experiments.

Invited Talk 3 (24, June)

Title: Phase retrieval algorithms with random masks
Speaker: Pengwen Chen (National Chung Hsing University)
Abstract: Phase retrieval aims to recover one unknown vector from its magnitude measurements, e.g., coherent diffractive imaging, where phase information is

missing. The recovery of phase information can be formulated as one minimization problem subject to a non convex high-dimensional torus set. In theory, uniqueness of solutions can be obtained under random masks. The introduction of random masks actually breaks the symmetry of Fourier matrices and creates spectral gap for the local convergence of many phase retrieval algorithms, including alternative projection methods and Fourier Douglas-Rachford algorithms. The spectral gap is related to the local convergence rate. In this talk, we shall present the convergence analysis as well as their fixed point property.
On the other hand, these alternative algorithms still could fail to generate the global solution effectively. To alleviate the stagnation of possible local solutions, we propose one null vector method as an initialization method for phase retrieval algorithms The method is motivated by the following observation: Gaussian random vectors in high dimensional space are always nearly orthogonal to each other. According to magnitude data, we can construct one sub-matrix assembled from the sensing vectors nearly orthogonal to the unknown vector. One candidate for the initialization vector is given by the singular vector of the sub-matrix corresponding to the least singular value. Thanks to isometric Fourier matrices, this vector coincides with the dominant singular vector of the complement sub-matrix. Empirical studies (non-ptychography and ptychography) indicate that its incredible closeness to the unknown vector, compared with other existing methods. In this talk, we present one nonasymptotic error bound in the case of random complex Gaussian matrices, which sheds some light on its superior performance in the Fourier coherent diffractive case with random masks.
If time permitted, we shall discuss the performance of these iterative algorithms on ptychographic Fresnel data. We shall show that the spectral gap becomes very small for certain Fresnel numbers. Actually, we do observe poor reconstruction occurs under these Fresnel numbers.
This is a joint work with Albert Fannjiang(UC Davis) and Giren Liu (NCKU).

Invited Talk 4 (24, June)

Title: Highly efficient semismooth Newton augmented Lagrangian methods for solving lasso problems
Speaker: Kim Chuan Toh (National University of Singapore)
Abstract: In this talk, we present a fast and robust algorithmic framework SSNAL for solving large scale lasso problems. SSNAL is a semismooth Newton based augmented Lagrangian algorithmic framework. We show that for lasso problems, both the primal and dual iteration sequences generated by SSNAL possess a remarkably fast linear convergence rate, which can even be superlinear asymptotically. We also conduct variational analysis to analyse the second order sparsity structure

of the underlying problems and proposed efficient numerical techniques to exploit the structure in our algorithm. Numerical comparison between our approach and state-of-the-art solvers on real data sets are presented to demonstrate the high efficiency and robustness of our proposed algorithm in solving difficult large scale lasso problems. For example, for a problem with over 4 million features and 16000 samples, SSNAL can solve it in 20 seconds, while the best alternative solver took 2400 seconds. This talk is based on joint work with Professor Sun Defeng and Dr Li Xudong.

Room AD (Building No.6)

Invited Talk 5 (25, June)

Title: Solving multi-linear systems with $\mathcal{M}$-tensors
Speaker: Yimin Wei (Fudan University)
Abstract: This talk is concerned with solving some structured multi-linear systems, especially focusing on the equations whose coefficient tensors are $\mathcal{M}$-tensors, or called $\mathcal{M}$-equations for short. We prove that a nonsingular $\mathcal{M}$-equation with a positive right-hand side always has a unique positive solution. Several iterative algorithms are proposed for solving multi-linear nonsingular $\mathcal{M}$-equations, generalizing the classical iterative methods and the Newton method for linear systems. Furthermore, we apply the $\mathcal{M}$-equations to some nonlinear differential equations and the inverse iteration for spectral radii of nonnegative tensors.

Invited Talk 6 (25, June)

Title: New analysis on Galerkin FEMs for nonlinear parabolic PDEs
Speaker: Weiwei Sun (City University of Hong Kong)
Abstract: Linearized (semi)-implicit schemes are the most commonly-used approximations in numerical solution of nonlinear parabolic equations since at each time step, the schemes only require the solution of a linear system. However the time step restriction condition of schemes is always a key issue in analysis and computation. For many nonlinear parabolic systems, error analysis of Galerkin type finite element methods with linearized semi-implicit schemes in the time direction is established mostly under certain time step condition $\tau \leq h^\alpha$ for some $\alpha > 0$. Such a time-step condition may result in the use of a very small time step and extremely time-consuming in practical computations. The problem becomes more serious when a non-uniform mesh or adaptive meshing is used.
In this talk, we introduce a new approach to unconditional error analysis of linearized semi-implicit Galerkin FEMs for a large class of nonlinear parabolic PDEs.

Student Paper Prize Session (23, June)

Room 213 (Building No.2)

Title: Unconditional convergence in maximum-norm of a second-order linearized scheme for a time-fractional Burgers-type equation
Speaker: Pin Lyu (University of Macau)
Abstract: We study linearized finite difference scheme for a time-fractional Burgers-type equation in this paper. A linearized scheme with second-order accuracy in time and space is proposed. The advantage of the scheme is that iterative method is not required for finding the approximated solutions. Nonlinearity involving derivatives causes difficulties in analysis. By refined estimates of our previous study, we show that the scheme unconditionally converges with second-order in maximum-norm. The theoretical results are justified by numerical tests.

Title: Point vortex dynamics on a toroidal surface
Speaker: Yuuki Shimizu (Kyoto University)
Abstract: Vortex interactions play an important role in the qualitatively understanding of two-dimensional incompressible and inviscid flow evolutions. We assume the vorticity is discretized with a finite number of delta-functions, called point vortices. Thanks to the invariance of the vorticity along the orbit of a fluid particle, the evolution of the vorticity can be described in terms of interactions between those point vortices. The dynamics of point vortices has been investigated well in unbounded planes with boundaries as well as on a sphere owing to their physical relevance. On the other hand, it is of a theoretical interest to investigate how geometric structures of curved surfaces gives rise to different vortex interactions that are not observed in vortex dynamics in the plane and on the sphere. In this talk, we compare the dynamics of point vortices on a toroidal surface with that in a plane, on a sphere and a hyperbolic disc and consider how is the dynamics affected by shapes of these surfaces. This is a joint work with Takashi Sakajo at Kyoto University.

Title: An efficient iterative thresholding method for image segmentation
Speaker: Dong Wang (The Hong Kong University of Science and Technology)
Abstract: We proposed an efficient iterative thresholding method for multi-phase image segmenta-tion. The algorithm is based on minimizing piecewise constant

Mumford-Shah functional in which the contour length (or perimeter) is approximated by a non-local multi-phase energy. The minimization problem is solved by an iterative method. Each iteration consists of computing simple convolutions followed by a thresholding step. The algorithm is easy to implement and has the optimal complexity $\mathrm{O}(N \log N)$ per iteration. We also show that the iterative algorithm has the total energy decaying property. We present some numerical results to show the efficiency of our method.

Parallel Sessions

Room AD (Building No.6)

Parallel Session 1 (23, June)

Title: Convergence and stability of the MAC scheme for Stokes/Darcy coupling problems based on finite difference methods
Speaker: Ming-Cheng Shiue (National Chiao Tung University)
Author(s): Ming-Cheng Shiue, Kian Chuan Ong and Ming-Chih Lai
Abstract: In this talk, to begin with, Stokes/Darcy coupling flows which arise from physical models such as biology, engineering and geophysical fluid dynamics are considered. In the literature, there are many numerical methods related to finite element methods applied to solve this coupling problem. Unlike finite element methods, due to that there is lack of natural variational formulation, in general, the analysis of the scheme based on finite difference methods becomes complicate. In this work, the MAC scheme for this coupling problem based on finite difference methods is used. Convergence and stability of the scheme will be presented. The second part will present the development of numerical schemes for Navier-Stokes and Darcy coupling problems based on projection methods. Numerical simulations demonstrate the results which match the case of only Navier-Stokes equations that also are computed using the projection method. These are joint research works with Ming-Chih Lai and Kian Chuan Ong.
Keywords: Stokes-Darcy, Mac scheme, finite difference, convergence, stability

Title: Numerical and mathematical analysis for the blow-up curve of solutions to 1-dimensional nonlinear wave equations
Speaker: Takiko Sasaki (Meiji University)
Author(s): Takiko Sasaki, Tetsuya Ishiwata
Abstract: We study a blow-up curve for the one dimensional wave equation $\partial_t^2 u - \partial_x^2 u = 2^p |\partial_t u|^{p-1} \partial_t u$ with the Dirichlet boundary condition. The purpose of this talk is to show that the blow-up curve T satisfies that $T'(x) \to -1$ as $x \to 0+0$ (1) under the suitable initial conditions. To prove the result, we convert the equation into a first order system, and then present some numerical investigations of the blow-up curves. From the numerical results, we were able to confirm (1) holds numerically. Moreover, under some assumptions, we were also able to confirm (1) holds mathematically.
Keywords: second-order hyperbolic equations, blow-up

Title: High-order compact schemes for fractional differential equations with mixed derivatives
Speaker: Chenyang Shi (University of Macau)
Author(s): Seakweng Vong , Chenyang Shi, Pin Lyu
Abstract: In this article, we consider two-dimensional fractional subdiffusion equations with mixed derivatives. A high-order compact scheme is proposed to solve the problem. We establish a sufficient condition and show that the scheme converges with fourth order in space and second order in time under this condition.
Keywords: fractional differential equation, high-order compact scheme, mixed derivatives

Title: Numerical analysis for blow-up problems of stochastic differential equations.
Speaker: YoungChol Yang (Shibaura Institute of Technology)
Author(s): Tetsuya Ishiwata, YoungChol Yang
Abstract: We consider a blow-up problem of stochastic differential equation (SDE) $dX(t) = aX(t)^p dt + X^q dW(t)$, and its numerical approximation. P. Groisman et al show that this equation almost surely have a blow-up solution under certain conditions. Its solution and blow up time are derived as stochastic processes. In this talk, we will add a few constraints and express the solution explicitly in the form of Brownian motion by using Ito's formula. Moreover, we show that the blow-up time of solution matches the first hitting time of the Brownian motion to a specific value M, which depends only on parameter p and initial value X_0. This result makes analyzing the blow-up time simple. We also propose a new numerical method and show some numerical examples.
Keywords: blow-up, stochastic differential equation, numerical approximation

Parallel Session 2 (23, June)

Title: Research and development of STEM curriculum in high school
Speaker: Yi-Wen Su (University of Taipei)
Author(s): Yi-Wen Su, Chinghsiang Yu, Ting-mei Yu, ChunTsung Hsueh, Chia-Yen Tsai
Abstract: Science, Technology, Engineering, and Mathematics (STEM) Education has attracted the attention of the education community in response to changes in the times and education reforms. Designing STEM courses so that students can use what they have learned is therefore a topic that concerns teachers in all levels. The purpose of this study is to explore how to develop and practice STEM

courses in the high school. The researchers are teacher educator and high school teachers. The course developed by this research is IQ light, which is a course module, is coordinated between the Mathematics and Living Technology teachers. The main design concept is that mathematics teachers use magnetic constructs to allow students to explore the structure of polyhedrons. The principles of basic polyhedrons, such as Plato's polyhedron and Archimedes' polyhedron, are introduced to guide students how to think about polyhedrons using mathematical modeling and to make polyhedron lamps. Then, the living technology teacher introduced the Sketch Up 3D modeling software, which allowed students to use this software to present the concepts and clarify the structure of polyhedrons. This software was used to draw the polyhedral unit shape, and together with a laser cutting machine to combine a polyhedron ball lamp and LED light bar, connecting a USB wire by welding to produce an IQ light finished product. The finished products, completed by the students, were exhibited in the Maker Faire Taipei 2017 and were also warmly received by the public. This study explores the effectiveness of teacher cooperation and students' learning in the development of STEM curriculum, and puts forward relevant reviews and recommendations.
Keywords: STEM, IQ light, high school

Title: Global synchronization of coupled memristor-based neural networks with time delays
Speaker: Jui-Pin Tseng (National Chengchi University)
Author(s): Jui-Pin Tseng
Abstract: This talk presents an approach to establish the global synchronization of coupled multiple memristor-based neural networks with delays. The coupled networks that are considered can incorporate both the internal delay in each individual network and the transmission delay across different networks. The coupling scheme, which consists of a nonlinear term and a sign term, is rather general. Based on an iterative approach, the respective global synchronization criteria, which depend on whether a transmission delay exists, are derived respectively.
Keywords: synchronization, memristor, neural network, delay

Title: Machine-learning prediction of fluid variables from data using reservoir computation
Speaker: Kengo Nakai (The University of Tokyo)
Author(s): Kengo Nakai, Yoshitaka Saiki
Abstract: We predict both microscopic and macroscopic variables of a chaotic fluid flow using reservoir computing. In our procedure of the prediction, we assume no prior knowledge of physical model describing a fluid flow except that its

behavior is complex but deterministic. We present two ways of prediction of the complex behavior; the first called partial-prediction requires continued knowledge of partial time-series data during the prediction as well as past time-series data, while the second called full-prediction requires only past time-series data as training data. For the first case, we are able to predict long-time motion of microscopic fluid variables. For the second case, we show that the reservoir dynamics constructed from only past data of energy functions can predict the future behavior of energy functions and reproduce the energy spectrum. This implies that the obtained reservoir system constructed without the knowledge of microscopic data is equivalent to the dynamical system describing macroscopic behavior of energy functions.
Keywords: machine-learning, fluid flow

Parallel Session 3 (24, June)

Title: Regularity of solutions to the stationary transport equation with the incoming boundary data
Speaker: Daisuke Kawagoe (Inha University)
Author(s): Daisuke Kawagoe
Abstract: We consider a boundary value problem of the stationary transport equation in a bounded convex domain with the incoming boundary condition, and we obtain two results on regularity of its solutions. The first result is to describe discontinuity of the solution which arises from discontinuous points of the inoming boundary condition, and we show the exponential decay of a jump of the solution on a discontinuous point. The decay gives an idea for solving an inverse problem to determine an unknown coefficient from boundary measurements of the solution to the boundary value problem. The second one is to give a precise estimate in a two dimensional case. We obtain a $W^{1,p}$ estimate of the solution for $1 \leq p < p_m$, where p_m is a real number depending only on the shape of the domain.
Keywords:

Title: Regularity of solutions for non-uniform nonlinear elliptic equations in a heterogeneous medium
Speaker: Li-Ming Yeh (National Chiao Tung University)
Author(s): Li-Ming Yeh
Abstract: Uniform estimate for the solutions of non-uniform nonlinear elliptic equations in a heterogeneous medium is considered. The heterogeneous medium consists of a periodic connected high permeability sub-region and a periodic disconnected matrix block subset with low permeability. Let $\epsilon \in (0, 1]$ denote the

size ratio of the matrix blocks to the whole domain and let $\omega^2 \in (0,1]$ denote the permeability ratio of the disconnected matrix block subset to the connected sub-region. The $C^{0,\alpha}$ norm for $\alpha \in (0,1)$ for the nonlinear elliptic solutions in the high permeability sub-region are shown to be bounded uniformly in ω, ϵ. However, the $C^{0,\alpha}$ norm of the nonlinear elliptic solutions in the low permeability subset can only be bounded uniformly in ϵ. Relations between the sources and the variation of the solutions in the low permeability subset are also presented in this talk.
Keywords: Non-uniform nonlinear elliptic equations, heterogeneous medium, permeability ratio

Title: Hopf-pitchfork bifurcation in a reaction-diffusion system with an integral term.
Speaker: Shunsuke Kobayashi (Meiji university)
Author(s): Shunsuke Kobayashi
Abstract: We study the bifurcation structure of chaotic solution in a two-component reaction-diffusion system with an integral term in one spatial dimension. The system has the triply degenerate point at the trivial solution. Around the triply degenerate point, a three-dimensional dynamical system on the center manifold is obtained. The reduced system can be transformed into normal form for the Hopf-Pitchfork bifurcation. The truncated normal form can possess the invariant tori and the heteroclinic loop. Furthermore, the system under the non S^1-symmetric perturbation may possess a heteroclinic cycle. Numerical results for the system are presented and found to be convincing.
Keywords: reaction-diffusion system, Hopf-pitchfork bifurcation, chaos

Parallel Session 4 (24, June)

Title: Asymptotic behavior of numerical solutions for the Allen-Cahn equation with coarse meshes
Speaker: Tomoya Kemmochi (Nagoya University)
Author(s): Tomoya Kemmochi
Abstract: The Allen-Cahn equation is a semilinear parabolic equation with a small parameter $\varepsilon > 0$, which is the simplest equation of phase field models. Most parts of the domain is separated into two parts. The solution is approximately one in the one part and minus one in the other. The parameter ε describes the "width" of the interface in a sense, that is, the measure of the part where the solution is approximately zero.
We are interested in numerical computation of the Allen-Cahn equation. Since the solution has a sharp interface with the width $O(\varepsilon)$, the mesh size, which is denoted

by h, should be smaller than ε. However, of course, when h becomes smaller, then the computational cost becomes much higher. Therefore, it is important to choose appropriate mesh size h in view of both accuracy and cost.
In this talk, we consider semi-discretization in space for the Allen-Cahn equation by the finite difference method with coarse meshes. When the mesh size h is bigger than ε, the numerical computation fails as expected. Indeed, the interface does not move. We will demonstrate why this phenomenon occurs, which gives a necessary condition for the mesh size for proper computation.
Keywords: Allen-Cahn equation, numerical analysis, finite difference method

Title: Improved error estimates for finite element solutions of parabolic Dirichlet boundary control problems
Speaker: Buyang Li (Hong Kong Polytechnic University)
Author(s): Wei Gong, Buyang Li
Abstract: The parabolic Dirichlet boundary control problem and its finite element discretization are considered in convex polygonal and polyhedral domains. We improve the existing results on the regularity of the solutions by establishing and utilizing the maximal L_p-regularity of parabolic equations under inhomogeneous Dirichlet boundary conditions. Based on the proved regularity of the solutions, we prove $O(h_1 - 1/q - \varepsilon)$ convergence for the semi-discrete finite element solutions for some $q > 2$, with q depending on the maximal interior angle at the corners and edges of the domain and ε being a positive number that can be arbitrarily small.
Keywords: Dirichlet boundary control, parabolic equation, finite element method, error estimate

Title: An asymptotic-based adaptive finite element method for Kohn-Sham equation
Speaker: Yedan Shen (University of Macau)
Author(s): Yedan Shen, Yang Kuang, Guanghui Hu
Abstract: In this paper, we propose an a posteriori error estimation for Kohn-Sham equation by coarsening mesh. The error estimation is derived from the difference of the total energies on two meshes, respectively. With the help of Hardy's inequality, it is shown that our analysis works smoothly for the all-electron model for a given electronic structure. Numerical tests show that such an a posteriori error estimation works very well in the proposed h-adaptive finite element method framework. In addition, a Poisson problem is proposed to approximate the wavefunctions on the coarsened mesh for improving the efficiency of the algorithm. The effectiveness of this improvement is analyzed and numerically tested.

Keywords: electronic structure calculation, Kohn-Sham density functional theory, adaptive finite element method, ground state energy, coarsening mesh

Title: Finite element analysis for a generalized Robin boundary value problem in a smooth domain
Speaker: Takahito Kashiwabara (The University of Tokyo)
Author(s): Takahito Kashiwabara
Abstract: We consider the Poisson equation in a domain Ω, and also the Poisson equation on the boundary, which involves the Laplace-Beltrami operator. The two PDEs are then coupled through the Neumann operator (i.e., the normal derivative on the boundary). This can be viewed as a generalized Robin boundary value problem, which is related with reduced-order models to examine fluid-structure interaction. In this talk, a linear finite element approximation to this problem, assuming that Ω is a smooth domain, is studied. The main difficulty is that we need to take into account the polyhedral approximation of the curved boundary, in particular, the error caused by the approximation of the Laplace-Beltrami operator. We prove the optimal rate of convergence $O(h)$ in the H^1-norms in the domain and on the boundary, under a regularity assumption on the exact solution.
Keywords: finite element method, error estimate, Laplace-Beltrami operator

Parallel Session 5 (24, June)

Title: Unique solvability of discontinuous ODE system for confined particles motion
Speaker: Zhenxing Yang (Kanazawa University)
Author(s): Zhenxing Yang, Masato Kimura, Patrick van Meurs
Abstract: We consider a system of discontinuous ordinary differential equations which represents general motion of particles in a fixed region. Since a classical solution may not exist, we define a mild solution to the discontinuous ODE system and show the existence and uniqueness of the solution. As an application, we consider a gradient flow of an interactive particle energy of particles confined in a bounded domain. Furthermore, we show several numerical examples of this confined gradient flow system and observe how particles attach and detach from the boundary.
Keywords: discontinuous ODE system, particle, mild solution

Title: Structure-preverving methods for PDEs via Green-Gauss formulae on Voronoi cells
Speaker: Daisuke Furihata (Osaka University)

Author(s): Daisuke Furihata
Abstract: In these decades, we have developed a few numerical methods to inherit essential properties from the original target problems, such as PDEs/ODEs. They are commonly called structure-preserving methods, and we indicated they are efficient, reliable and durable via some numerical computations on one-dimensional problems. However, if we would like to introduce reference points located arbitrarily in two- or three-dimensional regions, it is hard to design some structure-preserving methods. The reason is that we should define some finite difference/volume operators to discretize differential operators, however, in general, it is also severe problems to find/design some general Gauss-Green formulae based on them. This difficulty often prevents to design structure-preserving methods since Green-Gauss formulae are an essential key for variational calculation included in the process of the design.
In these years, we have found that there exist some rigorous discrete Gauss-Green formulae among finite difference/volume operators based on the Voronoi-Delaunay triangulations. Furthermore, we can apply them to design some structure-preserving numerical methods for some PDE problems and run numerical computations.
In this talk, we would like to indicate those finite difference/volume operators, Green-Gauss formulae and their proofs in detail and the obtained discrete variational derivative methods, which is one of the structure-preserving methods for PDEs, based on Voronoi cells.
Keywords: structure-preserving methods, Voronoi cell, discrete varitational derivative method

Title: 3D Poisson-Boltzmann computation of KcsA potassium channel
Speaker: Tzyy-Leng Horng (Feng Chia University)
Author(s): Tzyy-Leng Horng
Abstract: Ion channels are pore-forming trans-membrane proteins that allow ions to enter/leave cell. There are many important cell functions involving ion channel, e.g., establishing and regulating action potential in neurons and myocytes. The average time for an ion passing through ion channel is in the order of ms, which is infeasible for molecular dynamics simulation so far. Continuum model like Poisson-Boltzmann equation (PB) and Poisson-Nernst-Planck (PNP) equations are popular to describe ion channel in equilibrium and non-equilibrium situations. KcsA potassium channel is chosen to be studied here, since it is one of few ion channels having X-ray crystallographic structure. 3D PB and PNP simulations of KcsA channel have been a challenging task, since (1) geometry is complicated especially the narrow filter part requiring high resolution when generating meshes; (2) mathematical models are complicated since there are various versions of modified PB/PNP to choose; (3) physics is complicated such as distri-

butions of dielectric constant and diffusion coefficient, necessity to employ steric effect or not and solvation energy should be included or not. Here, a PDB 3F7Y KcsA structure with filter part replaced by that of PDB 1K4C is used as the structure for simulation. Unlike all other KcsA PDB structures, this synthetic structure guarantees that the channel is open. PB and modified PB equations are first extended to be pseudo-time-dependent with the steady-state solution being our only interest. The numerical framework adopted here to solve these time-dependent equations for electric potential is method of lines (MOL). Governing equation is first semi-discretized in space by 2nd order finite volume method under Cartesian grids with the edge value to cope with interface condition. This semi-discretized system forms a system of ordinary differential algebraic equations (ODAE) that can be further integrated by popular ODAE solvers. Mathematical models simulated here are (I) Classical PB, (II) modified PB with steric effect described by Bikerman model, and (III) modified PB as (II) with solvation energy included in addition. From simulation results, we found potassium ion is unrealistically crowded in the filter for model (I). For model (II), though potassium ion is no more unrealistically crowded in filter due to the inclusion of steric effect, there is no room for water to be in the filter. Finally, model (III) delivers the most reasonable physical result among all three models by obtaining reasonable potassium concentration under steric effect and allowing water residence in the filter at the same time.

Keywords: ion channel, Poisson-Boltzmann, finite-volume method, transmembrane protein

Parallel Session 6 (24, June)

Title: Computer-assisted proof of the existence of unimodal solutions to the Proudman-Johnson equation

Speaker: Tomoyuki Miyaji (Meiji University)
Author(s): Tomoyuki Miyaji, Hisashi Okamoto

Abstract: We present a computer-assisted proof for the existence of unimodal solutions to the Proudman-Johnson equation, which gives some self-similar solution to the 2D Navier-Stokes equations. We formulate the shooting method for the stationary Proudman-Johnson equation and solve it via the interval Newton method. A direct application of this strategy, however, does not work due to numerical instability of shooting method for a large Reynolds number. We overcome this difficulty by using both multiple-shooting method and multiple precision interval arithmetic.

Keywords: the Proudman-Johnson equation, unimodal solutions, interval analysis, computer- assisted proof, multiple shooting method

Title: Numerical solution of the Ostrovsky equation over variable topography
Speaker: Azwani Alias (Universiti Malaysia Terengganu)
Author(s): Azwani Alias, Nik Nur Amiza Nik ismail
Abstract: In the real world phenomena, internal nonlinear waves are often propagating through a non-uniform background medium known as variable topography. The effect of variable topography on the propagation of oceanic internal solitary waves in the absence of background rotation is relatively well studied and understood by variable coefficient Korteweg-de Vries type equations. However, the works that collaborate with background rotation and various variable topography, known as variable coefficient Ostrovsky equations is less understood. The aim of this research is to study the effects of various variable topography on the propagation of the internal nonlinear waves in the presence of rotation effect. Numerical simulation such as Pseudo-Spectra method will be used to analyze these effects. The intention is to get deeper understanding of the propagation of nonlinear wave packets with various variable topography.
Keywords: Ostrovsky equation, variable topography, pseudo spectral method

Title: Numerical computation of the radiative transport equation on nonconformal meshes
Speaker: Hiroshi Fujiwara (Kyoto University)
Author(s): Hiroshi Fujiwara
Abstract: In this talk, we propose the use of non-conformal meshes for numerical computations of the stationary radiative transport equation (RTE). RTE is an integro-differential equation, and is used in medical engineering fields as a mathematical model of near-infrared light propagation in biological tissue. Our numerical scheme is basically based on the discontinuous Galerkin method, and thus regularity and conformal meshes are assumed from the viewpoint of error analysis. However, in medical application, optical fibers are used to emit light, which is rather smaller than a target domain, and adaptive meshes have efficiency from quantitative viewpoint. In the presentation, we shall show error analysis and discuss comparisons with adaptive conformal mesh case in 2 dimensions.
Keywords: numerical analysis, radiative transport equation, nonconformal meshes

Parallel Session 7 (25, June)

Title: Improving numerical stability and analyzing backward error for heavily damped quadratic eigenvalue problem
Speaker: Hongjia Chen (University of Tsukuba)

Author(s): Hongjia Chen, Akira Imakura,Tetsuya Sakurai
Abstract: In this talk, we propose a method with Betcke's technique to improve the numerical stability for heavily damped quadratic eigenvalue problem (QEP). Heavily damped QEP is a special type of QEP that the norm of damping matrix is larger than the norm of other coefficient matrices. A classical approach for solving QEP is via a linearization form. We usually use QZ method to compute eigenpairs of the linearization form, and finally recover the eigenpairs of QEP from the eigenpairs of the linearization form. However, it can suffer from numerical instability when the norms of coefficient matrices vary widely. In this study, we have two objectives. The first objective is to improve numerical stability of computing eigenpairs in heavily damped QEP. To improve numerical stability, we combine the linearization form with Betcke's technique. The second objective is to explain why the use of Betcke's balancing technique improves the numerical stability of computing eigenpairs for the heavily damped QEP. To achieve the second objective, we investigate the backward error of the proposed method. The numerical experiments show that the proposed method improves numerical stability of computing eigenpairs for the heavily damped QEP.
Keywords: balancing technique, heavily damped QEP, backward error

Title: Relaxed MILU(0) Factorization with Block Red-Black Ordering for GPU parallelization of PIC simulation
Speaker: Akemi Shioya (The University of Electro-Communications)
Author(s): Akemi Shioya, Yusaku Yamamoto
Abstract: The combination of the block red-black ordering and the relaxed modified incomplete LU factorization without fill-ins (MILU(0)) provides a stable and highly parallelizable preconditioner for Krylov subspace methods. Introducing relaxation prevents zero pivots produced by the combination of the MILU(0) preconditioner with the red-block ordering, while keeping the benefit of reducing the number of iteration and synchronization points. In this strategy, the number of iterations decreases as the block size becomes larger. To take advantage of the preconditioner and the computational power of GPU, we consider an implementation in which large block sizes and performant data access patterns are compatible. The effects of improvement are investigated by solving Poisson's equation that accounts for the majority of computation time in PIC simulation for 3D process plasma apparatus. In this simulation, electric fields are repeatedly solved to calculate the behavior of sample particles at each time step. To reduce the overhead of ordering, we put the setting of index data that does not change with the time step out of the time loop. We illustrate that the computation time in GPU environments becomes small when the block size satisfies both conditions for good convergence and sufficient parallelism.

Keywords: linear system, modified incomplete factorizations, block red-black ordering, parallel processing

Title: The AAA algorithm for rational approximation

Speaker: Yuji Nakatsukasa (National Institute of Informatics)
Author(s): Yuji Nakatsukasa, Olivier Sete, Lloyd N. Trefethen

Abstract: Rational approximation can outperform polynomial approximation by a landslide when there are singularities in or near the domain of approximation. However, its use has been limited relative to polynomials, primarily due to ill-conditioning (in addition to spurious poles). In this work we show that the conditioning, and the overall utility of rational functions, can be improved dramatically by an adaptive barycentric representation for rational functions, wherein one chooses a basis depending not only on the domain but also the function to be approximated.

We introduce a new algorithm, called AAA (triple A, standing for "adaptive Antoulas-Anderson") for rational approximation on a real or complex domain. Even on a disk or interval the algorithm may outperform existing methods, and on more complicated domains it is especially competitive. The core ideas are (1) representation of the rational approximant in barycentric form with interpolation at certain support points and (2) greedy selection of the support points (which determines the basis) to avoid exponential instabilities.

Keywords: rational approximation, barycentric representation, stability

Room 61 (Building No.6)

Parallel Session 1 (23, June)

Title: PDE models for pricing Asian options
Speaker: Chi-Tien Lin (Providence University)
Author(s): C. Brown, J. C. Handley, CT Lin and K. J. Palmer
Abstract: In this talk, we consider fixed and floating strike European style Asian call and put options. For such options, there is no convenient closed-form formula for the prices. Previously, Rogers and Shi, Vecer, and Dubois and Lelievre have derived partial differential equations with one state variable, with the stock price as numeraire, for the option prices. In this talk, we derive a whole family of partial differential equations, each with one state variable with the stock price as numeraire, from which Asian options can be priced. Any one of these partial differential equations can be transformed into any other. This family includes four partial differential equations which have a particularly simple form including the three found by Rogers and Shi, Vecer, and Dubois and Lelievre. Recently, Vecer derive a new PDE using the average asset as numeraire. We perform numerical comparisons of the five partial differential equations by Crank-Nicolson method and conclude, as expected, that Vecer's equations and that of Dubois and Lelievre do better when the volatility is low but that with higher volatilities the performance of all five equations is similar. Vecer's equations are unique in possessing a certain martingale property and they perform numerically well or better than the others.
Keywords: Asian options, partial differential equations, one state variable, Crank–Nicolson

Title: State space model of realized volatility under the existence of dependent market microstructure noise
Speaker: Toru Yano (Shibaura Institute of Technology)
Author(s): Tetsuya Ishiwata, Toru Yano
Abstract: Volatility means the degree of variation of a stock price which is important in finance. However, volatility is unobservable and is estimated from observable data such as stock price. Realized Volatility (RV) is an estimator of the volatility calculated using high-frequency observed prices. RV has lately attracted considerable attention of econometrics and mathematical finance. However, it is known that high-frequency data includes observation errors called market microstructure noise (MN), and the RV calculated from this is also affected by MN. So, we can not get true volatility and we get noise contaminated RV (NCRV). Nagakura, Watanabe [2009] proposed a state space model that resolves NCRV

into true volatility and influence of MN. With this model, NCRV can be used as observation data to estimate and predict the true volatility excluding the influence of MN on a model basis. Although they assume independence for MN, empirical studies of Hansen, Lunde [2006] point out that MN has correlation with true stock price and autocorrelation. In this study, we assume these to MN and attempt to develop a model of Nagakura, Watanabe [2009]. In this talk, we introduce derived model and perform model comparison by applying the models to actual data.
Keywords: finance, data science, state space model, time series analysis, realized volatility, microstructure noise

Title: Stochastic polynomial chaos expansion method for a financial market model with uncertain volatility
Speaker: Yin-Tzer Shih (National Chung Hsing University)
Author(s): Yu-Tuan Lin, Yin-Tzer Shih
Abstract: This paper presents an arbitrary polynomial chaos expansion citeOlady for solving a financial market model with transactions costs and uncertain volatility. The nonlinear Black–Scholes equation provides the pricing of the European call option for the real market stock price. The stochastic Galerkin method with employing historical volatilities is used to approximate the raw data of volatilities distribution in log–normal random when implementing the arbitrary polynomial chaos expansion. The study illustrates that for the arbitrary polynomial chaos expansion offer a more accurate statistical estimation describing the uncertainty for the Black–Scholes model compared to Monte Carlo simulations and the generalized polynomial chaos expansion. Arbitrary polynomial chaos expansion can also be used for the model with unknown distributions of volatilities in short term.
Keywords: Black–Scholes formula, option pricing, polynomial chaos, uncertainty random stochastic

Title: A fast preconditioned iterative method for two-dimensional options pricing under fractional differential models
Speaker: Xu Chen (University of Macau)
Author(s): Xu Chen, Deng Ding, Siu-Long Lei, Wenfei Wang
Abstract: In recent years, fractional partial differential equation (FPDE) has been widely applied in options pricing problem, which better explain many important empirical facts of financial markets. However, the vast majority of the literature focus on pricing the single asset option under the FPDE framework. In this paper, a two-dimensional FPDE governing the valuation of rainbow options whose two underlying assets follow independent exponential Levy processes is established, and its boundary conditions are determined by one-dimensional FPDEs.

An unconditionally stable and second-order accurate finite difference scheme is proposed to discretize the established two-dimensional model. Given the block Toeplitz with Toeplitz block structure of the coefficient matrix, a fast Krylov subspace method based on fast Fourier transform can be utilized for solving the resulting linear system with $O(N \log N)$ computational complexity per iteration, where N is the matrix size. Furthermore, a block circulant with circulant block preconditioner is proposed to accelerate the convergence of the iterative method with theoretical analysis. In addition, a preconditioned Krylov subspace method is also proposed for solving the boundary conditions numerically with theoretical analysis of convergence rate. Numerical examples are given to demonstrate the accuracy and efficiency of our proposed fast preconditioned iterative methods.
Keywords: two-dimensional fractional partial differential equation, rainbow options pricing, finite moment log stable model, preconditioner

Parallel Session 2 (23, June)

Title: A numerical study of the Chebyshev collocation method for solving higher-order partial differential equations
Speaker: Somruthai Apornsaengsawang (Mahidol University)
Author(s): Somruthai Apornsaengsawang and Farida Chamchod
Abstract: This present study is devoted to investigating numerical solutions of the higher-order partial differential equations by the Chebyshev collocation method. At the collocation points, the problems are transformed into the matrix equations of linear algebraic equations with the unknown Chebyshev coefficients. Approximations of the solutions are then interpolated. To demonstrate efficiency and accuracy of the method, we include some examples and interpret their numerical results and errors. Our results verify the high accuracy of the method.
Keywords: Chebyshev collocation method, higher-order partial differential equations, interpolation

Title: An investigation of the hyperbolic telegraph equation with time delay by the Haar wavelet method
Speaker: Patipol Saengduean (Mahidol University)
Author(s): Patipol Saengduean, Farida Chamchod
Abstract: In this present study, the Haar wavelet method was implemented to approximate a solution of the hyperbolic telegraph equation. Due to mathematical simplicity of the method, it can be efficiently adjusted to tackle with time delay in the equation. This technique converts the problem to the algebraic equations of Haar coefficients that can be easily solved and used to interpolate a solution. To

analyze the efficiency and accuracy of such method, we provided some examples and compared our numerical results with exact solutions or solutions obtained from the finite difference method.
Keywords: Haar wavelet method, telegraph equation, time delay, finite difference method

Title: A mixed H^1-conforming finite element method for Maxwell's equations with non-H^1 solution
Speaker: Suh-Yuh Yang (National Central University)
Author(s): Huo-Yuan Duan, Roger C. E. Tan, Suh-Yuh Yang*, Cheng-Shu You
Abstract: We propose and analyze a mixed H1-conforming finite element method for solving Maxwell's equations in terms of electric field and Lagrange multiplier, where the multiplier is introduced accounting for the divergence constraint. We mainly focus on the case that the physical domain is non-convex and its boundary includes reentrant corners or edges, which may lead the solution of Maxwell's equations to be a non-H^1 very weak function and thus causes many numerical difficulties. A pair of H^1-conforming CP2-P1 elements for electric field and multiplier is studied and its stability and error bounds are also derived. Numerical experiments for source problems as well as eigenvalue problems are presented to illustrate the high performance of the proposed method.
Keywords: Maxwell's equations, non-H^1 solution, H^1-conforming finite element method, stabilized finite element method

Parallel Session 3 (24, June)

Title: Classification and evolution of bifurcation curves for the one-dimensional perturbed Gelfand equation with Dirichlet-Neumann boundary conditions
Speaker: Shin-Hwa Wang (National Tsing Hua University)
Author(s): Yu-Hao Liang and Shin-Hwa Wang
Abstract: We study the classification and evolution of bifurcation curves of positive solutions for the one-dimensional perturbed Gelfand equation with Dirichlet-Neumann boundary conditions given by

$$\begin{cases} u''(x) + \lambda \exp\left(\frac{au}{a+u}\right) = 0; 0 < x < 1, \\ u(0) = 0,\ u'(1) = -c < 0, \end{cases}$$

where $4 \leq a < a_1$, for some $a_1 \approx 4.107$. We prove that, for $4 \leq a < a_1$, there exist two nonnegative $c_0, (= c_0(a)) < c_1, (= c_1(a))$ satisfying $c_0 > 0$ for $4 \leq a < a^*$ with some $a^* \approx 4.069$, and $c_0 = 0$ for $a^* \leq a < a_1$, such that, on the $(\lambda, \|u\|_\infty)$-plane, (i) when $0 < c < c_0$, the bifurcation curve is strictly increasing; (ii) when $c = c_0$, the

bifurcation curve is monotone increasing; (iii) when $c_0 < c < c_1$, the bifurcation curve is S-shaped; (iv) when $c \geq c_1$, the bifurcation curve is *subset*-shaped. This work is a continuation of Liang and Wang (J. Differential Equations 260 (2016) 8358–8387) where authors studied this problem for $a \geq a_1$, and our results partially prove a conjecture on this problem for $4 \leq a < a_1$ in Liang and Wang (J. Differential Equations 260 (2016) 8358–8387).
Keywords: multiplicity, positive solution, perturbed Gelfand equation, S-shaped bifurcation curve, $\subset$-shaped bifurcation curve, time map

Title: Finite-time singularity for ODEs from the viewpoint of dynamical systems
Speaker: Kaname Matsue (Kyushu University)
Author(s): Kaname Matsue
Abstract: A geometric treatment of finite-time singularities for autonomous ordinary differential equations (ODEs) including their asymptotic behavior is concerned. In particular, blow-up behavior of solutions is the one of our main concerns. We show that dynamics on center-stable manifolds of "invariant sets at infinity" with appropriate time-scale desingularizations as well as blowing-up of singularities characterize dynamics of blow-up solutions as well as their rigorous blow-up rates not only of so-called "Type-I" but also of other types. This approach not only characterize monotonous blow-up behavior but also oscillatory blow-ups in terms of stable manifolds of "periodic orbits at infinity" for example. Moreover, this mechanism has the similar nature to other finite-time singularities such as finite traveling waves including extinction, compacton waves and quenching behavior. Consequently, the above geometric treatment reveals a common mechanism among finite-time singularities in (ordinary) differential equations.
Keywords: finite-time singularities (blow-up, extinction, compacton, quenching), asymptotic behavior, compactifications, desingularizations

Title: Rigorous numerics of finite-time singularity for ODEs
Speaker: Kaname Matsue (Kyushu University)
Author(s): Kaname Matsue
Abstract: This talk aims at providing rigorous numerical computation procedure for finite-time singularities in dynamical systems based on interval arithmetic. Combination of time-scale desingularization, computable quantitative estimation of asymptotic behavior and standard integration procedure of ordinary differential equations give us validations of true trajectories of dynamical systems involving finite-time singularities. Our focus includes finite-time extinction, traveling wave solutions with half-line or compact support, including several quantitative information such as extinction times and size of supports for compactons. Such validated

solutions lead to a plenty of composite wave solutions for degenerate parabolic equations, for example, with concrete information of profiles and evolutions. Finally note that blow-up solutions are also inside our focus, and we have several rigorous validation results of blow-up solutions.
Keywords: rigorous numerics, finite traveling waves, blow-up solutions, quantitative estimates in finite-time singularities

Parallel Session 4 (24, June)

Title: Error analysis of Crouzeix–Raviart and Raviart–Thomas finite element methods
Speaker: Takuya Tsuchiya (Ehime University)
Author(s): Kenta Kobayashi, Takuya Tsuchiya
Abstract: We discuss the error analysis of the lowest degree Crouzeix–Raviart and Raviart–Thomas finite element methods applied to a two-dimensional Poisson equation. To obtain error estimations, we use the techniques developed by Babuska–Aziz and the authors. We present error estimates in terms of the circumradius and the diameter of triangles in which the constants are independent of the geometric properties of the triangulations. Numerical experiments confirm the theoretical results obtained.
Keywords: Crouzeix–Raviart and Raviart–Thomas finite element methods, error estimation, triangulations, circumradias

Title: On the IAS scheme for strongly coupled systems of singular perturbation equations
Speaker: Po-Wen Hsieh (National Chung Hsing University)
Author(s): Po-Wen Hsieh, Suh-Yuh Yang, Cheng-Shu You
Abstract: The Il'in-Allen-Southwell (IAS) scheme is a robust finite difference scheme for treating scalar singular perturbation convection-diffusion equation whose solution may display strong boundary layer behavior. In this talk, we will apply this scheme to 1-D strongly coupled systems. By employing an alternating direction technique, the scheme can be extended to 2-D cases. From the numerical results, we can observe that when the perturbation parameter ε is small enough, the developed IAS scheme is first order convergent in the discrete maximum norm uniformly in ε on uniform meshes.
Keywords: strongly coupled system, singularly perturbed convection-diffusion equation, boundary and interior layers

Title: Remarks on the computation of blow-up problems
Speaker: Chien-Hong Cho (National Chung Cheng University)
Author(s): Chien-Hong Cho
Abstract: In many evolution equations, the solution may become unbounded in a finite time. Such a phenomenon is often called blow-up and the finite time is called the blow-up time. We consider two numerical methods which are often used for the computation of such problems, one is to define the temporal increment adaptively while another is to compute with uniform time mesh. It was known that even the numerical solution and the numerical blow-up time converge to the exact ones, the asymptotic behaviors, such as the blow-up rate and blow-up set, for the numerical solution do not always coincide with those of the exact solution. We would like to explore this problem in more detail. Moreover, we would also like to investigate in this talk a problem as to whether a higher order scheme gives a better approximation for blow-up solutions. Several examples will be reported for these problems.
Keywords: semi-linear heat equation, blow-up, blow-up rate, numerical blow-up rate

Title: A numerical estimating method of blow-up rates for nonlinear evolution equations with a scale invariance
Speaker: Takeo Ushijima (Tokyo University of Science)
Author(s): Koichi Anada, Tetsuya Ishiwata, Takeo Ushijima
Abstract: Many nonlinear evolution equations possess solutions which blow up in finite time. It is one of the most interesting issues concerning blow-up phenomena how the solutions develop singularities. To determine the blow-up rate is a major problem in such a direction. Depending on the equations, blow-up rates take the forms of various types such as simple power type and logarithmic type, and even more complex ones. There are vast amounts of literature deeply considering how solutions blow up. To our best knowledge, however, only a few studies have investigated numerical methods for blow-up rates. In this talk, we propose a simple but effective numerical method which estimates blow-up rates for a class of nonlinear evolution equations. Here, we consider the class of equations which satisfy a scaling invariance. Thanks to this scaling invariance, we adopt the rescaling algorithm and construct a sequence whose behavior leads to the blow-up rate. Applying the method to several nonlinear equations, we examine the effectiveness of the method. We show that our method is applicable to not only the simple power type blow-up rates but also more complex ones.
Keywords: nonlinear equation, blow-up rate, scale invariance, numerical method, rescaling algorithm

Parallel Session 5 (24, June)

Title: Discontinuous Galerkin method for an N-dimensional spherically symmetric Poisson equation
Speaker: Yuki Chiba (The University of Tokyo)
Author(s): Yuki Chiba, Norikazu Saito
Abstract: In the theory of PDE, it is known several critical phenomena with critical value related to space dimension N. If we can make numerical method for nonlinear PDEs in higher dimension, it is useful for studying critical phenomena through experimental consideration. So, we consider a spherically symmetric Poisson equation in N-dimensional ball as a model problem. This equation can be rewritten as a one-dimensional equation with singularity near origin. The previous study proposed finite element method using weight function to reduce singularity. One approach to use weight function x^{N-1} showed optimal weighted L^2 error estimate. However, if space dimension N is too large, there is a disadvantage of increasing error near origin because of flatness of weight function. The another approach to use weight function x showed optimal pointwise error estimate. In this paper, we see the PDE as singularly perturbed convection-diffusion equation through later approach, and apply discontinuous Galerkin method to it. We show some estimates and offer some numerical results.
Keywords: numerical analysis, discontinuous Galerkin method

Title: High order accuracy of self-gravitational force calculation on infinitely thin gaseous disks
Speaker: Chien-Chang Yen (Fu Jen Catholic University)
Author(s): Chien-Chang Yen, Rui-Zhu Wu
Abstract: In this talk, we focused on the self-gravitational force calculation of initesimally thin and bounded distribution of surface density in 3-D space. The method we proposed is to expand the surface density function based on B-spline function, and calculated the B-spline function and kernel integration by integral formula directly. The numerical simulations demonstrate the proposed method is high order accuracy and fast calculation.
Keywords: direction method, B-spline, self-gravitational force calculation

Title: Convergence analysis of a conservative finite difference scheme for the modified Hunter–Saxton equation
Speaker: Shun Sato (The University of Tokyo)
Author(s): Shun Sato
Abstract: The modified Hunter–Saxton equation models the propagation of short

capillary-gravity waves. As it involves a mixed derivative, its initial value problem on the periodic domain is much more complicated than the standard evolutionary equations. In particular, the convergence analysis of the numerical methods for the class of equations with a mixed derivative is yet to be investigated, and there are only one result for the simplest case in the literature. In this talk, we prove the convergence of a conservative finite difference scheme for the modified Hunter–Saxton equation. There, in order to overcome the difficulty appeared due to a mixed derivative, the mass conservation plays a crucial role. Since the mass conservation is a common property of equations with a mixed derivative, our strategy is expected to be a standard method for convergence analysis of the other equations.
Keywords: modified Hunter–Saxton equation, conservative numerical methods, convergence

Parallel Session 6 (24, June)

Title: A penalty method for the Stokes-Darcy problem and the discontinuous Galerkin approximation
Speaker: Guanyu Zhou (Tokyo University of Science)
Author(s): Guanyu Zhou, Takahito Kashiwabara, Issei Oikawa, Eric Chung
Abstract: For the Stokes-Darcy problem with a curved interface, it requires additional techniques for the numerical implementation of the interface boundary condition. To tackle this problem, we introduce a penalty method to treat the interface boundary condition which is easy to implement using discontinuous Galerkin method. The optimal error estimates of the penalty method and the finite element discretization are investigated. The numerical experiments are carried out which comfirms the theoretical results.
Keywords: Stokes-Darcy problem, discontinuous Galerkin method, penalty method, error estimates

Title: On Lyapunov functions constructed by verified computation
Speaker: Nobito Yamamoto (The University of Electro-Communications)
Author(s): Nobito Yamamoto, Masao Nakamura, Gen Terasaka, Kouki Nitta
Abstract: Constructing Lyapunov functions by verified computation is discussed. In the previous works by some of the authors, numerical verification methods have been established to construct Lyapunov functions of quadratic form within a certain neighborhood of hyperbolic equilibria of given dynamical systems described by ODEs. However it is impossible generally to find any Lyapunov function of quadratic form for a non-hyperbolic equilibrium. Our approach to solve the diffi-

culty is adopting some sort of projections to find so called quasi-Lyapunov functions, and we have derived special conditions which enable us to construct quasi-Lyapunov functions of quadratic form within a neighborhood of non-hyperbolic equilibria. In our talk, following an introduction of numerical verification methods to construct Lyapunov functions for hyperbolic equilibria, our approach to non-hyperbolic cases will be described together with some numerical examples.
Keywords: verified computation, dynamical system, ODEs, Lyapunov function

Title: Efficient numerical methods for stochastic optimal control problems for PDEs
Speaker: Hyung-Chun Lee (Ajou University)
Author(s): Hyung-Chun Lee
Abstract: In this talk, we consider an optimal control problem for an elliptic partial differential equation and Stokes equations with random inputs. To determine an applicable deterministic control $f(x)$, we consider the several cases which we compare for efficiency and feasibility. We prove the existence of optimal states, adjoint states and optimality conditions for each cases. We also derive the optimality systems for the four cases. The optimality system is then discretized by a standard finite element method for physical space and sparse grid collocation method and/or Monte Carlo method for probability space, respectively. The numerical experiments are performed for their efficiency and feasibility.
Keywords: stochastic optimal control, Monte Carlo, sparse grid collocation, finite element

Room 62 (Building No.6)

Parallel Session 1 (23, June)

Title: A framework of explicit eigenvalue bounds for self-adjoint partial differential operators
Speaker: Xuefeng Liu (Niigata University)
Author(s): Xuefeng Liu
Abstract: For the purpose of high-precision explicit eigenvalue bounds for self-adjoint differential operators defined over complicated domains, a general framework based on finite element methods is proposed.
First, rough but rigorous eigenvalue bounds can be obtained by using lower order finite element method along with a fundamental theorem in em X. Liu, A framework of verified eigenvalue bounds for self-adjoint differential operators, Applied Mathematics and Computation, 267, pp.341-355, 2015. For example, for the Laplace operator, the eigenvalues can be easily bounded by applying Crouzeix-Raviart finite elements. Explicit eigenvalue bounds for the following eigenvalue problems have been successfully obtained: the Laplacian, the Biharmonic operator, the Stokes operator, the Steklov eigenvalue problems.
Second, to obtain high-precision eigenvalue bounds, Lehmann-Goerisch's theorem along with high-order finite element methods is adopted in bounding eigenvalues. By further adopting the interval arithmetic, the explicit eigenvalue bounds from numerical computations can be mathematically correct. As a computer-assisted proof, the verified eigenvalue bounds have been used to investigate the solution existence of semi-linear elliptic differential equations.
Keywords: eigenvalue problem, lower bound, differential operator, finite element method

Title: On the semigroup property for some structured iterations
Speaker: Chiang Chunyueh (National Formosa University)
Author(s): Chun-Yueh Chiang , Matthew M. Lin
Abstract: Matrix equations are encountered in many applications of applied mathematics and engineering problems. Problems in determining the solutions of a matrix equation are closely related to a wide range of challenging scientific areas. Traditional approaches for finding numerical solution are based on fixed point iterations and the speed of the convergence is usually linear.
Recently, we built up a semigroup property for some binary matrix operations; to construct such a type of iterations for solving several different matrix equations, while the speed of convergence can be R-superlinearly with any order r is given. In this work, we want to generalize this property to analyze a special instance of

some structured iterations arising from a class of matrix equations. We show that this property can not only find out the solution, but also construct an iterative approach which converges to the solution with any desired order. Some examples are shown to demonstrate the robustness of our method. (A joint work with Prof. Matthew M. Lin)
Keywords: accelerated iterative method, matrix equation, semigroup property

Title: Solving two generalized nonlinear matrix equations
Speaker: Peter Chang-Yi Weng (Academia Sinica)
Author(s): Peter Chang-Yi Weng
Abstract: In this paper, we consider the numerical solutions of two generalized nonlinear matrix equations. Newton's method is applied to compute one of generalized nonlinear matrix equations and we get the generalized Stein equation, then we adapt the generalized Smith method to find the maximal Hermitian positive definite solution. Furthermore, we consider the properties of the solution for the generalized nonlinear matrix equation. The other generalized nonlinear matrix equation is computed by Newton's method to find the minimal Hermitian positive definite solution. Finally, two numerical examples are presented to illustrate the effectiveness of the theoretical results and the convergence behaviour of the considered methods.
Keywords: generalized nonlinear matrix equations, Newton's method, maximal and minimal Hermitian positive definite solutions, generalized Smith method, perturbation analysis

Title: Designing robust control using bilinear matrix inequalities
Speaker: Roberd Saragih (Institut Teknologi Bandung)
Author(s): Roberd Saragih
Abstract: The robust control has been applied to many areas since it can cover the problem having the disturbance, perturbation, and uncertainty. The difficulty associated with the robust control, however, is in solving the state dependent algebraic Ricatti equations (SDARE). To overcome this difficulty, we present the bilinear matrix inequalities (BMI) method for solving the SDARE. The BMI problem are not convex and have multiple local solutions and it is not solvable in polynomial time. The easiest method to implement for solving the BMI problem is the alternative minimization algorithm, this method is based on the iterative schemes of the alternation between analysis and synthesis via the linear matrix inequalities. It will transform the BMI problem to the LMIs problem, which can be solved easily via LMI solvers. However, this algorithm might converge very slowly, and even stop at the non stationary point. The choice of the initial value is important

for the convergence, so that an acceptable solution could be achieved.
Keywords: robust control, SDARE, bilinear matrix inequalities, linear matrix inequalities

Parallel Session 2 (23, June)

Title: Integer low-rank approximation and its applications
Speaker: Min Hsiung Lin (National Cheng Kung University)
Author(s): Lin, Min-Hsiung
Abstract: The low-rank approximation of integer matrices has received attention recently due to its capacity of naturally representing parts of integer data sets. Different from the general low-rank approximations, the integer approximation is naturally discrete, therefore, the conventional techniques for matrix approximation, such as SVD and non-negative matrix approximation, are inappropriate and unable to solve this problem. To the best of our knowledge, a numerical method for finding a low-rank integer approximation of an integer matrix has not been proposed in the literature earlier. In this talk, we want to propose a method to obtain the integer low-rank approximation of integer matrices. This method consists of recursively finding integer solutions of integer least square problems. Applications on the real world problems will be given.
Keywords: data mining, matrix factorization, integer least squares problem, clustering, association rule, pattern extraction

Title: Finding the largest eigenpair of an irreducible nonnegative tensor
Speaker: Liu, Ching-Sung (National University of Kaohsiung)
Author(s): C. H. Guo, and W. W. Lin
Abstract: In this talk, we will introduce a Newton–Noda iteration (NNI) for computing the Perron pair of a weakly irreducible nonnegative mth-order tensor $\mathcal{A}$, by combining the idea of Newton's method with the idea of the Noda iteration. The method requires the selection of a positive parameter θ_k in the kth iteration, and produces a scalar sequence approximating the spectral radius of $\mathcal{A}$ and a positive vector sequence approximating the Perron vector. We propose a halving procedure to determine the parameters θ_k, starting with $\theta_k = 1$ for each k, such that the scalar sequence is monotonically decreasing. Convergence of this sequence to the spectral radius of $\mathcal{A}$ (and convergence of the vector sequence to the Perron vector) is guaranteed for any initial positive unit vector, as long as the sequence θ_k so chosen is bounded below by a positive constant. In this case, we always have $\theta_k = 1$ near convergence and the convergence is quadratic. Very often, the halving procedure will return $\theta_k = 1$ (i.e., no halving is actually used) for each

k. If the tensor is semisymmetric, $m \geq 4$, and $\theta_k = 1$, then the computational work in the kth iteration of NNI is roughly the same as that for one iteration of the Ng–Qi–Zhou algorithm, which is linearly convergent for the smaller class of weakly primitive tensors.
Keywords: nonnegative tensor, M-matrix, nonnegative matrix, positivity preserving, quadratic convergence, Perron vector, Perron root

Title: A method to calculate SVD of sparse and tall-skinny matrices
Speaker: Hiroshi Murakami (Tokyo Metropolitan University)
Author(s): Hiroshi Murakami
Abstract: For a sparse and very tall-skinny matrix A of large size, we calculate the singular value decomposition $A =: Q\Sigma W^T$ by using the classical method. We calculate $C := A^T A$ using the sparsity of the matrix A, and make the eigenvalue decomposition of $C =: WDW^T$ and set $\Sigma := \sqrt{D}$.
Even if the original matrix A is very large, by the use of the sparsity it could be stored. However, the matrix Q will be dense in general, and it could be difficult to store the entire matrix elements of Q.
We can avoid to store Q in dense form. Small size matrices W and D can be constructed without change of A as above procedure, then Q can be represented implicitly by using the relation $Q = AW\Sigma^{\dagger}$, here $\dagger$ on the shoulder denotes the generalized inverse.
From the implicit representation of Q, we can easily calculate singular vectors (columns of Q) on demand. To keep the memory requirement low, instead to make and store all vectors at once, we generate only a small number of vectors at a time on demand.
Keywords: tall-skinny, SVD, sparse matrix

Parallel Session 3 (24, June)

Title: High-performance computing for 3D Maxwell equations with fourteen Bravais lattices
Speaker: Tsung-Ming Huang (National Taiwan Normal University)
Author(s): Tsung-Ming Huang, Tiexiang Li, Wei-De Li, Jia-Wei Lin, Wen-Wei Lin
Abstract: The numerical simulation of the band structure of three-dimensional photonic crystals leads to large-scale generalized eigenvalue problems (GEPs). Due to a high dimensional subspace associated with the eigenvalue zeros, it is very challenging to solve the GEP. In this paper, we focus on developing a high-performance computing method to solve GEP for all fourteen Bravais lattices. For each lattice, we derive the explicit matrix form of the discrete double-curl operator by

using Yee's scheme and classify all the matrices into four general types. The eigen-decompositions of these four general matrices are then derived. Based on these eigen-decompositions, the nullspace-free method is applied to exclude the zero eigenvalues from the associated generalized eigenvalue problem. Applying these theoretical results, a high-performance computing package FAME (Fast Algorithm for Maxwell's Equations) with GPU acceleration is proposed to find the target eigenpairs for any lattices. Numerical results illustrate that FAME successfully solves each of a set of 5.184 million dimension eigenvalue problems within 18 to 50 seconds on a workstation with NVIDIA Tesla P100 GPUs.
Keywords: Maxwell's equation, three-dimensional photonic crystals, generalized eigenvalue problems, Bravais lattices, eigen-decomposition, nullspace-free method, FAME, GPU

Title: An efficient and stable solver for Kohn–Sham equation
Speaker: Yang Kuang (University of Macau)
Author(s): Yang Kuang, Guanghui Hu
Abstract: We present an efficient and stable solver for Kohn–Sham equation which can help to speed up the convergence of self-consistent filed (SCF) iteration, and even effectively avoid the failure of SCF iteration. We find that for electronic structure calculations the imaginary time propagation (ITP) method to obtain the ground state will always give a convergent result. However, the wavefunctions should be propagated long time enough to get an accurate result which leads to the inefficiency of ITP. In this work, we take advantage of the convergence of ITP to generate a qualified initial guess for SCF iteration. Numerical examples show that with the ITP-generated initial guess, the SCF iteration is faster and stronger than it with random initial guess.
Keywords:

Title: Application of an energy-preserving integrator to quantum-mechanical wavepacket dynamics
Speaker: Yusaku Yamamoto (The University of Electro-Communications)
Author(s): Tsubasa Sakai, Shuhei Kudo, Hiroto Imachi, Yuto Miyatake, Takeo Hoshi and Yusaku Yamamoto
Abstract: Simulation of quantum-mechanical wavepacket dynamics plays a crucial role for the design of organic electronic devices. Here, the governing equation is the nonlinear time-dependent Schrodinger equation and the potential has both a random component due to structural disorder and a delta function-like component due to impurity atoms. To solve such an equation stably and accurately, we use the BM4 method, which is a parallelizable 4th order energy-preserving continuous

stage Runge-Kutta method recently proposed by Miyatake and Butcher (Y. Miyatake and J. C. Butcher, SIAM J. Numer. Anal., 54(3), 1993-2013). We applied the method to a two-dimensional time-dependent nonlinear Schrodinger equation with a delta function-like potential discretized on a regular grid with up to 640 x 640 mesh points. This system is a prototypical model of a two-dimensional disordered organic material, in which each mesh point corresponds to an organic molecule such as pentacene (C22H14) and the potential corresponds to a defect. Numerical tests show that the BM4 method can solve the equation stably despite the existence of the delta function-like potential and preserves the total energy to 14-digit accuracy throughout the simulation. We also parallelized the method using its inherent parallelism and achieved up to 2.8 times speedup with 3 computational nodes.
Keywords: quantum simulation, Runge-Kutta methods, structure-preserving methods, parallel computing

Parallel Session 4 (24, June)

Title: A direct-forcing immersed boundary projection method for fluid-solid interaction problems
Speaker: Cheng-Shu You (National Central University)
Author(s): Tzyy-Leng Horng, Po-Wen Hsieh, Suh-Yuh Yang, Cheng-Shu You
Abstract: We introduce a simple direct-forcing immersed boundary projection method in conjunction with a prediction-correction process for simulating the dynamics of fluid-solid interaction problems. The immersed solid object can be stationary or moving in the fluid with a prescribed velocity. This method is mainly based on the introduction of a virtual force which is distributed only on the immersed solid bodies and appended to the fluid momentum equations to accommodate the internal boundary conditions at the immersed solid boundaries. More specifically, we first predict the virtual force on the immersed solid domain by using the difference between the prescribed solid velocity and the computed velocity, which is obtained by applying the Choi-Moin projection scheme to the incompressible Navier-Stokes equations on the entire domain including the portion occupied by the solid bodies. The predicted virtual force is then added to the fluid momentum equations as an additional forcing term and we employ the same projection scheme again to correct the velocity field, pressure and virtual force. Numerical experiments of several benchmark problems are performed to illustrate the simplicity and high performance of the proposed prediction-correction approach.
Keywords:

Title: Generation of good point configurations by global optimization for interpolation in reproducing kernel Hilbert spaces
Speaker: Ken'ichiro Tanaka (The University of Tokyo)
Author(s): Ken'ichiro Tanaka
Abstract: The accuracy of approximation methods for functions depends crucially on the location of data points. In approximation theory, there are some popular points such as Chebyshev points, Fekete points, Leja points, Padua points, etc. They are mainly aimed at keeping the Lebesgue constant under control and known to be good also for kernel-based approximation.
For kernel-based approximation methods, there are other approaches based on the error bound of the interpolation in a reproducing kernel Hilbert space. In fact, such a bound is provided by the power function, which depends on the data points and the kernel of the space. For example, DeMarchi et al. (2005) propose a greedy algorithm for placing points one by one, and Iske (2000) uses a similar approach. In this work, we propose a global optimization approach for generating good point configurations for for interpolation in reproducing kernel Hilbert spaces. We provide an approximation of the power function based on Mercer's theorem and obtain an optimization problem to determine a good point configuration. Then, we adopt a convex relaxation of the problem to obtain its good approximate solution, which provides a good point configuration. By some numerical experiments, we can observe the good property of the point configuration.
Keywords: reproducing kernel Hilbert space, interpolation, point configuration, power function, global optimization

Title: Optimal estimation for the Fujino-Morley interpolation error constants
Speaker: Shih-Kang, Liao (Niigata University, JP & National Cheng Kung University, TW)
Author(s): Shih-Kang Liao, Xuefeng Liu
Abstract: Let K be a triangle with the largest edge length as h. The vertices of K are denoted by O, A and B and the edges by e_1, e_2, e_3. Given $u \in H^2(K)$, the Fujino-Morley interpolation Π^{FM} maps u to a quadratic polynomial that satisfies

$$(\Pi^{\text{FM}}u - u)(P) = 0, \quad P = O, A, B; \tag{1}$$

$$\int_{e_i} \frac{\partial}{\partial n}(\Pi^{\text{FM}}u - u)mds = 0, \quad i = 1, 2, 3. \tag{2}$$

In this talk, we consider the Fujino-Morley interpolation error constant C_0 and C_1, which satisfy

$$\|\Pi^{\text{FM}}u - u\| \leq C_0\|\Pi^{\text{FM}}u - u\|_2, \quad \|\Pi^{\text{FM}}u - u\|_1 \leq C_1\|\Pi^{\text{FM}}u - u\|_2.$$

In [Numer. Math., bf 126(1):33–51, may 2014.], em Carsten Carstensen and em Dietmar Gallistl provided rough bounds of constants C_0 and C_1. In our research, the problem of constant estimation is transformed to the eigenvalue problem for certain Biharmonic differential operator, which is further solved by applying the eigenvalue estimation method developed by em X. Liu[Appl. Math. Comput.,bf 267:341-355, 2015.]. Particularlly, for triangle elements with longest edge length less than 1, the optimal estimation for the constants is obtained as follows,

$$0.0735 \leq C_0 \leq 0.0736, \quad 0.1886 \leq C_1 \leq 0.1888.$$

Keywords:

Title: Approximate inversion method for time-fractional subdiffusion equations
Speaker: Seakweng Vong (University of Macau)
Author(s): Seakweng Vong
Abstract: When finite-difference method is applied to time-fractional subdiffusion equations, it usually leads to a large-scale linear system with a block lower triangular Toeplitz coefficient matrix. In this talk, the approximate inversion method is employed to solve this system. A sufficient condition is proved to guarantee the high accuracy of the approximate inversion method for solving the block lower triangular Toeplitz systems, which are easy to verify in practice and have a wide range of applications. Numerical experiments are presented to verify the validity of theoretical results. This talk is partially supported by the grant MYRG2017-00098-FST from University of Macau
Keywords: time-fractional subdiffusion equations, Approximate inversion method

Parallel Session 5 (24, June)

Title: Fast solution algorithms for exponentially tempered fractional diffusion equations
Speaker: Siu-Long Lei (University of Macau)
Author(s): Siu-Long Lei, Daoying Fan, Xu Chen
Abstract: In this talk, a fast-iterative method and a fast-direct method is proposed for solving one-dimensional and two-dimensional tempered fractional diffusion equations with constant coefficients. The proposed iterative method is accelerated by circulant preconditioning which is shown to converge superlinearly while the proposed direct method is based on circulant and skew-circulant representation for Toeplitz matrix inversion. Numerical examples are provided to illustrate the effectiveness and efficiency of the proposed methods.

Keywords: Toeplitz matrix, circulant preconditioner, fast Fourier transform, tempered fractional diffusion equations, circulant and skew-circulant representation of Toeplitz inversion

Title: Validated computation for the matrix principal logarithm
Speaker: Shinya Miyajima (Iwate University)
Author(s): Shinya Miyajima
Abstract: A matrix X is a logarithm of a matrix A if the exponential of X coincides with A. Any nonsingular matrix has infinitely many logarithms, but the one that is most useful in practice is the principal logarithm. For a matrix with no eigenvalues on the closed negative real axis, the principal logarithm is the globally unique one whose eigenvalues have imaginary parts lying in the interval $(-\pi, \pi)$. Numerical algorithms for the logarithm have been developed.
The work presented in this talk addresses the problem of verified computations for the principal logarithm, specifically, numerically computing an interval matrix which is guaranteed to contain the logarithm. The pioneering work seems to be the VERSOFT routine VERMATFUN. This routine is applicable not only to a logarithm but also to other matrix functions, requires quadruple complexity, and does not say that the logarithm contained in the computed interval is principal.
The purpose of this talk is to propose two iterative verification algorithms for the principal logarithm. The first algorithm is based on a numerical spectral decomposition and requires only cubic complexity per iteration. The second algorithm is based on a numerical Jordan decomposition and applicable even for defective matrices. Numerical results show the effectiveness and robustness of the algorithms.
Keywords: matrix logarithm, principal logarithm, verified numerical computation

Title: Computation of the matrix fractional power based on the double exponential formula
Speaker: Fuminori Tatsuoka (Nagoya University)
Author(s): Fuminori Tatsuoka, Tomohiro Sogabe, Yuto Miyatake, Shao-Liang Zhang
Abstract: The matrix fractional power has attracted attention because it arises in many research fields, such as lattice QCD calculations, fractional partial differential equations, and quantum communication channel.
We consider computation of the matrix fractional power by numerical integration. The matrix fractional power can be represented as an improper integral of a slowly decaying function over the half infinite interval. Conventional approaches are based on some variable transformations (e.g. [J. R. Cardoso, ETNA, 2012]) in order to

use Gaussian quadrature. However, the convergence of the approaches could be slow for an ill-conditioned matrix or a specific exponent. Therefore, these methods may not be the best choice in that situation.
When considering an improper integrals with one variable, the double exponential (DE) formula is known to be one of the best choices. This motivates us to consider the DE formula for the matrix fractional power. In this talk, we propose an algorithm for computing the matrix fractional power based on the DE formula. Since the transformed interval is infinite, we estimate the truncation error and give a promising finite interval. Some numerical examples show that the proposed algorithm works well even for the cases the convergence of the conventional approaches is slow.
Keywords: matrix fractional power, matrix function, numerical integration, the DE formula

Parallel Session 6 (24, June)

Title: Fast validated computation for the minimal nonnegative solution of the nonsymmetric algebraic Riccati equation
Speaker: Shinya Miyajima (Iwate University)
Author(s): Shinya Miyajima
Abstract: Consider the nonsymmetric algebraic Riccati matrix equation (NARE) associated with M-matrix. The NARE of this type appears in fluid queues models and transport equations. The solution of practical interest in these applications is the minimal nonnegative solution. Conditions for the existence of the solution and numerical algorithms for the solution are extensively studied.
The work presented in this talk addresses the problem of verified computation for the minimal nonnegative solution, specifically, computing an interval matrix which is guaranteed to contain the solution. While there are well-established verification algorithms for continuous and discrete time algebraic Riccati equations, less attention has been paid to the NARE. To the author's best knowledge, [S. Miyajima, Fast verified computation for solutions of algebraic Riccati equations arising in transport theory, Numer. Linear Algebra Appl., 24, 1-12, 2017] is the only literature which mentions the verification algorithm for the NARE. On the other hand, this paper treats a special case only.
The purpose of this talk is to propose an iterative verification algorithm for the minimal nonnegative solution. This algorithm requires only cubic complexity per iteration, and moreover verifies that the solution contained in the interval is unique. Numerical results show properties of the algorithm.
Keywords: nonsymmetric algebraic Riccati equation, minimal nonnegative solution, verified numerical computation

Title: Validated computation for the Hermitian positive definite solution of the conjugate discrete-time algebraic Riccati equation
Speaker: Shinya Miyajima (Iwate University)
Author(s): Shinya Miyajima
Abstract: In this talk, we consider the conjugate discrete-time algebraic Riccati matrix equation (CDARE). Investigating the CDARE is a parallel study of a conjugate nonlinear matrix equation, which has an application in the study of modern quantum theory. The solution of interest in the CDARE is the Hermitian positive definite (HPD) solution. In [M.M. Lin, C.-Y. Chiang, An accelerated technique for solving one type of discrete-time algebraic Riccati equations, J. Comp. Appl. Math., 338, 91-110, 2018], conditions for the existence of the HPD solution are elegantly derived, a fast iterative algorithm for the solution is proposed, and it is shown that the speed of convergence can be of any desired order.
The work presented in this talk addresses the problem of verified computation for the HPD solution, specifically, computing an interval matrix which is guaranteed to contain the solution. To the author's best knowledge, the verification algorithm designed specifically for the CDARE has not been written down in literatures.
The purpose of this talk is to propose an iterative verification algorithm for the HPD solution. This algorithm requires only cubic complexity per iteration, and moreover verifies that the solution contained in the interval is unique. Numerical results show properties of the algorithm.
Keywords: conjugate discrete-time algebraic Riccati equation, Hermitian positive definite solution, verified numerical computation

Title: Inheritance properties of the Krylov subspace method for solving continuous-time algebraic Riccati equations
Speaker: Hung-Yuan Fan (National Taiwan Normal University)
Author(s): Liping Zhang and Eric King-wah Chu
Abstract: In this talk we consider the numerical solution of large-scale continuous-time algebraic Riccati equations arisen from the LQG optimal control problems. We propose a projection method from a rational Krylov subspace interpretation of the doubling algorithm. More importantly, we prove that the solvability of the projected algebraic Riccati equation does not have to be assumed but is inheritted, under mild and reasonable assumptions. Some numerical examples are presented for illustrating the inheritance properties of the proposed method.
Keywords: algebraic Riccati equation, Arnoldi process, Cayley transform, large-scale problem, LQG optimal control, projection method, rational Krylov subspace

Room 63 (Building No.6)

Parallel Session 1 (23, June)

Title: Pseudospectral matrix element model for sloshing simulation in rectangular tank
Speaker: Ming-Jyh Chern (National Taiwan University of Science and Technology)
Author(s): Ming-Jyh Chern, Nima Vaziri
Abstract: Sloshing motion is a free surface flow in a container due to external excitation such as earthquake, vibration during rocket launch and wave impact around a ship. Hydrodynamic loading of sloshing motion may damage the container. Especially, when resonance occurs, the container may be broken. The proposed pseudospectral matrix element (PSME) model is to provide a high order numerical simulation of sloshing motion. A 3-D rectangular tank is considered in this model. Prescribed tank motion is utilized to excite liquid sloshing in the tank. The sigma transformation is used to capture the transient free surface profile in the PSME model. Effects of liquid depth and the aspect ratio of the tank on sloshing motion are discussed in the study. Free surface variations of sloshing are obtained in the results. Hydrodynamic loadings on the tank are calculated for design of the tank. The first order and the second order resonance phenomena are found in the simulations and their effects are discussed.
Keywords: sloshing, pseudospectral matrix element method, resonance, sigma transformation

Title: Numerical simulation of tidal bore Bono at Kampar river
Speaker: Sri R. Pudjaprasetya (Institut Teknologi Bandung)
Author(s): A.C. Bayu, S.R. Pudjaprasetya, U.J. Wisha, S. Husrin
Abstract: Tidal bore is a natural phenomena sometimes encountered in rivers. In Indonesia, this natural phenomenon is found in the Kampar River, which is known as tidal bore Bono. Sometimes, these tidal bore phenomena disappear, as happened to the Mascaret, tidal bore on the River Seine France. Through an understanding of the formation of tidal bore mechanism, there is hope that the tidal bore Bono in Kampar River can be preserved. In this paper, the occurrence of tidal bore Bono is simulated using the non-hydrostatic Saint-Venant equation under a staggered grid formulation. To test the accuracy of the implementation, several scenarios of hydraulic jumps were simulated first. The numerical results has shown to quantitatively conform the analytical formula of bore height and velocity, two parameters that are important to characterize a bore wave. Further, by adopting a model that incorporates the non-hydrostatic pressure, our simulation

show the appearance of an undular bore accompanying the shock front. Finally, using tidal current data measured along Kampar River estuary, our simulation using the actual river topography can show the appearance of tidal bore Bono. Our simulations were shown to be in fair agreement with the measurement.
Keywords: hydraulic jump, undular bore, Saint-Venant equations, non-hydrostatic numerical scheme

Title: Repulsive 2-body correlation function in two-dimensional point-vortex system evidenced by numerical simulatin on PEZY-SC2
Speaker: Yuichi Yatsuyanagi (Shizuoka University)
Author(s): Yuichi Yatsuyanagi(Shizuoka University), Hiroshi Ohtsuka(Kanazawa University), Tadatsugu Hatori(NIFS), Toshikazu Ebisuzaki(RIKEN) and Aklio Sanpei (Kyoto Institute of Technology)
Abstract: In a (neutral) plasma Debye shield is a dielectric phenomenon associated with counter-charged particles. Although there is no counter-charged particles in non-neutral pure electron plasmas, Debye shield is accomplished by a density depression, i.e. by the formation of a hole. To reveal its mechanism, we study a 2-body correlation function in two-dimensional point vortex system as the dynamics of the electrons in the perpendicular plane to the strong magnetic field is identical with the two-dimensional Euler equation, which can be solved by the point vortex model. The obtained solution shows a repulsive correlation in certain range of distance, which corresponds a hole formation. To evidence the analytical result, numerical simulations of two-dimensional point vortex simulations with 100-1000 vortices are performed on a brand-new supercomputer, PEZY-SC2 at RIKEN. I will mainly present numerical result.
Keywords: point vortex simulation, numerical simulation, PEZY-SC2, non-neutral plasma experiments

Title: On the precise structure of the impulse response for solutions of two-dimensional Liouville type equations
Speaker: Hiroshi Ohtsuka (Kanazawa University)
Author(s): Tadatsugu Hatori (NIFS), Hiroshi Ohtsuka (Kanazawa Univ.), Yuichi Yatsuyanagi (Shizuoka Univ.)
Abstract: Motivated by the experimental facts, the formation of a hole, observed in confined non-neutral plasma, we are interested in the impulse response for solutions of two-dimensional Liouville type equations, that is, the asymptotic behavior for solutions of Liouville type equations with one singular source as the singularity vanishes. The solutions of Liouville type equations are considered to represent the mean field approximation of the density of particles in non-neutral plasma. In

this talk, we will present several facts derived from the exact solution for singular Liouville type equation established by Prajapat and Tarantello (2001) and will discuss some phenomenological meaning of them.
Keywords: Liouville type equation, singular Liouville type equation, non-neutral plasma experiments

Parallel Session 2 (23, June)

Title: Transmission dynamics of two strains of porcine reproductive and respiratory syndrome virus: cross-immunity, virulence, and vaccination
Speaker: Phithakdet Phoongurn (Mahidol University)
Author(s): Phithakdet Phoo-Ngurn and Farida Chamchod
Abstract: Porcine reproductive and respiratory syndrome is an important swine disease that causes reproductive failure and respiratory problems in pigs. The disease leads to significant economic losses to the swine industry. In this present study, a mathematical model for describing transmission dynamics of two different strains of porcine reproductive and respiratory syndrome virus (PRRSV) with cross-immunity was developed to investigate the effects of cross-immunity and invasion of a highly pathogenic strain. We found that cross-immunity and vaccination strategies play an import role in determining severity of an outbreak, prevalence of PRRSV, and invasion of a new strain.
Keywords: PRRSV, mathematical modeling, cross-immunity, transmission dynamics

Title: Modeling the spread of rabies among vagrant dogs: short- and long-term incubation, seasonality, and vaccination
Speaker: Pirommas Techitnutsarut (Mahidol University)
Author(s): Pirommas Techitnutsarut, Farida Chamchod
Abstract: Rabies is a fatal neurological disease that is endemic in many parts of the world. The disease generally affects mammals but domestic dogs are the main reservoir. In this study, we developed a mathematical model that incorporates two types of an incubation period, short- and long-term, to investigate the spread of rabies among vagrant dogs. By taking seasonality in transmission and recruitment into account, we predict that outbreaks of rabies among vagrant dogs peak at every dry season. Moreover, we found that an incubation period may delay outbreaks and vaccination may help reduce the prevalence of rabies.
Keywords: rabies, incubation period, vagrant dogs, transmission dynamics, seasonality

Title: Traveling wave solutions of an epidemic model with free boundary
Speaker: Takeo Ushijima (Tokyo University of Science)
Author(s): Yoichi Enatsu, Emiko Ishiwata, Takeo Ushijima
Abstract: Free boundary problems are recently used to model phenomena of biological invasion for species such as migration into a new habitat (see, e.g., Du & Lin (2010) and references therein). These ideas are also applied to epidemic models in order to investigate the front motion of infected individuals spreading into a region where disease is not prevalent (see, e.g., Kim et al. (2013)). In this talk, we consider a simple diffusive epidemic model. Hosono & Ilyas (1995) and Kaellen (1984) proved the existence of traveling wave solutions of the model. We extend the results in Kaellen (1984) to the model with free boundary, namely we prove the existence of a traveling wave solution. For free boundary problems, solutions propagating with the same profile and the same speed are also called semi wave solutions in some literatures, e.g., Du & Lou (2015) and Kawai & Yamada (2016). We numerically investigate the existence and non-existence region of the semi wave with respect to given parameter values in the model. We also observe the front motion of the model with free boundary.
Keywords: free boundary, epidemic model

Parallel Session 3 (24, June)

Title: Global bounded variation solutions describing Fanno-Rayleigh fluid flows in nozzles
Speaker: Shih-Wei Chou (National Central University)
Author(s): Shih-Wei Chou, John M. Hong, Bo-Chih Huang and Reyna Quita
Abstract: In this talk, we investigate the initial-boundary value problem of compressible Euler equations including friction and heating that model the transonic Fanno-Rayleigh flows through symmetric variable area nozzles. In particular, the case of contracting nozzles is considered. A new version of a generalized Glimm scheme (GGS) is presented for establishing the global existence of entropy solutions with bounded variation. The extended Glimm-Goodman's type of wave interaction estimates are investigated to determine the stability of the scheme and the positivity of gas velocity that results in the existence of the weak solution. Moreover, a quantitative relation between the shape of the nozzle, friction, and heat is proposed for the global existence result in the contracting nozzle. Numerical simulations of the contraction-expansion and expansion-contraction nozzles are presented to validate the scheme.
Keywords: Fanno-Rayleigh flows, transonic flow, compressible Euler equations, entropy solutions, initial-boundary value problem, Riemann problem, boundary Riemann problem, generalized Glimm scheme

Title: Multiscale reconstruction algorithm in time harmonic viscoelastic equation for MR elastography
Speaker: Suguru Maekawa (Kyoto University)
Author(s): Suguru Maekawa
Abstract: In this talk, we will discuss on coefficient recostruction of time harmonic viscoelastic equation for MR Elastography, which is one of modalities to identify stiffness of human tissue. We will consider a minimizing problem of a certain cost function as a formularization for reconstruction. For this problem we can apply gradient method. However the results by some conventional gradient methods are unreliable. In this presentation, we will propose a multiscale reconstruction algorithm for fast and reliable reconstruction.
Keywords: MR elastography, time harmonic viscoelastic equation, coefficient reconstruction

Title: An ε-Stokes problem with several pressure boundary conditions
Speaker: Kazunori Matsui (Kanazawa University)
Author(s): Masato Kimura, Kazunori Matsui, Adrian Muntean, Hirofumi Notsu
Abstract: We propose an ε-Stokes problem connecting the classical Stokes problem and the corresponding pressure-Poisson equation using one parameter $\varepsilon > 0$. We show that the solution to the ε-Stokes problem, convergences as ε tends to 0 or ∞ to the Stokes and pressure-Poisson problem, respectively. We also establish error estimates in suitable norms between the solutions to ε-Stokes problem, pressure-Poisson problem and Stokes problem, respectively. Numerical results illustrating our analysis work are presented.
Keywords: Stokes problem, pressure-Poisson equation, asymptotic analysis, finite element method

Parallel Session 4 (24, June)

Title: Two-layer non-hydrostatic scheme for simulations of wave runup
Speaker: Maria Artanta Ginting (Institut Teknologi Bandung)
Author(s): M. A. Ginting, S. R. Pudjaprasetya, D. Adytia
Abstract: A non-hydrostatic model is implemented to simulate a wave runup. This model is approximated by resolving the fluid depth into two-layer with equal depths. The equations are then solved by applying the staggered grid scheme. For wave generation mechanism the embedded influxing as proposed by Liam et.al. (2014) is adopted. The first benchmark test was simulating a periodic wave runup of Carrier and Greenspan. Good agreement between numerical result and the

analytical formula are obtained for both; surface profile as well as the moving shoreline. Further, runup simulation were conducted for solitary waves climbing up a sloping beach, following the experimental set up by Synolakis. Two simulations with solitary waves of small and large amplitudes were conducted. Again good agreement were obtained, especially for the prediction of run up height.
Keywords: non-hydrostatic model, wave runup, embedded influxing

Title: The collective motion of camphor disks in a annular water channel
Speaker: Mamoru Okamoto (Hokkaido University)
Author(s): Mamoru Okamoto, Masaharu Nagayama, Satoshi Nakata
Abstract: Billiard and jamming like motions of camphor papers placed over water have recently been observed in annular water channels. We investigate the mechanisms of these motions by constructing a mathematical model for the camphor system. In particular, we study the motion of two camphor papers by means of numerical simulation and mathematical analysis. As a result of our investigations, we have uncovered various morphologies of the camphor disk motions. Moreover, we were able to obtain the existence and stability of rotational and cluster motions numerically, by means of computer aided analysis. We have found that the billiard-like phenomenon is caused by the coexistence of uniform rotational and symmetrical oscillatory motions, and that the jamming phenomenon arises from a Hopf bifurcation of the uniform rotating motion.
Keywords: mathematical modeling, self-propelled system, collective motion

Title: The effect of cubic basic concentration gradient on the onset of double-diffusive convection in micropolar fluids
Speaker: Ruwaidiah Idris (Universiti Malaysia Terengganu)
Author(s): Ruwaidiah Idris
Abstract: In this paper, the linear stability analysis is perform to study the effect of cubic basic concentration gradient to the onset of double-diffusive convection in micropolar fluid. The influence of various parameters on the onset of convection has been analyzed. It is observed that, the basic concentration gradient has minimize influence to the suspended particle then destabilize the system.
Keywords: cubic concentration, double-diffusive, micropolar fluid

Title: Energy-preserving model reduction for Poisson systems
Speaker: Yuto Miyatake (Osaka University)
Author(s): Yuto Miyatake
Abstract: Model reduction methods have been widely used to solve very large dynamical systems efficiently. The basic idea of the methods is to approximate such

large systems with much lower and simpler ones such that the reduced systems capture the given solution data as precise as possible. However, most conventional approaches could destroy other aspects of the original system. This motivates us to consider new types of morel reduction methods that can keep some underlying structures of the problem. In the last few years, the main focus has been put on the symplecticity or energy-preservation of Hamiltonian systems. In this talk, keeping in mind that discretizing Hamiltonian PDEs often leads to Poisson systems, we propose an energy-preserving model reduction technique for Poisson systems. We also show numerical results to confirm the efficiency taking the KdV equation as our working example.
Keywords: structure-preserving numerical methods, model reduction

Parallel Session 5 (24, June)

Title: Riemannian optimization methods for IEPs
Speaker: Xiao-Qing Jin (University of Macau)
Author(s): Xiao-Qing Jin
Abstract: In this talk, we use the Riemannian inexact Newton method to solve some inverse eigenvalue problems from matrix computations. Both theoretical and numerical results will be given.
Keywords:

Title: Continuation Methods for Computing Eigenpairs of Nonnegative Tensors
Speaker: Yueh-Cheng Kuo (National university of Kaohsiung)
Author(s): Yueh-Cheng Kuo, Wen-Wei Lin, Ching-Sung Liu
Abstract: In this talk, a homotopy continuation method for the computation of nonnegative Z-/H-eigenpairs of a nonnegative tensor is presented. We show that the homotopy continuation method is guaranteed to compute a nonnegative eigenpair. Additionally, using degree analysis, we show that the number of positive Z-eigenpairs of an irreducible nonnegative tensor is odd. A novel homotopy continuation method is proposed to compute an odd number of positive Z-eigenpairs, and some numerical results are presented.
Keywords: continuation method, nonnegative tensor, Z-eigenpair

Title: Structure-preserving flows of symplectic matrix pairs
Speaker: Shih-Feng Shieh (National Taiwan Normal University)
Author(s): Shih-Feng Shieh
Abstract: We construct a nonlinear differential equation of matrix pairs that is

invariant (the in a class of symplectic matrix pairs. Its solution also preserves invariant subspaces on the whole orbit (the Eigenvector-Preserving Property). Such a flow is called a structure-preserving flow and is governed by a Riccati differential equation (RDE) for some suitable Hamiltonian matrix. In addition, Radon's lemma leads to an explicit form of this equation. Therefore, blow-ups for the structure-preserving flows may happen at a finite t. To continue, we then utilize the Grassmann manifolds to extend the domain of the structure-preserving flow to the whole $\mathbb{R}$ subtracting some isolated points. On the other hand, the Structure-Preserving Doubling Algorithm (SDA) is an efficient numerical method for solving algebraic Riccati equations and nonlinear matrix equations. In conjunction with the structure-preserving flow, we consider the two special classes of symplectic pairs corresponding algorithms SDA-1 and SDA-2. It is shown that at $t = 2^{k-1}, k \in \mathbb{Z}$ this flow passes through the iterates generated by SDA-1 and SDA-2, respectively. Therefore, the SDA and its corresponding structure-preserving flow have identical asymptotic behaviors, including the stability, instability, periodicity, and quasi-periodicity of the dynamics.
Keywords:

Room 64 (Building No.6)

Parallel Session 1 (23, June)

Title: A self-propelled particle model for representing collective cell migrations
Speaker: Takamichi Sushida (Hokkaido University)
Author(s): Takamichi Sushida, Hitomi Mori, Sumire Ishida, Kazuya Furusawa, Hisashi Haga, and Masakazu Akiyama
Abstract: Recently, in the fruiting body formation of Dictyostelium discoideum (D. discoideum) and the somite formation of the zebrafish covered with the basement membrane, since collective rotational migrations are observed when cellular tissues elongate, the relationship between collective rotational migrations and tissue elongations has been attracted. In this study, in order to describe cellular mechanisms causing collective rotational migrations, we construct a mathematical model assuming typical cellular mechanisms. As a result of numerical simulations, when individual cells release diffusible substances such as cyclic AMP of D. discoideum, it is shown that chemotaxis induces collective rotational migrations robustly. In addition, such as cells in a somite of the zebrafish, when cell clusters are covered with the basement membrane, by representing the membrane using Phase-field method, it is shown that the repulsive force from the membrane occurs collective rotational migrations. In particular, by a nonlinearity of the magnitude of driving force and the speed of cell migration introducing into our model, we show that switch rotational migrations which repeat inversion of rotational direction occur. Moreover, by changing the cellular culture environment taking numerical results of our model as a hint, we discover a new experimental result that cells exert switch rotational migrations.
Keywords: collective cell migration, morphogenesis, self-propelled particle model, phase-field method, numerical simulation

Title: A two-item inventory-dependent demand model with return and all-units discount
Speaker: Dharma Lesmono (Universitas Katolik Parahyangan)
Author(s): Dharma Lesmono, Taufik Limansyah, Neilshan Loedy
Abstract: In this paper, we propose a two-item inventory model with deterministic demands, return and all-units discount. We consider a retailer who sells two products, where demands of these two products are deterministic and have inventory-dependent demand feature in the sense that demands are related to the number of inventory available at certain time. In developing our model, we assume that supplier offers quantity discount to the retailer, these two products have different constant deterioration rates and retailer can return some of unsold products

at some costs near the end of the period. The objective of the model is to find the optimal return time and the optimal ordering quantity that minimizes the total cost for the retailer. In dealing with this model, we consider two replenishment policies, namely the individual and joint replenishment policy. Some numerical examples are given to illustrate our model and to compare the individual and joint replenishment policies by considering quantity discount or not in terms of their total costs. We found that joint replenishment policy by considering quantity discount mostly gives the minimum total cost.

Keywords: inventory-dependent demand model, two-item, deterioration, all-units discount

Title: Mathematical model of transmission dynamics and optimal control strategies for 2009 A/H1N1 influenza in the Republic of Korea

Speaker: Soyoung Kim (Konkuk University)

Author(s): Soyoung Kim, Jonggul Lee, and Eunok Jung

Abstract: A mathematical model for the transmission dynamics of the 2009 A/H1N1 influenza epidemic in the Republic of Korea is developed. The simulation period is separated into three consecutive periods based on the government's intervention strategies: the nonpharmaceutical strategy is used during Period 1. The nonpharmaceutical and antiviral strategies are executed during Period 2 and the vaccine strategy is added during Period 3. During Period 1, we estimate the reduction in the transmission rate due to the government's intervention policies as a difference between the data-fitted and uncontrolled transmission rate that is derived from the basic reproductive number, R0, of the model without intervention. This quantified reduced transmission rate is used as an upperbound of the nonpharmaceutical control for studying optimal control strategies, which is a new approach for determining the realistic upperbound of control. In this study, we also explore the real-time prediction of incidence using the mathematical model during the early stage of the epidemic. We investigate the impact of vaccination coverage and timing with respect to the cumulative incidence. The result implies that early vaccination plays a significant role for preventing the epidemic.

Keywords: pandemic influenza, mathematical model, vaccine strategy, optimal control, predicition

Title: Transmission dynamics of methicillin-resistant Staphylococcus aureus (MRSA) among patients in an intensive care unit and nursing home residents: optimal control efforts and influences of patient and resident numbers

Speaker: Farida Chamchod (Mahidol University)

Author(s): Farida Chamchod

Abstract: Owing to advancing age, chronic illness, and scarce resources, nursing homes have been viewed as an important reservoir of methicillin-resistant Staphylococcus aureus (MRSA). As residents are frequently transferred from nursing homes to hospitals, MRSA can possibly be repeatedly introduced into those two interconnected institutions. In this study, a mathematical model was developed to investigate the effects of patient sharing, patient turnover, and control efforts on the prevalence levels of MRSA in nursing homes and hospitals. The results help underline how characteristics of nursing homes and residents, and the presence of hospitalized residents can lead to the increased prevalence of MRSA. Moreover, control efforts towards nursing home residents in both settings may help reduce the overall prevalence of MRSA.
Keywords: MRSA, transmission dynamics, mathematical modeling, optimal control

Parallel Session 2 (23, June)

Title: A mathematical modeling of sensory receptors in skin toward understanding a tactile illusion
Speaker: Masaaki Uesaka (Hokkaido University)
Author(s): Masaaki Uesaka, Masafumi Nakatani, Zixia Zhao, Hiroyuki Kitahata, Masaharu Nagayama
Abstract: Tactile sensation provides reliable information on the geometric properties of objects and texture of a surface. However, it is not necessarily faithful to actual geometric properties and this discrepancy is recognized as the tactile illusion. We approach "fishbone tactile illusion", which is one of such illusion by using the mathematical model. Our model simulates a set of process of active potential firing of nerves when human finger touches the texture and consists of the Maxwell model of viscoelastic material and the model of mechanoreceptors in human skin and Hodgkin-Huxley model. We discuss the validity of the model and show the simulation results.
Together with this model, we performed a psycological experiments corresponding to our mathematical model. Comparing this experiment results and simulation results, we propose the interpretation between the intensity of illusion and simulation results.
Keywords: fishbone tactile illusion, mathematical modeling, tactile sensation

Title: Effects of drug regimen and drug-induced death rate on a avascular tumor: a mathematical modeling study
Speaker: Chayasin Saetia (Mahidol University)

Author(s): Chayasin Sae-Tia, Farida Chamchod
Abstract: An aim of this present study is to investigate factors that may influence drug and cell kinetics during cancer chemotherapy in a patient. A mathematical model is based on a system of ordinary and partial differential equations for describing cell velocity, drug concentration, and tumor radius. We found that strategies of a drug regimen and drug-induced death rate may affect the tumor radius outcome after the chemotherapy. Our work also suggests possible treatment regimens that may be useful to help design an efficient strategy for the cancer therapy.
Keywords: drug delivery, drug kinetics, cancer modeling, cancer therapy

Title: The effect of spatial heterogeneity on the viral dynamics during antiretroviral treatment
Speaker: Chang-Yuan Cheng (National Pingtung University)
Author(s): Chang-Yuan Cheng
Abstract: Classical virus models were proposed based on the concept of well-mixture within the host. However, during a drug treatment, the drug concentration may be low in some regions (drug sanctuary) and then the spatial heterogeneity can be an issue in the research. We explore an virus model in heterogeneous environments, which imitates the complexity of the human body. How the heterogeneous environments affect the the drug efficacy and then the viral dynamics are significant in administrating a drug therapy. Especially, it is interesting to study the optimal phase difference between multi-drug therapy and establish the optimal distribution of drugs in the multi-compartmental environment.
Keywords: viral dynamics, spatial heterogeneity

Parallel Session 3 (24, June)

Title: Backward bifurcation of a network-based SIS epidemic model with saturated treatment function
Speaker: Chun-Hsien Li (National Kaohsiung Normal University)
Author(s): Yi-Jie Huang, Chun-Hsien Li
Abstract: In this talk, we consider a network-based SIS epidemic model with saturated treatment function to characterize the saturation phenomenon of the limited medical resources. In this model, we first obtain a threshold value R0 and then we show that a backward bifurcation occurs under some condition. More precisely, the saturation treatment function leads to a backward bifurcation. In this case, R0¡1 is not sufficient to eradicate the disease from the population. Numerical experiments are provided to support the theoretical results.
Keywords: complex network, epidemic model, saturated treatment function,

backward bifurcation

Title: Simulation of influenza A/H5N1 in host
Speaker: Hidenori Yasuda (Josai University)
Author(s): Hidenori Yasuda, Shohji Kawachi, Kazuo Suzuki
Abstract: To elucidate the pathogenesis associated with highly pathogenic avian influenza A/H5N1 infection, simulations were conducted using a mathematical model of mice. Simulated results suggest antibody therapy showed prominent improvement.
Keywords: highly pathogenic avian influenza A/H5N1, mathematical model, antibody therapy, leukopenia

Title: 3D image morphing by using large deformation diffeomorphic metric map with discrete Green kernel
Speaker: Chin-Tien Wu (National Chiao-Tung University)
Author(s): Chin-Tien Wu
Abstract: Major challenges in 3D image processing includes (1) geometry processing, (2) texture mapping (3) image morphing and (4) managing huge amount of data in 3D, etc. In this talk, we shall briefly address these problems and focus on discussing issues in 3D image morphing. To manage 3D image data, Gu and Yau proposed to compress the data using mean curvature H and conformal factor $lambda$. We have followed Gu and Yau's idea on 3D video compressing where key frames in the video are selected and 3d images between key frames are obtained by interpolation according to the deformation map built in the conformal parameters $(H,lambda)$ space. In order to capture detail geometric features and avoid mesh tangling, an energy-minimizing conformal parameterization is proposed. Moreover, a discrete large deformation diffeomorphic metric map (DLDDMM) is introduced to generate the geometry and texture images on the init disk. The discrete Green kernel in DLDDMM is computed by finite element method. We shall also briefly review the conformal parameterization and LDDMM methods. Finally, some of our numerical results will be presented.
Keywords: conformal parameterization, LDDMM, 3d image

Parallel Session 4 (24, June)

Title: Hopf-Fold bifurcation in a delayed Hindmarsh-Rose model
Speaker: Shyanshiou Chen (National Taiwan Normal University)
Author(s): ShyanShiou Chen
Abstract: In this talk, we will show the existence of the travelling waves in a

Hindmarsh-Rose-type (HRT) equation with delay and spatial terms by fining their heteroclinic orbits. A Hopf bifurcation had been studied for the model with delay term and without spatial term. However, it is not enough to study a single neuron since a population of neurons has been thought of a function to cooperate with another population. Hence, to understand dynamics of a single population seems to be an important way to realize some of possible cooperation. For the purpose, one of schemes is to study their Hopf and Fold-Hopf (FH) bifurcation which is applied to show the existence of periodic orbits and heteroclinic orbits for a single population. By the bifurcation theory in functional differential equation, the HRT will be reduced in a normal form with abstract ordinary differential equation and the center manifold theory. Then some conditions of parameters for the existence of Hopf and FH bifurcation are given.
Keywords: bifurcation, neuron

Title: Self-sustained shear driven dynamos
Speaker: Kengo Deguchi (Monash University)
Author(s): Kengo Deguchi
Abstract: A large Reynolds number matched asymptotic expansion is concerned for nonlinear 3D magneto-hydrodynamic (MHD) dynamo states driven by a shear. The theory has emerged out of a nice combination of the vortex-wave interaction theory by Hall & Smith (1991) and the resonant absorption theories for Alfv ?en and cusp waves, developed in solar physics community. The dynamos are self-sustained, in the sense that they are maintained without any linear instability mechanism of the basic flow. There are two classes of dynamos can be sought. The first class of dynamos appears when we consider the similar scaling for both hydrodynamic and magnetic fields. In this case the dynamos must be supported by a small external magnetic field, but induce much bigger magnetic field. The external magnetic field can actually be switched off to yield the second class of dynamos, which is now purely driven by shear. The theory is compared with the unstable invariant solutions of the full MHD equations at finite Reynolds numbers. The dynamo solutions can be found by continuing the hydrodynamic solution branch of plane Couette flow. Using an external magnetic field as a homotopy parameter, the dynamo solutions can indeed be found even at zero-external magnetic field condition. Their asymptotic development can be excellently explained by the asymptotic theory.
Keywords: magnetohydrodynamics, asymptotic analysis, invariant solutions

Title: An invariant for the comparison of composition operators for reproducing kernel Hilbert spaces
Speaker: Isao Ishikawa (RIKEN Center for Advanced Inteligent Project / Keio University)
Author(s): Keisuke Fujii, Masahiro Ikeda, Yuka Hashimoto, Yoshinobu Kawahara
Abstract: Classifying time series datas (sequences in the Euclid space) is important problem for the real world. Our task is giving a "good" mathematical invariant to classify them. Dynamical system is one of the effective mathematical model to analyze them, namely, we assume each time series data is generated by a dynamical system. In terms of the theory of reproducing kernel Hilbert spaces (RKHS), the time series datas and the dynamical systems are regarded as sequences of vectors and composition operators in RKHS, respectively. We define an invariant to measure "distance" between two dynamical systems (composition operators) in the framework of RKHS. This invariant has an explicit formula which can be easily implemented, on the other hand it includes mathematically difficult problems such as the bounded-ness of composition operators. This study is the joint work with Ikeda (RIKEN AIP/ Keio Univ), Hashimoto (RIKEN AIP/ Keio Univ), Fujii (RIKEN AIP) and Kawahara (RIKEN AIP/ Osaka Univ.).
Keywords: dynamical system, reproducing kernel Hilbert space

Title: Topological data analysis of across-sniff habituation in olfactory cortex
Speaker: Keiji Miura (Kwansei Gakuin University)
Author(s): Yuki Usui, Ayaka Onishi, Keiji Miura
Abstract: Although it is well known that animals habituate to odors across sniffs, its neural basis is still unclear. While many neurons we recorded from the olfactory cortex (anterior piriform cortex) decreased firing rates for the continued odor stimulation, some increased firing rates. Therefore, it is necessary to characterize the responses dynamically as a whole to understand the habituation in the olfactory cortex. The principal component analysis revealed that the neural responses at the first and second sniffs after the odor delivery looked different. In fact, the topological data analysis revealed that the orbit of the neural responses for the two sniffs did not necessarily repeat the same loop twice. These findings suggest that the olfactory cortex could underlie the odor habituation across sniffs.
Keywords: topological data analysis, neuroscience

Parallel Session 5 (24, June)

Title: Fractal structure of a nonlinear cellular automaton and the singular function

Speaker: Akane Kawaharada (Kyoto University of Education)
Author(s): Akane Kawaharada, Takao Namiki

Abstract: The authors study the relation between two-dimensional symmetric elementary cellular automata and the singular function. It is well known that each linear cellular automaton with prime number of states has its “limit set” (a limit of a series of spatio-temporal patterns contracted by time), however, in case of nonlinear automata, the existence of a limit set has not been reported even if a case study. In this talk, the authors show the existence of a nonlinear cellular automaton which has the limit set and calculate the fractal dimension (the box-counting dimension) of the boundary of its limit set. We also show that the spatio-temporal patterns of the automaton are characterized by the singular function that is a fractal curve.

Keywords: cellular automaton, fractal geometry, singular function

Title: Mathematical modeling for stabilization of stratum granulosum and epidermal desquamation

Speaker: Takeshi Gotoda (Hokkaido university)
Author(s): Takeshi Gotoda, Masaaki Uesaka, Yusuke Yasugahira, Yasuaki Kobayashi, Hiroyuki Kitahata, Mitsuhiro Denda, Masaharu Nagayama

Abstract: The stratum granulosum is a thin layer of cells migrating from the stratum spinosum and found just below the stratum corneum. Tight junctions occur in the second layer of the stratum granulosum and plays a crucial role in the functional barrier in the epidermal together with the stratum corneum. Using a mathematical model of the epidermis, we propose a stabilization mechanism of the stratum granulosum. We show that, in the mathematical model, the stratum granulosum is formed and its layer structure is maintained stably by assuming that a stimulant, which promotes the differentiation process of cells, is released when cells undergo cornification. We also introduce our trial model for understanding the mechanism of occurence of tight junctions in the stratum granulosum from the viewpoint of the mathematical modeling. Regarding the epidermal desquamation, we propose a mathematical model of the stratum corneum with the desquamation process, considering the proteases that play a central role in the degradation of macula adherens.

Keywords: mathematical modeling, numerical simulation, stratum granulosum, desquamation of stratum corneum

Title: Wave transmission coefficient of trapezoidal submerged breakwater
Speaker: Ikha Magdalena (Institut Teknologi Bandung)
Author(s): I. Magdalena
Abstract: In this research, a wave transmission coefficient of the trapezoidal breakwater is derived analytically. We use shallow water equations to study the damping mechanism that is explained by the transmission coefficient. Numerically, we solve the equations using finite volume method on a staggered grid. Moreover, our numerical method is free from damping error that is very important in this case, because we want to get the actual amplitude reduction only from the trapezoidal breakwater. For validation, we compare our numerical result with the analytical solution.
Keywords: wave transmission coefficient, trapezoidal breakwater, shallow water equations, staggered grid

Room B (Building No.6)

Parallel Session 7 (25, June)

Title: Delay-induced blow-up in some oscillation models
Speaker: Tetsuya Ishiwata (Shibaura Institute of Technology)
Author(s): Emiko Ishiwata, Tetsuya Ishiwata, Yukihiko Nakata
Abstract: It is well-known that time-lags or histories sometimes play a essential role in the phenomena and thus many mathematical model with delay-effects are studied mathematically and numerically. It is also well-known that the delay-effects cause an instability or an oscillatory. In this talk we consider the effects of time-delay for such instabilities from the viewpoint of a finite time blow-up of the solutions and show "delay-induced blow-up" phenomena for a very simple oscillation model with a constant delay. We also show the emergence of infinity many periodic solutions, while the non-delay system has only one stable limit cycle. Finally we show some numerical examples and give our observations.
Keywords: delay differential equation, blow-up, periodic solution

Title: Dipole problems for the one-dimensional thin-film equation
Speaker: Mark Bowen (Waseda University)
Author(s): Mark Bowen, Thomas P. Witelksi, J. R. King, J. Hulshof
Abstract: We investigate the dynamics of a thin liquid film spreading in a semi-infinite domain x¿0, so that x=0 corresponds to an edge over which fluid can drain. In particular, we investigate self-similar solutions of the one-dimensional "thin-film" equation (which is a fourth order degenerate parabolic equation) on the half-line $x > 0$. Such solutions typically feature an anomalous exponent and are said to be similarity solutions of the second-kind (generally requiring the numerical solution of a nonlinear eigenvalue problem in order to obtain the scaling exponent); when there are no free exponents, the self-similar solution is of the first kind. In order to make progress, we employ a four-dimensional phase-space analysis, matched asymptotic expansions and numerical simulations.
We will also discuss the extension of our results to (non-physical) self-similar solutions featuring sign-changes and describe how classes of first and second-kind similarity solutions interact. We will also comment on the difficulties of obtaining sign-change solutions to degenerate diffusion equations.
Keywords: thin-film, degenerate parabolic equation, self-similar solutions

Room C (Building No.6)

Parallel Session 7 (25, June)

Title: Cavitation and corresponding temperature distribution in soft tissue during HIFU thermal therapy
Speaker: Ekaterina Zilonova (National Taiwan University)
Author(s): E. Zilonova, M. Solovchuk, T.W.H. Sheu
Abstract: High intensity focused ultrasound is a rapidly developing medical technology for fully noninvasive surgery. Nowadays, it has a wide range of therapeutic applications (such as tumor ablation in different parts of the body, acoustic hemostasis, drug and gene delivery, treatment of neurological disorders). High intensity waves propagating through the medium may lead to the formation of cavities, which can be filled with gas or vapor. This effect is known as acoustic cavitation. The present study investigates the cavitation presence impact on the HIFU thermal therapy process in soft tissue. For these purposes, a new coupled mathematical model is introduced that incorporates bubble dynamics model, viscoelastic model for soft tissue simulation, two temperature models for bubble's interior and exterior and diffusion model for the calculation of vapor mass concentration within the bubble. Dependency of the bubble dynamics on soft tissue viscoelastic properties has been investigated. The continuous temperature distribution inside and outside the oscillating bubble is going to be presented. The impact of the vapor mass flux effect on the temperature distribution has been studied. The observed significant temperature elevation in tissue outside the bubble emphasizes that the presence of cavitation during thermal therapy can't be ignored.
Keywords: cavitation in soft tissue, temperature distribution, vapor mass diffusion, high intensity focused ultrasound, heat deposition

Title: Delay-embedding time-series analysis based on Sturm-Liouville framework for dynamical reconstruction
Speaker: Naoto Nakano (Kyoto University)
Author(s): Naoto Nakano
Abstract: Delay embedding is well-known for non-linear time-series analysis, and it is used in several research fields. Takens theorem ensures validity of the delay embedding analysis: embedded data preserves the topological properties possessed by the original dynamics so long as one embeds it within some phase space of sufficiently large dimension. This means that, for example, an attractor can be reconstructed by the delay coordinate system topologically. However, configuration of embedded data may easily vary with the delay width and the delay dimension,

namely, "the way of embedding". Here, we investigate the mathematical structure of the framework of delay-embedding to provide Ansatz to choose the appropriate way of embedding, in order to utilise for time-series prediction. In short, mathematical theories of the Hilbert-Schmidt integral operator and the corresponding Sturm-Liouville eigenvalue problem underlie the framework. We will show some numerical results of the present method.
Keywords: delay-embedding, dynamical reconstruction, time-series analysis, Sturm-Liouville problem, data-driven dynamical modelling