The 6th International Conference on Scientific Computing and Partial Differential Equations

On the Occasion of Roland Glowinski's 80th Birthday

(SCPDE2017)

June 5-8, 2017

Hong Kong Baptist University

香港浸會大學 HONG KONG BAPTIST UNIVERSITY

Department of Mathematics

HKMS

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Special Issue

- A special issue based on this conference will be published by the international journal: Methods and Applications of Analysis;
- Guest editors: Patrick Le Tallec, Jacques Rappaz, Xiao-Ping Wang and Xiaoming Yuan;
- Deadline for submission: 31 October 2017;
- Format: full paper.

All published research articles in this special issue, after initial editor screening, will undergo rigorous refereeing by independent expert referees. Manuscripts should be in PDF format and be submitted directly via email: maaedit@ims.cuhk.edu.hk

Program in Detail

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15:15-16:00	Felix Kwok Title: On the Time-domain Decomposition of Optimal Control Problems
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Title and Abstract

Martin Berggren, Umeå University, Sweden

Title: On the Use of Nonlinear Filters and Morphological Operators for Topology Optimization of Microwave Devices

Abstract: A standard way of carrying out design optimization is known as density-based topology optimization. In this approach, a design variable with values between zero and unity, which often can be thought about as a "density", is determined at each point in the region subject to design. The extremal values of the design variable indicate that corresponding point is occupied solely by one of two materials, say material or void. The desired end result is usually that the design variable attains either of the extreme values at each point. However, due to the use of gradient-based optimization methods, which need the design variable to be defined in a continuum of values, some presence of intermediate values is tolerated, at least prior to convergence of the algorithm. The end result will be a function, visualized as a pixel or voxel map, which can be viewed as an image of the optimized device.

An early example of this approach was presented by Glowinski at a symposium held at Ecole Polytechnique in 1983 (published as Numerical Simulation for some Applied Problems Originating from Continuum Mechanics, published in 1984 by Springer in the volume *Trends and Applications of Pure Mathematics to Mechanics*). This approach has developed into something of a success story and is presently used in the design of advanced mechanical components, particularly in the automotive and aeronautical industries. For instance, wing sections of both the Airbus A380 and the Boeing 787 Dreamliner were designed using density-based topology optimization.

Since the end result of such an optimization is a high-dimensional image-like density function—these days it can contain millions or even billions of pixels or voxels—image-processing-like tools are increasingly exploited in algorithms for density-based topology optimization. A standard tool, since a long time, is the image-blurring linear filter, which is used to deal with issues of well-posedness and numerical stability. A more recent development is the use of nonlinear filtering operations and the exploitation of the basic operators of *mathematical morphology*, that is, the erosion, dilation, opening, and closing operators.

Density-based topology optimization methods are by now quite mature for the design of elastic structures, but substantially less effort has been directed towards electromagnetic applications such as the design of metallic microwave devices. The main reason appears to be the *ohmic barrier* problem, which emanates from the fact that materials with zero or infinite conductivity are lossless, but materials with a finite conductivity yield substantial, usually unwanted ohmic losses when interacting with electromagnetic waves. When the optimization problem is formulated in a way that encourages low-loss devices, the ohmic barrier will make it difficult for a gradient-based algorithm to switch a region in the design domain continuously between zero and infinite conductivities, since any change from the extremal values will degrade performance. Here we show how nonlinear filters based on *integral f* (or quasiarithmetic) *means* can be used for two purposes. First, such a filter together with a continuation procedure can be used to manage the ohmic barrier. Second, a nonlinear filter can be used to approximate morphological operators in order to avoid scattered material distributions and scattered holes in the material. The case study for which these effects are demonstrated is the design of radiating surfaces in a transitional element between a coaxial cable and a wave guide operating in the microwave regime.

Alexandre Caboussat, Haute Ecole de Gestion de Genève / University of Applied Sciences Western Switzerland, Switzerland

Title: Numerical Approximation of the 3D Monge-Ampère Equation and Related Problems

Abstract: We consider the Dirichlet problem for the real elliptic Monge-Ampère equation for arbitrary domains in three space dimensions. A least-squares approach is developed via a relaxation algorithm. We advocate an iterative approach that allows to solve a sequence of linear variational problems and of algebraic eigenvalue problems. Mixed, low order, finite element approximations are used for the discretization.

The linear variational problems are solved with a conjugate gradient algorithm. Unlike the Monge-Ampère equation in two space dimensions, the local eigenvalue problems exhibit a cubic nonlinearity. We design efficient and robust algorithms to solve this nonlinearity, relying on safeguarded Newton methods for reduced problems, or Runge-Kutta approaches for the corresponding flow problem.

Via numerical experiments, we verify the convergence of the iterative sequence to the exact solution, if the problem admits a classical solution. When a smooth solution does not exist, the proposed method allows to obtain an approximate solution in a least-squares sense.

We conclude by showing how to apply similar numerical techniques to other fully nonlinear elliptic equations.

This is joint work with D. Gourzoulidis, M. Picasso (Mathematics Institute, EPFL, Lausanne, Switzerland), and R. Glowinski (University of Houston, Texas, USA).

Raymond Chan, the Chinese University of Hong Kong, Hong Kong

Title: A Three-stage Approach for Segmenting Degraded Color Images: Smoothing, Lifting and Thresholding (SLaT)

Abstract: In this talk, we introduce a SLaT (Smoothing, Lifting and Thresholding) method with three stages for multiphase segmentation of color images corrupted by different degradations: noise, information loss and blur. At the first stage, a convex variant of the Mumford-Shah model is applied to each channel to obtain a smooth image. We show that the model has unique solution under different degradations. In order to handle the color information properly, the second stage is dimension lifting where we consider a new vector-valued image composed of the restored image and its transform in a secondary color space to provide additional information. This ensures that even if the first color space has highly correlated channels, we can still have enough information to give good segmentation results. In the last stage, we apply multichannel thresholding to the combined vector-valued image to find the segmentation. The number of phases is only required in the last stage, so users can modify it without the need of solving the previous stages again. Experiments demonstrate that our SLaT method gives excellent results in terms of segmentation quality and CPU time in comparison with other state-of-the-art segmentation methods.

Joint work with: X.H. Cai, M. Nikolova and T.Y. Zeng

Philippe Ciarlet, City University of Hong Kong, Hong Kong

Title: Continuity of a Surface as a Function of Its Fundamental Forms, Nonlinear Korn Inequalities on a Surface, and Applications

Abstract: It is well known that a surface can be recovered from its two fundamental forms if they satisfy the Gauss and Codazzi-Mainardi compatibility equations on a simply-connected domain, in which case the surface is uniquely determined only up to isometric equivalence.

It is less known that in this case the surface becomes a continuous function of its fundamental forms, again up to isometric equivalence, for various topologies, such as the Fréchet topology of continuously differentiable functions, or those corresponding to various Sobolev norms.

In this talk, we will review such continuity results obtained during the past fifteen years, with special emphasis on those that can be derived by means of nonlinear Korn inequalities on a surface.

We will also mention potential applications of such results, such as the intrinsic approach to nonlinear shell theory, where the unknowns are the fundamental forms of the deformed middle surface of a shell, or the numerical reconstruction of the Earth surface by means of the knowledge of its fundamental forms on a discrete grid.

Jean-Michel Coron, Paris VI, France

Title: Rapid and Finite-time Stabilization

Abstract: We present various results on the rapid and the finite-time stabilization of control systems. This includes control systems in finite dimension (with an application to a quadcopter sliding on a plane) as well as control systems modeled by means of partial differential equations (1-D linear hyperbolic systems and 1-D linear parabolic equations).

Alain Dervieux, INRIA, France

Title: Anisotropic Adjoint-Based Mesh Adaptation for Some k-exact Approximations

Abstract: In the 70's Roland Glowinski proposed to apply the optimal control methods to new solutions of several numerical analysis problems. Inspired by these works, researchers at INRIA have formulated mesh adaptation as optimal control problems and attempt to solve it by using adjoint states. The talk will review three such formulations. Feature-based or Hessian-based formulations minimize the interpolation error for a given field with respect to a parametrization of the mesh. The talk concentrates on parameterizations by Riemannian metric. In the case of a linear interpolation, the main asymtotic term of interpolation error is the Hessian matrix, of same format as the Riemannian metric field. Goal-oriented formulation minimize the error committed on a scalar output and is really an optimal control problem, with state system and adjoint system. A difficult point is to take into account the anisotropy. Several ideas have been proposed to attack this point. Let us mention an *a priori* analysis relying on element-mapping proposed in [2]. In [1], a metric optimization is performed from local perturbation of the mesh and of the solution. Our proposition establishes a connection with the interpolation error. In fact, in many applications it is important to have a good accuracy of the whole solution field and the norm-oriented formulation minimizes in a prescribed norm of the approximation error.

Although not a systematic approach, the proposed analysis can be applied to a large number of physical models discretization. The communication will present a sample of such analyses for CFD models, from Poisson equation to compressible Navier-Stokes. Extension to unsteady flows is they considered. The case of a higher-order approximation carries new difficulties which we discuss then. A last point is the question of mesh adaptation when the computational domain is deformed during the time.

REFERENCES

[1] Yano, M., & Darmofal, D. 2012. An optimization framework for anisotropic simplex mesh adaptation. *JCP*, **231**(22), 7626–7649.

[2] Formaggia, L., & Perotto, S. 2003. Anisotropic a priori error estimates for elliptic problems. *Numer. Math.*, **94**, 67–92.

Bjorn Engquist, University of Texas at Austin, USA

Title: Seismic Imaging and the Monge-Ampère Equation

Abstract: A fundamental inverse problem in seismic imaging can be formulated as PDE constrained minimization where the miss-match between measured and computed signals plays an important role. The purpose is to find properties such as wave velocity and location of reflecting sub layers, which are represented by coefficients in the PDE. We propose using optimal transport and the Wasserstein metric for this miss-match. The optimal transport can be given by the gradient of the solution to a Monge-Ampère equation. We will discuss numerical approximations of the viscosity solution to Monge-Ampère equations and the application to exploration seismology. Numerical examples comparing different techniques will be presented.

Xiaobing Feng, University of Tennessee, USA

Title: Narrow-Stencil Numerical Methods for Fully Nonlinear Second PDEs

Abstract: In this talk I shall first present a newly developed narrow-stencil finite difference framework for approximating viscosity solutions of fully nonlinear second order PDEs (such as Hamilton-Jacobi-Bellman and Monge-Ampere equations). The focus of the talk will be on discussing how to compensate the loss of monotonicity of the schemes (due to the use of narrow stencils) in order to ensure the convergence of the schemes, and to explain some key new concepts such as generalized monotonicity, consistency and numerical moment. The connection between the proposed methods and some well-known finite difference methods for first order Hamilton-Jacobi equations will be explained. I shall then discuss how to extend these finite difference techniques to the (high order) discontinuous Galerkin setting, This talk is based on some recent joint works with Tom Lewis of the University of North Carolina and Chiu-Yen Kao of Claremont Mckenna College in California.

Jiwen He, University of Houston, USA

Title: Diffeomorphic Matching and Dynamic Deformable Surfaces in 3D Medical Imaging

Abstract: We consider optimal matching of submanifolds such as curves and surfaces by a variational approach based on Hilbert spaces of diffeomorphic transformations. In an abstract setting, the optimal matching is formulated as a minimization problem involving actions of diffeomorphisms on regular Borel measures considered as supporting measures of the reference and the target submanifolds. The objective functional consists of two parts measuring the elastic energy of the dynamically deformed surfaces and the quality of the matching. To make the problem computationally accessible, we use reproducing kernel Hilbert spaces with radial kernels and weighted sums of Dirac measures which gives rise to diffeomorphic point matching and amounts to the solution of a finite dimensional minimization problem. We present a matching algorithm based on the first order necessary optimality conditions which include an initial-value problem for a dynamical system in the trajectories describing the deformation of the surfaces and a final-time problem associated with the adjoint equations. The performance of the algorithm is illustrated by numerical results for examples from medical image analysis.

Juárez V Héctor, Universidad Autónoma Metropolitana - Iztapalapa, México

Title: Optimal Control and Inverse Problems with Variational Methods: Numerical Solution

Abstract: Honoring Roland Glowinski's 80th birthday, I will present some recent applications where a control and/or inverse problem is solved with techniques that can be found in the so called `*red book*' [1] or that have been inspired on his research. These problems include the Cauchy problem for the Laplace equation in an annular region, detection of electrical sources from measurements on the exterior boundary of a domain and control of diffusion on 3D-surfaces. Actually, some Mexican researchers and graduate students have learned quite a bit about these topics thanks to the great influence of professor Glowinski and, of course, thanks to his generous collaboration and help.

[1] R. Glowinski, J. L. Lions, J. He, Exact and Approximate Controllability for Distributed Parameter Systems: A Numerical Approach (Encyclopedia of Mathematics and its Applications), Cambridge University Press New York, NY, USA, 2008.

Tommi Kärkkäinen, University of Jyväskylä, Finland

Title: An Operator-Splitting Method for Sparse Neural Networks

Abstract: In 2010 operator splitting methods found their way into data mining, machine learning, and neural computation because of their excellent parallelization capabilities. Common task among these disciplines is the creation of data-based models to approximate an unknown function represented through the so-called learning data, i.e. given set of input-output samples. The purpose of the talk is to consider such a situation, with an attempt to construct sparse models with minimal number of active model parameters. This problem leads to a discrete, nonconvex optimization problem, which can be solved with an operator splitting method. Such method is described and some preliminary numerical results are given.

Felix Kwok, Hong Kong Baptist University, Hong Kong

Title: On the Time-Domain Decomposition of Optimal Control Problems

Abstract: The solution of optimal control problems over a long time horizon, particularly when the constraints are of the PDE type, leads to very large systems of equations that are strongly coupled. It is thus desirable to solve such systems in parallel over many processors. In addition to parallelization in space, one can introduce additional parallelism using domain decomposition "in time", i.e., by subdividing the time horizon into smaller, non-overlapping time intervals and by solving these subproblems in parallel. In this talk, we will discuss two such approaches: the first one is inspired by optimized Schwarz methods in domain decomposition, whereas the second is a parareal-type method. In both cases, we will show some theoretical convergence results as well as numerical examples illustrating the convergence behaviour of the methods.

Patrick Le Tallec, École Polytechnique, France

Title: Conservative and Entropy Controlled Remap for ALE Simulations in very Large Deformations

Abstract: For many multimaterial problems such as fluid-structure interaction, impact or implosion problems, the materials are in very large strains due to their nature or to the forces applied. In our situations of interest, we also have a strong coupling between energy and momentum conservation laws, due to intense transfers between internal and kinetic energy and to strong advection effects. We are then faced with three main challenges: accurate material interface tracking which is important when dealing with highly energetic nonmiscible materials, total energy conservation which is required in presence of strong shocks, and proper entropy control. The last aspect is often overlooked. Even if total energy is conserved, a poor handling of the kinetic energy will lead to an error in entropy, resulting in diffusion, overheating or lack of robustness and accuracy in presence of nonlinear state laws.

A Lagrangian framework either in finite volumes or in finite elements allows an accurate tracking of the interfaces between materials, the boundary of the mesh staying at the interface between material domains. It respects the spatial localisation of the internal energy, and energy conservation when using compatible discretisation rules for momentum and energy equations [1]. It gives also a direct access to elastoplastic shear stresses. But it fails in presence of large mesh distortions. Mesh smoothing techniques are then required, which means that mass, momentum, strains and energy must be transfered from one mesh to another.

The purpose of the paper is to analyze the impact of this remapping on nodal mass relocalisation, energy conservation and entropy production. We will see that even a very accurate remapping using $L2$ projection techniques with mesh intersection calculation and exact integration strongly affects the kinetic energy because of nodal mass relocalisation and velocity projection. If one projects the total energy, there will be a significative entropy error. If one projects the internal energy, the total energy will not be conserved. We will also show that we need to correct both velocity and internal energy after projection in order to restore total energy conservation in an entropy controlled way, while preserving the conservation of linear momentum.

[1] V.A Dobrev, T. Kolev, R.N. Rieben, *High Order Curvilinear Finite Element Methods for Lagrangian Hydrodynamics.* SIAM J. Sci. Comput. Vol. 34, No. 5, pp. B606 - B641 (2012).

[2] A. Claisse A. Llor et C. Fochesato, it Energy preservation and entropy in Lagrangian space- and time-staggered hydrodynamic schemes. J. Comp. Phys. 309-324 (2016).

Shingyu Leung, Hong Kong University of Science and Technology, Hong Kong

Title: Some Applications of Operator Splitting in Scientific Computing

Abstract: We present several recent applications of operator splitting method in various fields of scientific computing. These applications include travel time tomography, wave propagation in an isotropic acoustic medium occupied by a moving fluid, front propagation problem with obstacles modeled by a time-dependent Hamilton-Jacobi (HJ) equation, determination of the effective Hamiltonian in the homogenization theory of a HJ equation, and an optimal transport problem with obstacle based on the Monge-Ampére operator. We will show examples to demonstrate the performance and efficiency of these proposed operator splitting approaches. These works are joint with Roland Glowinski, Jianliang Qian, Wenbin Li and Hao Liu, and are supported by the Hong Kong RGC grants 16303114 and 16309316.

Kaitai Li, Xi'an Jiao Tong University, China

Title: Mixed Tensor Analysis on a 2D-manifold Embedded into Higher Dimension Space and Application to 3D-Linear and Nonlinear Elastic Shell

Abstact: Establish a semi-geodesic coordinates based on middle surface of 3D-shell, provide the relationship of metric tensors, Christoffel symbol, etc. and differential operators on the surface and in 3D Riemann space, give formulations of 3D Lame-Navier equation under this semi-coordinate system. Auume that solution of 3D elastoc eqiations in shell can be made Taylor expansion with respect to transverse variable, obtain two dimensional boundary value problems satisfied by the coefficients of Taylor expansion.

Pierre-Louis Lions, Collége de France, École Polytechnique, France

Title: Interfaces, junctions and stratification

Abstract: We address in this talk a systematic study of Partial Differential Equations models involving junctions and networks, interfaces and stratification. We concentrate here on nonlinear equations in the context of viscosity solutions theory.

Mila Nikolova, CMLA Research Center for Applied Math, France

Title: Alternating Block Coordinate Proximal Forward-Backward Descent for Nonconvex Regularised Problems with Biconvex Terms

Abstract: In this work we consider a broad class of optimization problems composed out of a biconvex data-fidelity terms and smooth, possibly nonconvex separable regularisation terms. We propose a family of attractive schemes for solving this class of problems. It is based on the standard alternate proximal linearized forward-backward approach. Unlike the existing prox-based algorithms, our approach exploits the biconvex structure of the data term. Thus we use proximity operators with respect to convex functions only. The iterates are uniquely defined, independently of the form of regularization terms.

Stanley Osher, UCLA, USA

Title: Overcoming the Curse of Dimensionality for Hamilton-Jacobi Equations with Applications to Control and Differential Games

Abstract: It is well known that certain Hamilton-Jacobi partial differential equations (HJ PDE's) play an important role in analyzing control theory and differential games. The cost of standard numerical algorithms for HJ PDE's is exponential in the space dimension and time, with huge memory requirements. Here we propose and test methods for solving a large class of these problems without the use of grids or significant numerical approximation. We begin with the classical Hopf and Hopf-Lax formulas which enable us to solve state independent problems via variational methods originating in compressive sensing with remarkable results. We can evaluate the solution in 10^ (-4) to 10^ (-8) seconds per evaluation on a laptop. The method is embarrassingly parallel and has low memory requirements. Recently, with a slightly more complicated, but still embarrassingly parallel method, we have extended this in great generality to state dependent HJ equations, apparently, with the help of parallel computers, overcoming the curse of dimensionality for these problems.

The term, "curse of dimensionality" was coined by Richard Bellman in 1957 when he did his classic work on dynamic optimization.

Tsorng-Whay Pan, University of Houston, USA

Title: Distributed Lagrange Multiplier/Fictitious Domain Methods for Simulating Particle Motion in Fluid Flows

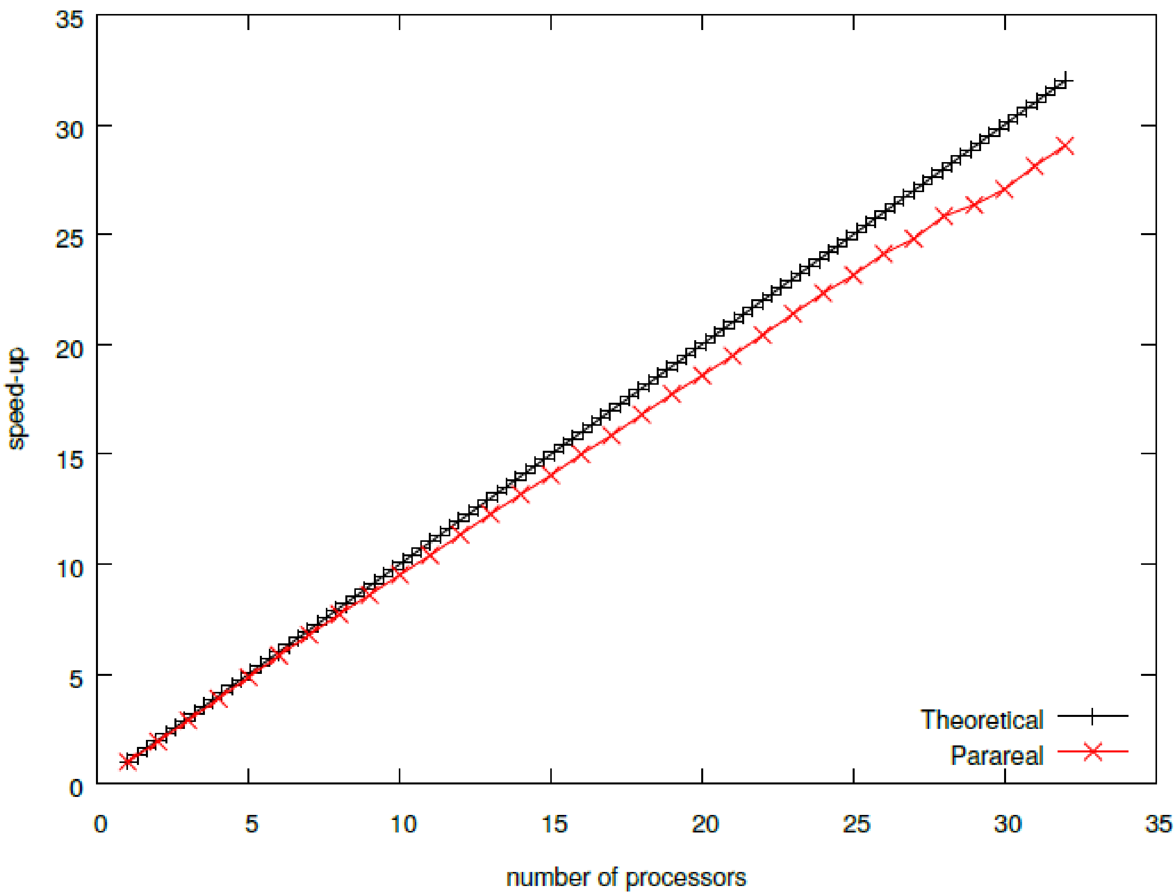
Abstract: In this talk we will first present novel distributed Lagrange multiplier/fictitious domain (DLM/FD) methods for simulating fluid-particle interactions in three-dimensional (3D) Stokes flow. For the particle motion in Newtonian fluids, the methodology has been validated by comparing the numerical results with those available in the literature. The numerical study of the motions of spheres and prolate ellipsoids will be presented. For Oldroyd-B viscoelastic fluids, similar methodologies will be discussed. The numerical results concerning two ball encounters in a 3D bounded shear flow for the Weissenberg number up to 1 will be presented. For many neutrally buoyant spheres interacting in bounded shear flows of Oldroyd-B fluids at low Reynolds number, we will discuss the numerical methodologies and present some preliminary numerical results.

Olivier Pironneau, Paris VI, France

Title: The Parareal Algorithm for American Option

Abstract: For risk assessment large banks have to compute every day a very large number of American options. GPU cards provide a cheap road to parallel computation with a reduction of CPU time of an order of magnitude at least. However algorithm to compute American contracts are quite difficult to parallelise.

This talk will provide a description of the parareal method applied to American contracts with the objective of parallel computing. We perform a decomposition of the time interval to maturity (0, T) into subintervals, each allocated to one processor; on each sub-interval the Longstaff-Schwartz Monte-Carlo method is used. Matching is done by a multi-level algorithm. A proof of convergence will be given and a numerical section will assess the performance. Comparison with other numerical methods will also be given. This work is in cooperation with Gilles Pages and Guillaume Sall.



Jianliang Qian, Michigan State University, USA

Title: Babich-Like Ansatz for Three-Dimensional Point-Source Maxwell's Equations in an Inhomogeneous Medium at High Frequencies

Abstract: We propose a novel Babich-like ansatz consisting of an infinite series of dyadic coefficients (three-by-three matrices) and spherical Hankel functions for solving point-source Maxwell's equations in an inhomogeneous medium so as to produce the so-called dyadic Green's function. Using properties of spherical Hankel functions, we derive governing equations for the unknown asymptotics of the ansatz including the traveltime function and dyadic coefficients. By proposing matching conditions at the point source, we rigorously derive asymptotic behaviors of these geometrical-optics ingredients near the source so that their initial data at the source point are well-defined. To verify the feasibility of the proposed ansatz, we truncate the ansatz to keep only the first two terms, and we further develop partial-differential-equation based Eulerian approaches to compute the resulting asymptotic solutions. Since the system of governing equations for each dyadic coefficient is strongly coupled, we introduce auxiliary variables to transform these strongly coupled systems into decoupled scalar equations. Furthermore, we develop high-order Lax-Friedrichs weighted essentially non-oscillatory schemes for computing these auxiliary variables so that the Green's function can be constructed. Numerical examples demonstrate that our new ansatz yields a uniform asymptotic solution in the region of space containing a point source but no other caustics.

Annalisa Quaini, University of Houston, USA

Title: Modeling and Computations of Self-Propelled Elastic Cylindrical Micro-Swimmers

Abstract: We study propulsion of micro-swimmers in 3D creeping flow. The swimmers are assumed to be made of elastic cylindrical hollow tubes. The swimming is generated by the contractions of the tube's elastic membrane walls producing a traveling wave in the form of a ``step-function" traversing the swimmer from right to left, propelling the swimmer from left to right. The problem is motivated by medical applications such as drug delivery. The influence of several non-dimensional design parameters on the velocity of the swimmer is investigated, including the swimmer aspect ratio, and the amplitude of the traveling wave relative to the swimmer radius. An immersed boundary method based on a finite element method approach is successfully combined with an elastic spring network model to simulate the two-way fluid-structure interaction coupling between the elastic cylindrical tube and the flow of a 3D viscous, incompressible fluid. To gain a deeper insight into the influence of various parameters on the swimmer speed, a reduced 1D fluid-structure interaction model was derived and validated. It was found that fast swimmers are those with large tube aspect ratios, and with the amplitude of the traveling wave which is roughly 50% of the reference swimmer radius.

Jacques Rappaz, EPFL, Switzerland

Title: On Von Karman Turbulent Flow Near a Wall

Abstract: Mixing-length models are often used by engineers in order to take into ac- count turbulence phenomena in a flow. This kind of model consists to add a turbulent viscosity to the laminar one in the equations of Navier-Stokes. When the flow is arising between two close walls, von Karman model consists to add a viscosity which depends on the rate of strain multiplied by the square of distance to the wall.

In this talk we present a mathematical analysis of this kind of models. In particular we explain why von Karman's model is numerically ill-conditioned when the laminar viscosity is small.

Qin Sheng, Baylor University, USA

Title: An Explorative Endeavor with Eikonal and Decomposition Methods for Highly Oscillatory Wave Problems

Abstract: This preliminary report concerns the latest eikonal splitting and domain decomposed methods for solving paraxial Helmholtz equations with high wave numbers. Radially symmetric transverse domains are considered in the latter case.

The differential equations targeted are used for modeling propagations of high intensity laser pulses over a long distance without diffractions in multi-physics applications. Self-focusing of high intensity beams may be balanced with the de-focusing effect of created ionized plasma channel in the situation, and considerations of simple-structured and effective grid adaptations are often essential. To this end, arc-length based adaptations are utilized in transverse and beam propagation directions in our explorations. Asymptotic stability of the computational procedures is investigated. It is shown rigorously that the fully discretized oscillation-free eikonal and decomposition methods on arbitrary grids are stable in the asymptotic sense with a stability index one. Simulation experiments are carried out to illustrate our concern and preliminary conclusions.

Xuecheng Tai, Hong Kong Baptist University, Hong Kong

Title: Augmented Lagrangian Method for Image Segmentation using Elastica Energy that Prefers Convex Contours

Abstract: In the talk, we consider an Euler's elastica based image segmentation model. An interesting feature of this model lies in its preference of convex segmentation contour. However, due to the high order and non-differentiable term, it is often nontrivial to minimize the associated functional. In this work, we propose using augmented Lagrangian method to tackle the minimization problem. Especially, we design a novel augmented Lagrangian functional that deals with the mean curvature term differently as those ones in the previous works. The new treatment reduces the number of Lagrange multipliers employed, and more importantly, it helps represent the curvature more effectively and faithfully. Numerical experiments validate the efficiency of the proposed augmented Lagrangian method and also demonstrate new features of this particular segmentation model, such as shape driven and data driven properties.

Richard Tapia, Rice University, USA

Title: Inverse, Shifted Inverse, and Rayleigh Quotient Iteration as Newton's Method

Abstract: Normalized inverse iteration, shifted inverse iteration, and Raleigh quotient iteration (RQI) are well known algorithms for computing an eigenvector of a symmetric matrix. In this study, we demonstrate that each of these algorithms can be viewed as a standard form of Newton's method from the nonlinear programming literature, followed by the normalization. This provides an explanation for the good behavior of RQI despite the need to solve systems with nearly singular coefficient matrices; the singularity can be viewed as essentially removable. Our equivalence result also leads us naturally to a proof that Raleigh quotient iteration is cubically convergent with constant at worst 1. An interesting part of our study is the explanation as to why as normalized Newton's method inverse and shifted inverse iteration are only linearly convergent and not quadratically convergent and why RQI is cubically convergent and not just quadratically convergent.

Marina Vidrascu, INRIA, France

Title: Coupling Schemes For Fluid-Structure Interaction: Comparative Study and Validation

Abstract: In this talk we present a numerical study in which several solution procedures for incompressible fluid structure interaction (FSI) are compared and validated against the results of an experimental FSI benchmark ([1],[2]). The mathematical model couples the incompressible Navier-Stokes equations in ALE formalism with the elastodynamics equations (both 3D and shell solid models are considered). Finite elements with compatible meshes are used for the discretization in space for both, the fluid and the solid.

We consider an archetypal sample of state-of-the-art numerical methods for FSI covering the three main families of coupling schemes: strongly coupled, semi-implicit and loosely coupled. All the solution procedures discussed are partitioned and, from the coupling algorithm standpoint, parameter free. Very good agreement is observed between the numerical results and the experimental data. The comparisons indicate that strong coupling can be efficiently avoided, via semi-implicit and loosely coupled schemes, without compromising stability and accuracy.

References

[1] M. Landajuela, M. Vidrascu, D. Chapelle and M.A. Fernández. Coupling schemes for the FSI forward prediction challenge: comparative study and validation. Int. J. Numer. Meth. Biomed. Engng. (2016); DOI: 10.1002/cnm.2813

[2] N. Gaddum, O. Holub, A. Hessenthaler, R. Sinkus and D. Nordsletten. Benchmark experiment for validation of fluid-structure interaction algorithms. 4th International Conference on Computational & Mathematical Biomedical Engineering (CMBE15), Cachan (France), 2015.

Jinchao Xu, Pennsylvania State University, USA

Title: Algebraic Multigrid Methods

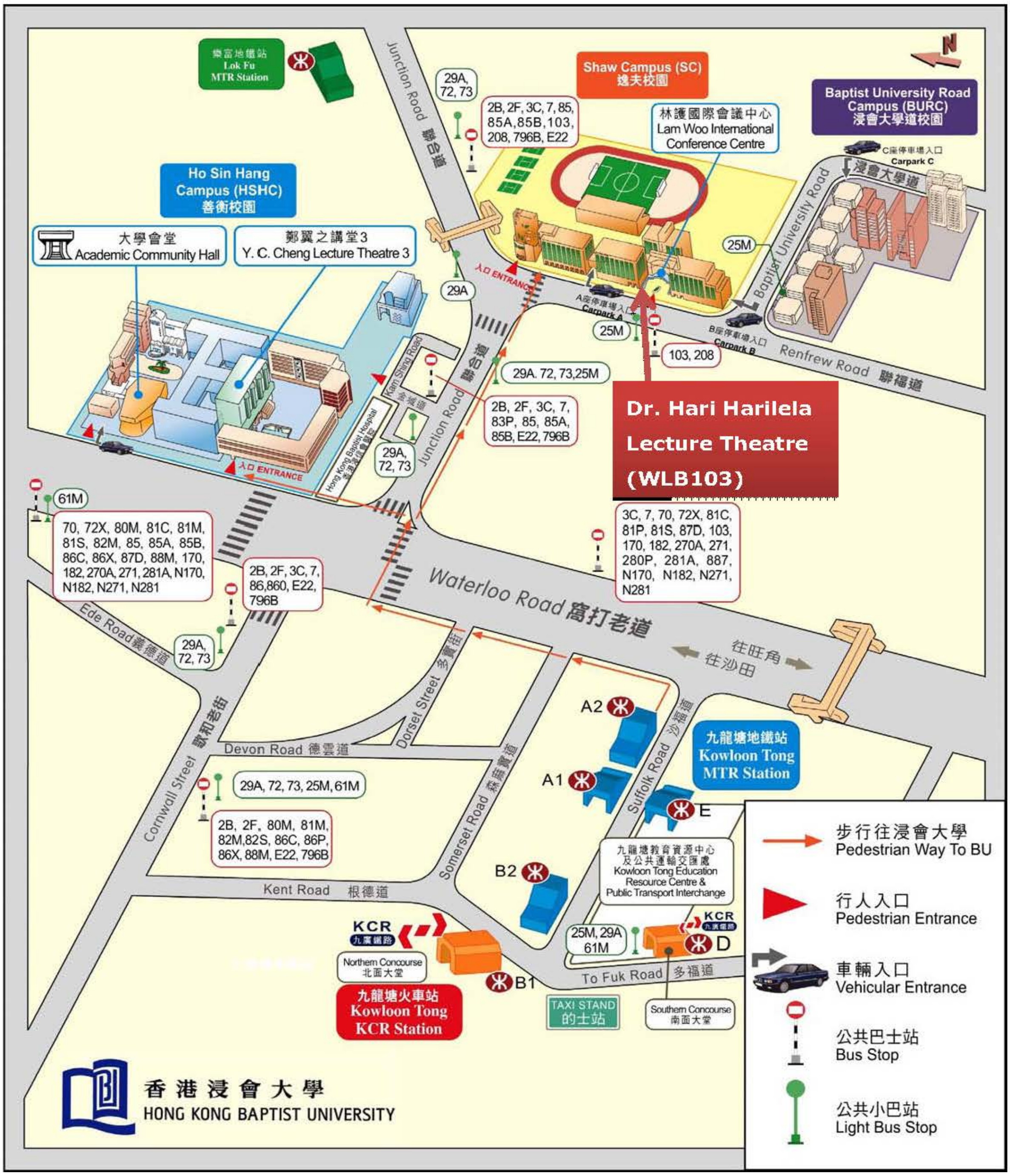
Abstract:： In this talk, I will present a general framework for the design and analysis of Algebraic or Abstract Multi-Grid (AMG) methods. Given a smoother, such as Gauss-Seidel or Jacobi, we provide a general approach to the construction of a quasi-optimal coarse space and we prove that under appropriate assumptions the resulting two-level AMG method for the underlying linear system converges uniformly with respect to the size of the problem, the coefficient variation, and the anisotropy. Our theory applies to most existing multigrid methods, including the standard geometric multigrid method, the classic AMG, energy-minimization AMG, unsmoothed and smoothed aggregation AMG, and spectral AMGe. These results are summarized in a recent survey article entitled “Algebraic Multigrid Methods” in Acta Numerica (Vol 26)

Some Useful Information

Conference venue

WLB103, Dr. Hari Harilela Lecture Theatre, Lam Woo International Conference Centre, 55 Renfrew Road, Shaw Campus, Hong Kong Baptist University

Walking instruction: Kowloon Tong (MTR A2-Exit) to Hong Kong Baptist University, WLB103.



Transportation Arrangement

University-Hotel Shuttle Bus Time Schedule

Date	Time	Pick-up point	Drop-off point
June 5	08:30	Harbour Plaza Metropolis	Dr. Hari Harilela Lecture Theatre, HKBU
	18:30	Dr. Hari Harilela Lecture Theatre, HKBU	Harbour Plaza Metropolis
June 6	9:00	Harbour Plaza Metropolis	Dr. Hari Harilela Lecture Theatre, HKBU
	14:30	Dr. Hari Harilela Lecture Theatre, HKBU	Harbour Plaza Metropolis
June 7	9:00	Harbour Plaza Metropolis	Dr. Hari Harilela Lecture Theatre, HKBU
	18:30	Dr. Hari Harilela Lecture Theatre, HKBU	East Ocean Seaview Restaurant, TST, 11/F, No.1 Peking Road, Tsim Sha Tsui, Hong Kong
	22:00	East Ocean Seaview Restaurant, TST, 11/F, No.1 Peking Road, Tsim Sha Tsui, Hong Kong	Harbour Plaza Metropolis
June 8	9:00	Harbour Plaza Metropolis	Dr. Hari Harilela Lecture Theatre, HKBU
	18:30	Dr. Hari Harilela Lecture Theatre, HKBU	Harbour Plaza Metropolis

Airport-Hotel Shuttle Bus Time Schedule

Airport to Harbour Plaza Metropolis			Harbour Plaza Metropolis to Airport	
7:15	12:45	18:15	05:15	16:15
7:45	13:15	18:45	06:15	17:15
8:15	13:45	19:15	07:15	18:15
8:45	14:15	19:45	08:15	19:15
9:15	14:45	20:15	09:15	20:15
9:45	15:15	20:45	10:15	21:15
10:15	15:45	21:15	11:15	
10:45	16:15	21:45	12:15	
11:15	16:45	22:15	13:15	
11:45	17:15	22:45	14:15	
12:15	17:45		15:15	

Remarks: 1. HK $140 per person per trip (Hotel to Airport or Airport to Hotel);

2. Travelling time consumed approximately 1 hour.

Organizing committee

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