2014 SPRING PROGRESS IN MATHEMATICAL AND COMPUTATIONAL STUDIES ON SCIENCE AND ENGINEERING PROBLEMS

WORKSHOPS

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Feature Extraction from Design Space

Prof. Shigeru Obayashi

This tutorial discusses the difference between optimization and design, and proposes how to put optimization to good use in engineering design. Design activity can be regarded as an inference to obtain the best design candidate. If computational tools create a Bird's-eye view of the design space, the result provides the map that supports an inference by a designer. If multiple design objectives are specified, design space can be regarded as a multi-objective optimization problem. Among the multiple design objectives, conflicting objectives are essential and they will provide Pareto-optimal solutions, which form Pareto front, a key feature in the design space. For feature extraction from design space in high dimensions, Multi-Objective Design Exploration (MODE) has been developed. MODE is not intended to provide an optimal solution but to reveal the structure of the design space from trade-off information and to visualize it as a panorama for a designer. This tutorial will also introduce the basic tools of MODE.

For material related to this talk, click here.

Multi-Objective Design Exploration (MODE) and Its Applications

Prof. Shigeru Obayashi

In Japan, an R&D project was carried out toward the development of environmentally friendly high performance regional jet aircraft under auspices from New Energy Development Organization of Japan (NEDO). In the project, several research programs were investigated by industry-government-university cooperation and the present topic is one of them, that is, the development of a practical Multidisciplinary Design Optimization (MDO) system. The resulting system was named as Multi-Objective Design Exploration (MODE). MODE reveals the structure of the design space from the trade-off information and visualizes it as a panorama for a designer. The present form of MODE consists of Kriging Model, Adaptive Range Multi Objective Genetic Algorithms, Analysis of Variance and Self-Organizing Map. The application to the regional jet design illustrates how the present approach finds design knowledge.

For material related to this talk, click here.

Basics of Optimization Methods

Prof. Meng-Sing Liou

Applications of optimization methods to real-world engineering problems have become an integral part of design process; the level of analysis has rapidly progressed from simple system model to high-fidelity model requiring advanced computational tools in recent years, thanks to the availability of high performance computers. In this lecture, we shall present some fundamentals regarding optimization theory and approaches that are of relevance to today's practices, in particular the genetic algorithms and adjoint methods. A typical engineering system usually embodies multiple disciplines, such as fluid, structural, propulsion, and control; as a result, multiple objectives are to be simultaneously optimized. Hence, intensive computational efforts are involved in optimization and often advanced computational strategies needed. Methods for achieving an efficient and robust searching of the so-called Pareto Front will be outlined. Finally, we shall show examples of applications of optimization to aeronautical propulsion problems.

For material related to this talk, click here.

Optimization of Hybrid Wingbody Aircraft

Prof. Meng-Sing Liou

The hybrid wing-body (HWB) aircraft has a configuration uniquely different from the current fleet, also referred to as tube-and-wing (T&W). Its fuselage and wings are integrated into a flying wing and it is claimed to have several performance advantages over the T&W, such as significantly lighter weight, higher lift to drag ratio, and lower fuel burn. Also, its wide airframe body is beneficial for shielding downward-propagating noise coming from the engines installed above the aircraft. Thus it is a concept being intensively studied to meet the NASA's aggressive metric for economic and environmental requirements targeted up to 2020s. In particular, we shall describe two configurations respectively denoted as N2B and N3-X. The engines in both concepts are embedded into the airframe, with thick boundary layers ingested into the inlet, resulting in increased distortion and total pressure loss. Moreover, the installation of engines close to the body produces significant aerodynamic interferences. Consequently, the intended benefits could be compromised with the degradation of aerodynamic performance, propulsive efficiency and structural tolerance to distortion. Hence, it is a textbook example of a multidisciplinary and multiobjective design of a complex system and in this lecture we shall describe how the modern optimization approach can play an important role and make a significant impact in the development of the HWB concepts.

For material related to this talk, click here.

Ground States and Dynamics of the Nonlinear Schrodinger/Gross-Pitaevskii Equations

Prof. Weizhu Bao

In this talk, I begin with a brief derivation of the nonlinear Schrodinger/Gross-Pitaevskii equations (NLSE/GPE) from Bose-Einstein condensates (BEC) and/or nonlinear optics. Then I will present some mathematical results on the existence and uniqueness as well as non-existence of the ground states of NLSE/GPE under different external potentials and parameter regimes. Dynamical properties of NLSE/GPE are then discussed, which include conservation laws, soliton solutions, well-posedness and/or finite time blowup. Efficient and accurate numerical methods will be presented for computing numerically the ground states and dynamics. Extension to NLSE/GPE with an angular momentum rotation term and/or non-local dipole-dipole interaction will be presented. Finally, applications to collapse and xplosion of BEC, quantum transport and quantized vortex interaction will be investigated.

For material related to this talk, click here.

Modeling, Analysis and Simulation for Degenerate Dipolar Quatum Gas

Prof. Weizhu Bao

In this talk, I will present our recent work on mathematical models, asymptotic analysis and numerical simulation for degenerate dipolar quantum gas. As preparatory steps, I begin with the three-dimensional Gross-Pitaevskii equation with a long-range dipolar interaction potential which is used to model the degenerate dipolar quantum gas and eformulate it as a Gross-Pitaevskii-Poisson type system by decoupling the two-body dipolar interaction potential which is highly singular into short-range (or local) and long-range interactions (or repulsive and attractive interactions). Based on this new mathematical formulation, we prove rigorously existence and uniqueness as well as nonexistence of the ground states, and discuss the existence of global weak solution and finite time blowup of the dynamics in different parameter regimes of dipolar quantum gas. In addition, a backward Euler sine pseudospectral method is presented for computing the ground states and a time-splitting sine pseudospectral method is proposed for computing the dynamics of dipolar BECs.

Due to the adoption of new mathematical formulation, our new numerical methods avoid evaluating integrals with high singularity and thus they are more efficient and accurate than those numerical methods currently used in the literatures for solving the problem. In addition, new mathematical formulations in two-dimensions and one dimension for dipolar quantum gas are obtained when the external trapping potential is highly confined in one or two directions. Numerical results are presented to confirm our analytical results and demonstrate the efficiency and accuracy of our numerical methods. Some interesting physical phenomena are discussed too. [1] W. Bao, Y. Cai and H. Wang, Efficient numerical methods for computing ground states and dynamics of dipolar Bose-Einstein condensates, J. Comput. Phys., 229 (2010), pp. 7874-7892. [2] Y. Cai, M. Rosenkranz, Z. Lei and W. Bao, Mean-field regime of trapped dipolar Bose-Einstein condensates in one and two dimensions, Phys. Rev. A, 82 (2010), article 043623. [3] W. Bao, N. Ben Abdallah and Y. Cai, Gross-Pitaevskii-Poisson equations for dipolar Bose-Einstein condensate with anisotropic confinement, SIAM J. Math. Anal, 44 (2012), pp. 1713-1741.

For material related to this talk, click here.

Discontinuous Galerkin Finite Element Methods

Prof. Jianxian Qiu

The discontinuous Galerkin (DG) method, which is a finite element method suitable for solving convection dominated partial differential equations (PDEs). This method has gained a lot of popularity in recent years because of its nice mathematical properties in stability and convergence, its flexibility to many different PDEs from applications, and its efficiency for adaptivity and parallel implementation. In this lecture, we will give a general introduction and a detail implementation of the DG methods for solving time-dependent, convection-dominated PDEs, including the hyperbolic conservation laws, convection-diffusion equations. We will also discuss cell entropy inequalities, nonlinear stability of DG methods.

For material related to this talk, click here.

Weighted Essentially Non-Oscillatory limiters for Runge-Kutta Discontinuous Galerkin Methods

Prof. Jianxian Qiu

In the presentation we will describe our recent work on a class of new limiters, called WENO (weighted essentially non-oscillatory) type limiters, for Runge-Kutta discontinuous Galerkin (RKDG) methods. The goal of designing such limiters is to obtain a robust and high order limiting procedure to simultaneously obtain uniform high order accuracy and sharp,non-oscillatory shock transition for the RKDG method. We adopt the following framework:first we identify the "troubled cells", namely those cells which might need the limiting procedure; then we replace the solution polynomials in those troubled cells by reconstructed polynomials using WENO methodology which maintain the original cell averages (conservation), have the same orders of accuracy as before, but are less oscillatory. These methods work quite well in our numerical tests for both one and two dimensional cases, which will be shown in the presentation.

For material related to this talk, click here.