2013 FALL PROGRESS IN MATHEMATICAL AND COMPUTATIONAL STUDIES ON SCIENCE AND ENGINEERING PROBLEMS

WORKSHOPS

理論科學研究中心
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Multi-dimensional Limiting Strategy for Finite Volume and Higher-order Methods

Prof. Chongam Kim

The present seminar deals with the multi-dimensional limiting process (MLP) on unstructured grids to compute compressible flows. Compared with traditional limiting strategies, such as TVD or ENO-type schemes, MLP effectively controls unwanted oscillations particularly in multiple dimensions. Especially, this oscillation-control mechanism has been established by combining the local maximum principle and the multi-dimensional limiting (MLP) condition, which leads to the formulation of the efficient and accurate MLP-u slope limiters. Recently, this limiting philosophy is hierarchically extended into higher-order Pn approximation. The resulting algorithm, called the hierarchical MLP, facilitates the accurate capturing of detailed flow structures in both continuous and discontinuous regions. This algorithm has been developed in the modal discontinuous Galerkin (DG) framework, but it also can be formulated into a nodal framework, most notably the correction procedure via reconstruction (CPR) framework. Troubled-cells are detected within the MLP concept, and then the projection procedure and MLP slope limiter adjust sub-cell distributions. Through extensive numerical analyses and computations on unstructured grids, it is demonstrated that the proposed method yields outstanding performance in resolving non-compressive as well as compressive flow features.

For material related to this talk, click here.

Progress in Limiting Strategy: From one-dimensional concepts to Multi-dimensional Limiting Process

Prof. Chongam Kim

This tutorial surveys various limiting strategies to solve compressible flows. Starting from the basic concept of non-linear stability for hyperbolic conservation laws, it reviews some remarkable progresses of limiting methods, such as TVD-MUSCL and ENO/WENO. While these approaches may work successfully in many cases, it is often insufficient or almost impossible to control oscillations near shock discontinuity in multi-dimensional situations. In order to find out a suitable criterion for oscillation-control in multiple dimensions, the one-dimensional monotonic condition is extended to multi-dimensional space, and multi-dimensional limiting process (MLP) is formulated on structured grids. By examining its design principle and implementation on structured grids in detail, we explore remarkably enhanced accuracy and convergence characteristics to compute multi-dimensional compressible flows.

For material related to this talk, click here.

Application of Optimized High Order Compact Schemes for Aeroacoustics and Turbulence simulations.

Prof. Duck-Joo Lee

A compact scheme is preferred in real simulations because of compact stencil with the same quality of flows. Those high resolution schemes are superior in capturing acoustic wave, vorticity wave and entropy wave in convection term. Boundary problems in the body surface and near the computational domain will be discussed. Non-reflection boundary condition in the computational domain is used. Up-wind schemes or mixed central schemes are used. Flow around a circular cylinder is simulated to show the vortex shedding and characteristics of acoustic radiation due to the fluctuations of surface pressure. Relation between dipole and quadruple source will be discussed. Several feedback mechanisms between acoustic and flows will be shown such as in the cavity flow, whistle noise and supersonic jet screech tone. Possible simulations of incompressible and compressible high Reynolds turbulence flow will be discussed.

For material related to this talk, click here.

High Order High Resolution Difference Schemes

Prof. Duck-Joo Lee

High order finite schemes have low truncation errors, which does not guarantee a good quality of solution for time dependent problems. Taylor series is used to rank the order of schemes. A Fourier analysis provides an effective ways to quantify dissipative error and dispersion(phase) error. Low dispersion error is critical in simulation of unsteady flows and propagating waves. Convection term in the Navier-Stokes equation is important in the generation of nonlinear phenomena of turbulence and in the propagation of wave through a moving medium. Accurate and high resolution schemes for the space derivative in the convection term are introduced and analyzed in details. Most of high resolution finite scheme is central scheme because of zero dissipation error. Direct comparisons of high resolution schemes will be shown in wave number domain. So called DRP(Dispersion-Relation-Preserving) scheme, Spectral-Like scheme and Optimized High Order Compact schemes are compared with conventional 2nd order central scheme and standard Pade scheme. A unified Lomax approach in the stability analysis will be introduced.

For material related to this talk, click here.

Adjoint based hp-Adaptations for the CPR method

Prof. Z. J. Wang

Solution based mesh (h) and order (p) adaptations (hp-adaptations) are critical in extracting the benefits of high-order methods. Error indicators are a critical element of hp-adaptations. In this talk, we will describe several widely used error indicators, including feature, residual, entropy and adjoint based ones. Then the implementation of hp-adaptations with a differential solution method, the correction procedure via reconstruction (CPR) is described. The importance of adjoint-consistency is addressed. Finally, the advantage of the hp-adaptations is illustrated with several benchmark problems from the 1st International Workshop on High-Order CFD methods.

For material related to this talk, click here.

An introduction to discontinuous high-order methods

Prof. Z. J. Wang

In this tutorial, we will start with why we need high-order accuracy in CFD simulations. Then the current status of high-order CFD methods will be discussed, followed by a presentation of several high-order methods: including the discontinuous Galerkin (DG) method, spectral volume (SV), spectral difference (SD) methods, and the flux reconstruction (FR) or the correction procedure via reconstruction (CPR) formulation. All the methods possess the following properties: k-exactness on arbitrary grids, and compactness, which is especially important for parallel computing on clusters of CPUs and GPUs. In addition, the application of high-order methods to compute real world flow problems will be presented. The talk will conclude with several remaining challenges in the research on high-order methods.

For material related to this talk, click here.

Computational modelling of moving and deforming boundary flow problems

Prof. Khoon Seng Yeo

In recent years, a good deal of CFD research has gone into the development of schemes for dealing with moving and deforming boundary problems. These have been motivated by applications to biological or bio-medical related flows, flows with interfaces as in free surface flow and multi-phase flows. The main approaches may be broadly divided into two groups: body conformal and non-body conformal grids. The former comprises the well-known Finite Volume, Finite Element, and Composite/Chimera grid methods. Non-body conformal grids usually employ a background grid, which is frequently Cartesian: interface may be explicitly tracked by a phase function (Volume-of-Fluid methods) or a gradient function (Level Set methods); or interface may be defined by a diffused interpolation scheme (such as the Immersed Boundary Methods and its many variants). In this workshop I will describe a body-conformal CFD scheme that is based on a hybrid Cartesian-meshfree grid. In this scheme, the boundary/body and its near field are discretized by meshfree nodes and set against a background Cartesian grid frame. The scheme provides accurate boundary definition and good geometric flexibility. Discretization at non-Cartesian nodes is carried by a generalized finite difference (GFD) scheme, while discretization on Cartesian nodes (which form the bulk of computational nodes) follows the highly efficient standard central FD. The meshfree nodes convect with the motion and deformation of the boundary/body; the latter are incorporated into the fluid dynamics via an ALE procedure. Dynamic interaction of fluid and body leading to motion is solved by an implicit iterative procedure. The scheme is well tailored for external type deforming boundary driven flows such as those that arise in animal propulsion. Applications have been made to the study of fish swimming and flapping wing flight. A high-order generalized difference scheme with highly compact support was also recently developed.

For material related to this talk, click here.

Research in flapping-wing flight of insect-like flyers

Prof. Khoon Seng Yeo

The study of animal propulsion, in particular the flight of birds and insects and the swimming of fishes have been very much the preserve of zoologists and biologists and a few physical scientists. In more recent times, it has also attracted growing interests from researchers in the field of engineering. This is due in part to advances in science and engineering up to a point where we could begin to attempt to mimic nature (bio-mimicry) and a general belief that we could learn from nature, whose systems are worth copying because they are highly optimized for the functions that they serve due to long evolutionary selection. In this seminar, I will describe recent works that we have done on flapping wing aerodynamics and flight of insect-like flyers in the Department of Mechanical Engineering at the National University of Singapore, where we have programmes of experimental and computational studies. Insects have been described as the most agile and accomplished of all aerial flyers (bird included); and with good justifications too, for many could fly backwards, upside down or even mate in flight. Research of the last 30 years have shown that insects, especially the smaller ones, rely on a variety of unsteady aerodynamic mechanisms to generate the requisite lift to keep themselves in flight – that however is only the most basic requirement of flight. The present talk will focus primarily on the computational works. The talk will cover recent and on-going works we are doing on the free hovering flight and forward flight of small flapping-wing insects. I will also talk about the fluid dynamics of clap-and-fling, a lift enhancement technique used mainly by very small insects and some larger flyers.

For material related to this talk, click here.