DR. MATTHEW R. SMITH

ASSISTANT PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING, NCKU

Contact Details:

Email: msmith@mail.ncku.edu.tw Room Number: 91714 Extension: 62114

ASSISTANT PROF. M.R. SMITH

DEP. OF MECH. ENG., NCKU

EDUCATION

PhD. in Mechanical Engineering (2006-2008)

University of Queensland, Brisbane, Australia.

M.Phil in Mechanical Engineering (2002-2003)

University of Queensland, Brisbane, Australia.

B.Eng in Mechanical and Space Engineering (1998-2001)

University of Queensland, Brisbane, Australia.

PREVIOUS EMPLOYERS

National Center for High-performance Computing, National Chiao Tung University, The University of Queensland, Dominican School in Kaohsiung, Nordon Cylinders, Boeing Australia, Royal Australian Air Force.

CURRENT RESEARCH

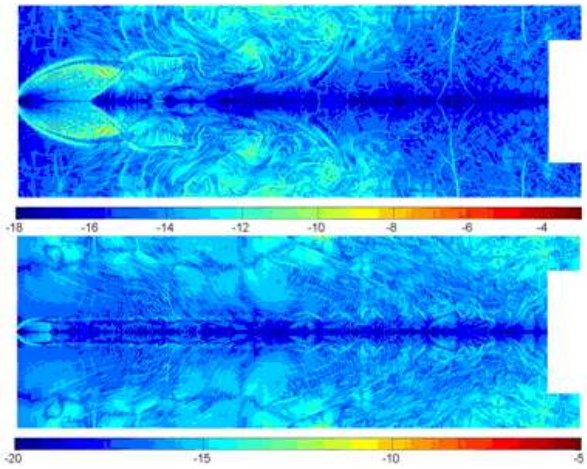
Computational Fluid Dynamics

The practice of employing numerical analysis in the study of the dynamics of fluids is a relatively new field (<100 years) which is still evolving rapidly. Research in my laboratory focuses on novel approaches to finding approximate solutions to the governing equations of fluids through various approaches, of which integral balance, algebraic, physical and kinetic theory based approaches form a part. In the last 5 years we have developed numerous schemes capable of simulating high resolution shocked (hypersonic) and subsonic flows. Several of the CFD schemes developed in the last 5 years are (to name a few):

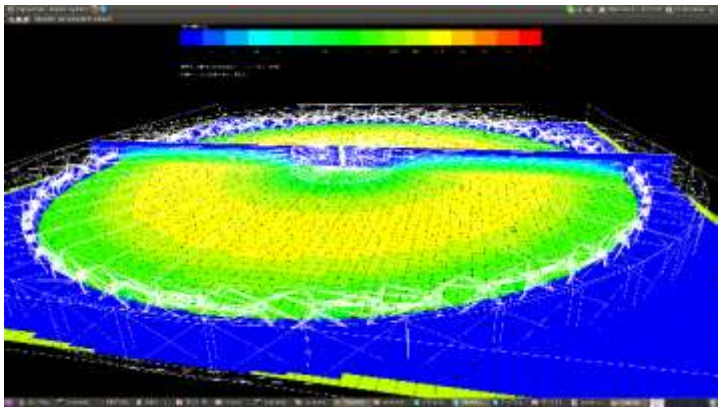
- HLLG (Harten Lax and Van Leer with Gradient inclusion),
- Quiet Direct Simultion (QDS) – a higher order FVM recasting of the QDSMC approach.
- SHLL (Split HLL) – for efficient vector computation of the Euler Equations.

RESEARCH SUMMARY

- Computational Fluid Dynamics,
- Numerical Analysis of Partial and Ordinary Differential Equations in Engineering,
- High Performance and Parallel Computing,
- Heterogeneous Computing using GPU and Xeon Phi Coprocessors,
- Optimization using Genetic Algorithms,
- Structural Mechanics,
- Hydraulic Systems,
- Rarefied Gas Dynamics.



Axisymmetric QDS Simulation of a PPCVD reactor performed in cooperation with Dr. C.W. Lim and Prof. M. Jermy.



In-house real-time GPU accelerated MOCVD transient simulation through a non-symmetric reactor with chemical reactions.

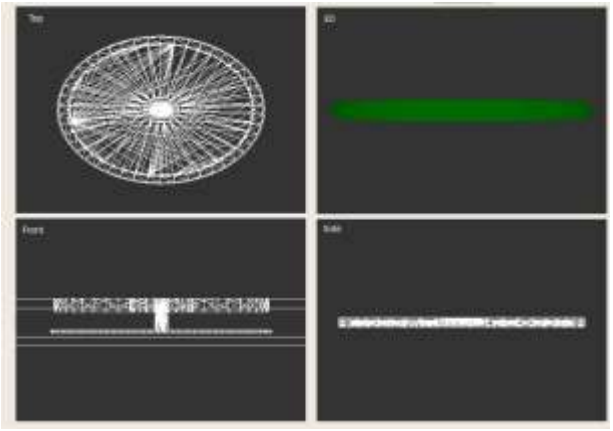
Numerical Analysis of Partial and Ordinary Differential Equations

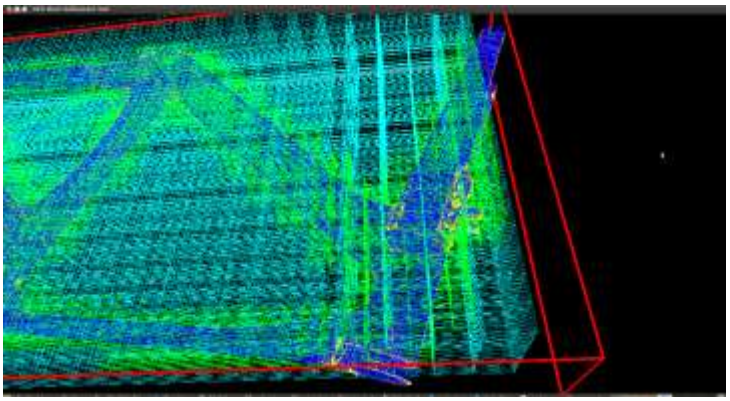
Most of the phenomena we see in real-life situations can be described through the use of Ordinary and Partial Differential Equations. Many of these do not have analytical solutions – and as such, if we wish to use these equations to investigate their behavior, we are often required to resort to the use of numerical analysis. In my laboratory, we investigate the three most commonly used approaches – the Finite Volume Method (FVM), the Finite Element Method (FEM) and the Finite Difference Method (FDM). We also investigate tools for non-linear systems such as Jacobian (gradient-based) solutions in addition to solutions in Krylov subspace. While many of these approaches require a strong mathematics background, we are able to use these techniques to find results relevant to our studies in Mechanical Engineering.

High Performance and Parallel Computing using GPU and Intel PHI

Several advanced manufacturing methods require a clear understanding of the complex flow of heat and mass throughout their reactors in order to produce better products. In order to resolve these flows, we often require cell resolutions on the order of millions (or hundreds of millions) of cells. In addition to these resolution requirements, local and international industrial collaborators also have significant time pressure – hence, we must employ parallel computing in order to meet their needs.

With support from leading companies such as Acer and Nvidia, we currently employ several high-speed computing servers containing (i) numerous GPU computing devices, such as Tesla cards and several high-performance GTX cards, (ii) the Intel Xeon Phi Coprocessor, and (iii) the latest Intel and AMD high performance computing cores. We currently employ approaches such as (i) Nvidia's CUDA, (ii) OpenCL, (iii) AVX intrinsics, (iv) OpenMP and MPI for multi-core parallel extensions. In addition, we focus on the development of novel numerical schemes to ensure a high degree of suitability for our target architecture. Using these algorithms, speedups of over 100 times per device are possible using the latest computing coprocessors when compared to the performance on a conventional Xeon computing CPU.





[Top Left] Simulation Interface for real-time GPU and coprocessor simulation using Qt, [Top Right] Adaptive grid interface accelerated using CUDA and developed together with Velocite Tech (Taiwan), [Bottom] Demonstration with Acer at Nvidia's 2013 GTC conference.

Recent Publications and Conference Papers

M.R. Smith, J.-Y. Liu, F.-A. Kuo, and J.-S. Wu, Efficient Hybrid CPU-Centered Parallelization of the QDS Method for Ideal Compressible Gas Flows, Computers and Fluids, (Submitted), 2013.

M.R. Smith, Y.-C., Chen, A. Ferguson, and J.-S., Wu, Higher Order Direction Decoupling for the Uniform Equilibrium Flux Method and it's Acceleration using Graphics Processing Units, Computers and Fluids (Submitted), 2013.

M.R. Smith, J.-Y., Liu, F.-A. Kuo, and J.-S. Wu, Hybrid OpenMP/AVX Acceleration of a Higher Order Quiet Direct Simulation Method for the Euler Equations, Procedia Engineering, 61, pp. 152-157, 2013.

M.R. Smith, Y.-C. Chen, J.-Y. Liu, A. Ferguson, and J.-S. Wu, Extension of the Uniform Equilibrium Flux Method (UEFM) to Second Order Accuracy and its Graphics Processing Unit Acceleration, Procedia Engineering, 61, pp. 70-75, 2013.

Y.-J. Lin, M.R. Smith, F.-A. Kuo, H.M. Cave, J.-C. Huang and J.-S. Wu, A True Directional Reconstruction to the Quiet Direct Simulation Method, Computer Physics Communications, 184[11], pp. 2378–2390, 2013.

C.-W. Lim, M.R. Smith, M.C. Jermy, J.-S. Wu and S.P. Krumdieck, The Direction Decoupled Quiet Direct Simulation Method for Rapid Simulation of Axisymmetric Inviscid Unsteady Flow in Pulsed Pressure Chemical Vapour Deposition, Computers and Fluids, 88, pp:14-27, 2013.

C.-C. Su, M.R. Smith, J.-S. Wu, C.-W. Hsieh, K.-C. Tseng and F.-A. Kuo, Very Large Scale Simulations on Multiple Graphics Processing Units (GPUs) for the Direct Simulation Monte Carlo Method, Journal of Computational Physics, 231, pp. 7932-7958, 2012.

K-M. Lin, C.-T. Hung, F.-N. Hwang, M.R. Smith, Y.-W. Yang and J.-S. Wu, Development of a Parallel Semi-Implicit two-dimensional Plasma Fluid Modeling Code using the Finite Volume Method, Computer Physics Communications, 183[6], pp. 1225-1236, 2012.

F.-A. Kuo, M.R. Smith, C.-W. Hsieh, C.-Y. Chou and J.-S. Wu, GPU acceleration for general conservation equations and its application to several engineering problems, Computers and Fluids, 45[1]: pp. 147-154, 2011.

M.R. Smith, K.-M. Lin, C.-T. Hung, Y.-S. Chen, and J.-S. Wu, Development of an improved spatial reconstruction technique for the HLL method and its applications, Journal of Computational Physics, 230: pp. 477–493, 2011.
M.R. Smith, C.-T. Hung, K.-M. Lin, J.-S. Wu and J.-P. Yu, Development of a semi-implicit fluid modeling code using finite-volume method based on Cartesian grids, Computer Physics Communications, 182[1]: pp. 170-172, 2011.
A. Ferguson, M.R. Smith and J.-S. Wu, Accurate True Direction Solutions to the Euler Equations Using a Uniform Distribution Equilibrium Method, CMES, 63[1]: pp. 79-100, 2010.
M.R. Smith, F.-A. Kuo, C.-W. Hsieh, J.-P. Yu, J.-S. Wu and A. Ferguson, Rapid Optimization of blast-wave mitigation strategies using Quiet Direct Simulation and Genetic Algorithm, Computer Physics Communications, 181: pp. 1025–1036, 2010.
M.R. Smith, H.M. Cave, J.-S. Wu, M.C. Jermy and Y.-S. Chen, An improved Quiet Direct Simulation method for Eulerian fluids using a second-order scheme, Journal of Computational Physics, 228: pp. 2213-2224, 2009.
M.R. Smith, M.N. Macrossan and M.M. Abdel-Jawad, Effects of Direction Decoupling in Flux Calculation in Finite Volume Solvers, Journal of Computational Physics, 227: pp 4142-4161, 2008.

Conference Papers

M.R. Smith and Y.-C. Chen, Accelerated Composite Distribution Function Methods for Computational Fluid Dynamics using GPU, International Workshop on Computational Science and Engineering, October 14-17, 2013, National Taiwan University, Taipei, Taiwan.
M.R. Smith, Vector Accelerated Finite Volume Computations with Adaptive Grids using GPU and Advanced Vector Extensions, 2013 Conference on Computational Mathematics and Annual Meeting of TWSIAM, June 1-2, 2013, Providence University, Taichung, Taiwan.

M.R. Smith, Y.-C. Chen, J.-Y. Liu, A. Ferguson, and J.-S. Wu, Extension of the Uniform Equilibrium Flux Method (UEFM) to Second Order Accuracy and its Graphics Processing Unit Acceleration, 25th International Conference on Parallel Computational Fluid Dynamics, ChangSha, China, May 20-25, 2013.
M.R. Smith, J.-Y., Liu, F.-A. Kuo, and J.-S. Wu, Hybrid OpenMP/AVX Acceleration of a Higher Order Quiet Direct Simulation Method for the Euler Equations, 25th International Conference on Parallel Computational Fluid Dynamics, ChangSha, China, May 20-25, 2013.
F.-A. Kuo, M.R. Smith, J.-P. Su and J.-S. Wu, An Explicit Finite-Volume Euler Equation Solver on a Cartesian Grid using Cubic-Spline Immersed Boundary Method on Multiple Graphics Processor Units, 2013 Asian-Pacific Conference on Aerospace Technology and Science, HsinChu, Taiwan, May 23-26, 2013.
C.-C. Su, J.-S. Wu, M. R. Smith, C.-W. Hsieh, K.-C. Tseng, and F.-A. Kuo, A multiple-GPU accelerated Direct Simulation Monte Carlo, DSMC11: Santa Fe, New Mexico, USA; September 25-28, 2011.
C.-C. Su, J.-S. Wu, M. R. Smith, C.-W. Hsieh, K.-C. Tseng, and F.-A. Kuo , Parallel Implementation of DSMC on Multiple-GPUs Using MPI-CUDA, 18th National Taiwan CFD Conference, Ilan, August 5-8, 2011.
J.-S. Wu, T.-H. Chou, Y.-S. Chen, H.-W. Hu, M.-T. Ho, H.-P. Lin, T.-L. Chen, M.R. Smith, B. Wu and Y.-Y. Lian, University-based Hybrid Sounding Rocket Research in Taiwan, The 28th International Symposium on Space Technology and Science, Okinawa, Japan, June 5-12, 2011.
C.-C. Su, M. R. Smith, C.-W. Hsieh, K.-C. Tseng, F.-A. Kuo and J.-S. Wu, Parallel Direct Simulation Monte Carlo Computation on Multiple GPUs Using MPI-CUDA, 23rd International Conference on Parallel Computational Fluid Dynamics, May 16-20, Barcelona, Spain 2011.
K.-M. Lin, C.-T. Hung, M.R. Smith and J.-S. Wu, One-dimensional Fluid Modeling of Helium/Oxygen Dielectric Barrier Discharge Driven by a Nearly Sinusoidal AC Power Source, 7th International Conference on Fluid Dynamics, Sendai, Japan, November 1-3, 2010.

M.R. Smith, F.-A. Kuo, H.M. Cave, M.C. Jermy and J.-S. Wu, Quiet Direct Simulation (QDS) of Viscous Flow Using the Chapman-Enskog Distribution, 27th International Symposium on Rarefied Gas Dynamics, Asilomar, California, July 10-15th, 2010.
C.-C. Su, C.-W. Hsieh, M. R. Smith, M. C. Jermy and J.-S. Wu, Parallel Direct Simulation Monte Carlo Computation using CUDA on GPUs, 27th International Symposium on Rarefied Gas Dynamics, Asilomar, California, July 10-15th, 2010.
Y.-J. Lin, M.R. Smith, H.M. Cave, J.-C. Huang and J.-S. Wu, General Higher Order Extension to the Quiet Direct Simulation Method, 27th International Symposium on Rarefied Gas Dynamics, Asilomar, California, July 10-15th, 2010.
M.R. Smith, H. M. Cave, J-S. Wu, and M. N. Macrossan. An approximate method for solving rarefied and transitional flows using TDEFM with isotropic mesh adaptation. Proc. of the 26th International Symposium on Rarefied Gas Dynamics (AIP Conf. Proc. v1084), pages 371{376, Melville, New York, 2009. American Institute of Physics.
H.M. Cave, C.-W. Lim, M.C. Jermy, J.-S. Wu, M.R. Smith, and S.P. Krumdieck, CVD flow field modeling using the Quiet Direct Simulation (QDS) method, EuroCVD 17/CVD 17 Issue 8, by Wörhoff, K, Ed. Swihart, M.T., Barreca, D., Wörhoff, K and Adomaitsi, R., The Electrochemical Society, 2009.
K.-M. Lin, M.R. Smith and J.-S. Wu, Development of a large scale Fluid Modelling Code using a Finite Volume Method, 2009 International Conference on Computational Physics, Kaohsiung Dec 15-19th, 2009.
M. R. Smith and J.-S. Wu, Rapid Gas Flow Computation Using a High Resolution Kinetic Flux Scheme (Invited), 2009 Meeting of the Taiwan Annual Mathematics Society (中華民國數學年會), December 2009.
A. Ferguson, M.R. Smith and J.-S. Wu, True Directional Equilibrium Fluxes using an Integral Particle Method, PSFVIP-7, Kaohsiung, November 16th-19th, 2009.
M. R. Smith, Differential Evolution Algorithms in High Resolution CFD Applications (Invited), 2009 Taiwan-Japan Joint workshop on Numerical Analysis and Scientific Computation, Taipei, Nov. 7-8th, 2009.
M.R. Smith, H.M. Cave, F.-A. Kuo, Y.-J. Lin, J.-S. Wu, C.-W. Lim and M.C. Jermy, Overview and Outlook of Quiet Direct Simulation (QDS) Method as a Flow Solver (Invited), The 5th Taiwan-Japan Workshop on Mechanical & Aerospace Engineering, Nantou, October 21-24, 2009.
M.R. Smith F.-A. Kuo, C.-Y. Chou, J.-S. Wu and H.M. Cave, Application of a Kinetic Theory based solver of the Euler Equations using GPU, International Conference on Parallel Computational Fluid Dynamics 2009, NASA Ames (San Francisco), May 2009.
M.R. Smith, G.-Z. Song and J.-S. Wu, High resolution FVM simulation of competitive flora species (Invited), HPC Asia 2009, Kaohsiung, March 2 – 5th, 2009.
M.R. Smith, H.M. Cave and J.-S. Wu, The Inclusion of Spatial Gradients into HLL Fluxes and Their Application (Invited), HPC Asia 2009, Kaohsiung, March 2 – 5th, 2009.
M.R. Smith et al. Simulation of Debris Formation and Movement Resulting from a Blast Wave in an Urban Environment (Best Paper Award), 15th National Taiwan CFD Conference, Kaohsiung 2008.
M.N. Macrossan, M.R. Smith, M.V. Metchnik, and P. A. Pinto. True direction flux method applications on rectangular 2D meshes. In M. S. Ivanov and A. K. Rebrov, editors, Proc. of the 25th Int. Symp. on Rarefied Gas Dynamics, St. Petersburg, Russia, 21-28 July, 2006, pages 239-244, 2007.
M.R. Smith, M.N. Macrossan, M.M. Abdel-Jawad, and A. Ferguson, DSMC in the Euler Limit and its approximate Kinetic Theory Fluxes, 14th National Taiwan CFD Conference, Nantou, 2007.
M.R. Smith and M.N. Macrossan, Two Dimensional Isotropic Mesh Adaptation for viscous flow of a kinetic theory gas using TDEFM, 16th Australasian Fluid Mechanics Conference (AFMC), Gold Coast, Queensland, 3-7th December, 2007.