An Adaptive, Higher-order Discontinuous Galerkin Finite Element Method for Aerodynamics

David Darmofal

Aerospace Computational Design Laboratory
Massachusetts Institute of Technology

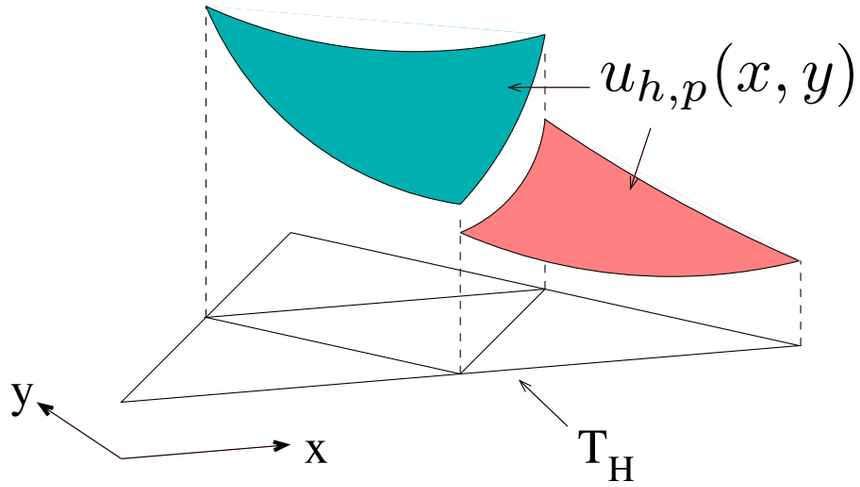
September 9, 2013

Research Objective

Develop a CFD method that autonomously and efficiently solves the RANS equations to a specified discretization error for aerodynamic quantities.

- 10 year effort
- 20 graduate students
- Papers, presentations, and theses
- Group-developed software: *Project X*

Discontinuous Galerkin discretization



- Inviscid flux function: Roe
- Viscous discretization: BR2
- Asymptotically dual-consistent source
- Regularization/shock capturing
  - PDE-based artificial viscosity (Barter 2010)
  - Improvements for anisotropic meshes
- Spalart-Allmaras with SA-negative mods (2012)

Solver description

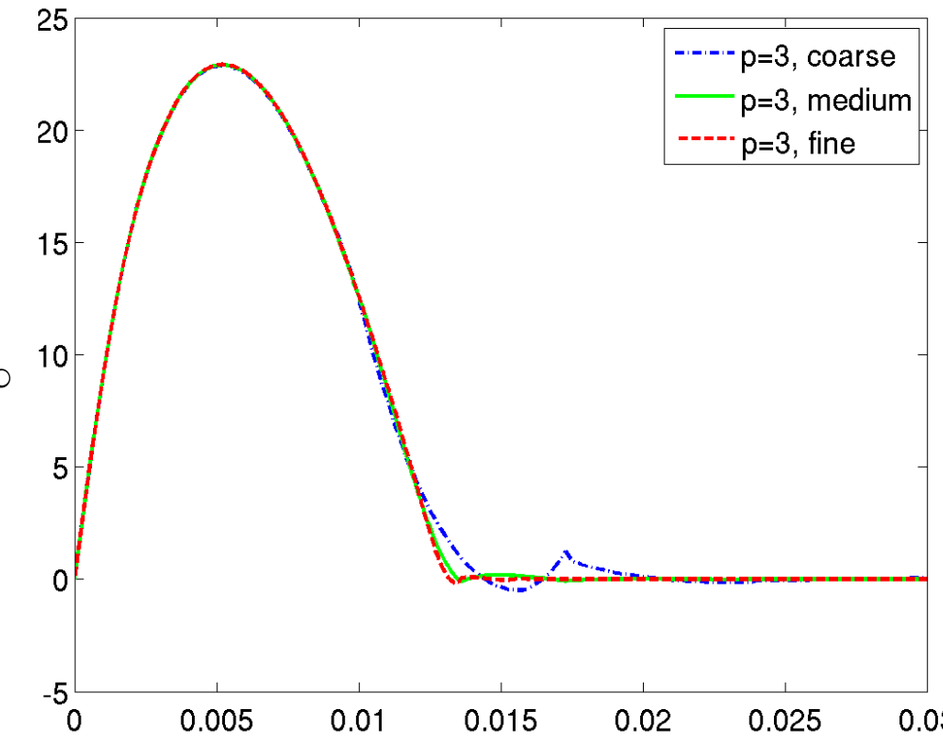
- Time-damped Newton Krylov (GMRES)
- Preconditioning:
  - Block ILU(0) using MDF re-ordering and $p=0$ correction (Persson & Peraire 2007)
  - In-place factorization (Diosady 2009)
- Line-search to guarantee residual decrease
- Parallel: minimum overlap, restricted additive Schwartz

DG details (for Euler/NS/RANS)

- Inviscid flux function: Roe
- Viscous discretization: Bassi-Rebay 2nd method
- Asymptotically dual-consistent source discretization (gradients include lifting contribution)
- BCs imposed weakly through fluxes
- Default quadrature for integrates:
  - Interior: $2(p+1) + q-1$ polynomials exactly
  - Faces: $2(p+2) + q-1$ polynomials exactly

RANS-SA model

- Improved robustness for negative eddy viscosity is critical for higher-order discretizations



- Previously used modifications reported by Oliver (2008)

- Moro et al (2011) modifications:
  + more robust than Oliver
  - modifies SA for positive eddy viscosity

- Presently use Allmaras et al (2012) modifications:
  + as robust as Moro et al
  + does not modify SA for physically-relevant flow regimes