Implementation and Assessment of High-Order Methods in the Framework of SU2

Presenters: K. Singh, D. Drikakis, M. Frank, I. Kokkinakis
Presentation Outline

• Test Problem Definition: Double Vortex Pairing

• Numerical Schemes Assessed
  • 2nd and 3rd order MUSCL schemes within SU2 Finite Volume solver
  • 3rd order Discontinuous Galerkin method within SU2

• Performance Criteria
  • Vortex Evolution
  • Mach Number Effect
  • Momentum Thickness
  • Total Variation Bounded
Description of Problem: Double Vortex Pairing

- Mixing layer formed by two co-flowing streams of water
- Initial velocity perturbations inflate forming two distinct vortices
- Vortices roll around each other eventually merging to form one vortical structure
- Chosen as test problem due to presence of fine structures and discontinuities

(a) 1.0s  
(b) 2.0s  
(c) 3.0s  
(d) 4.0s  
(e) 5.0s  
(f) 6.0s
Double Vortex Pairing: Reference Solution

- Reference solution obtained using in-house code CNS3D
- Structured Grid Finite Volume solver
- 2\textsuperscript{nd} to 11\textsuperscript{th} order accurate MUSCL + WENO schemes
- 2\textsuperscript{nd} to 4\textsuperscript{th} order accurate time stepping Runge-Kutta schemes
- Used in previous journal publication investigating Double Vortex Pairing
- CNS3D used extensively in past for iLES/DNS simulations
Double Vortex Pairing: 64x64 grid, M = 0.2

Settings (kept constant throughout):
- Classical RK4 Explicit Time Stepping
- Unsteady CFL = 0.3
- Riemann Solver: HLLC
- MUSCL 2\textsuperscript{nd} order uses the Venkatakrishnan Limiter
- MUSCL 3\textsuperscript{rd} order uses the Drikakis-Zoltak Limiter
- Passive Scalar Contour Lines: PS =0.25,0.5,0.75
- Reynolds Number = 1600

Nomenclature:
- FV = Finite Volume
- M2 = MUSCL 2\textsuperscript{nd} order
- M3 = MUSCL 3\textsuperscript{rd} order
- LMC = Low Mach Correction
- M = Mach Number
Double Vortex Pairing: 64x64 grid, M=0.02

Nomenclature:
• FV = Finite Volume
• M2 = MUSCL 2nd order
• M3 = MUSCL 3rd order
• LMC = Low Mach Correction
• k = Limiter Coefficient
Double Vortex Pairing: 256x256 grid, $M=0.2$

-FV-M2
-FV-M3
-FV-M2-LMC
-FV-M3-LMC
Double Vortex Pairing: 256x256 grid, M=0.02
Double Vortex Pairing: Momentum Thickness

(a) $M = 0.2$

(b) $M = 0.02$
Discontinuous Galerkin 3\textsuperscript{rd} Order

\begin{itemize}
\item[(a)] $M = 0.2$, 64x64
\item[(b)] $M = 0.2$, 128x128
\item[(c)] $M = 0.02$, 64x64
\item[(d)] $M = 0.02$, 128x128
\end{itemize}
Double Vortex Pairing: Momentum Thickness
3rd order Discontinuous Galerkin - TVB issues on 64x64 grid

(a) 3rd order DG, M = 0.2
(b) 11th order WENO-FV, M = 0.2
(c) 3rd order DG, M = 0.02
(d) 11th order WENO-FV, M = 0.02
3\textsuperscript{rd} order Discontinuous Galerkin - TVB issues on 128x128 grid

(a) 3\textsuperscript{rd} order DG, M = 0.2

(b) 11\textsuperscript{th} order WENO-FV, M = 0.2

(c) 3\textsuperscript{rd} order DG, M = 0.02

(d) 11\textsuperscript{th} order WENO-FV, M = 0.02
Conclusions

• Addition of LMC greatly improved results of the FV within SU2.

• 3\textsuperscript{rd} order accurate DG scheme produced results with sharper resolution than its FV counterparts.

• The 3\textsuperscript{rd} order DG scheme captures the non-linear behavior of the mixing layer, as well as converges to a final momentum thickness agreeable with the FV solver.

• 3\textsuperscript{rd} order DG scheme contained regions of flow with over/undershoots when compared to 11\textsuperscript{th} order WENO scheme.