# C1.5 Radial expansion wave

## 1. Code description

XFlow is a high-order discontinuous Galerkin (DG) finite element solver written in ANSI C, intended to be run on Linux-type platforms. Relevant supported equation sets include compressible Euler, Navier-Stokes, and RANS with the Spalart-Allmaras model. High-order is achieved compactly within elements using various high-order bases on triangles, tetrahedra, quadrilaterals, and hexahedra. Parallel runs are supported using domain partitioning and MPI communication. Visual post-processing is performed with an in-house plotter. Output-based adaptivity is available using discrete adjoints.

## 2. Case summary

A fourth-order Runge-Kutta explicit solver was used for all runs in this case. The number of time steps was set using a high-order CFL condition as described in Cockburn and Shu's DG review paper (2001), with an additional conservative factor of 0.25 multiplying the CFL. The results represent the entropy errors at t=2 for a specific heat ratio of 1.4. Runs were performed on the *nyx* supercomputing cluster at the University of Michigan. The number of cores was 8 for all meshes and orders. On one core of the nyx machine, one TauBench unit is equivalent to 16.5 seconds of compute time.

## 3. Meshes

The 2D meshes were generated using a Matlab script and consisted of triangular elements. A supersonic boundary condition is imposed on all domain boundaries.

## 4. 2D Results

The following figures and table present the requested data obtained for the 2D case.

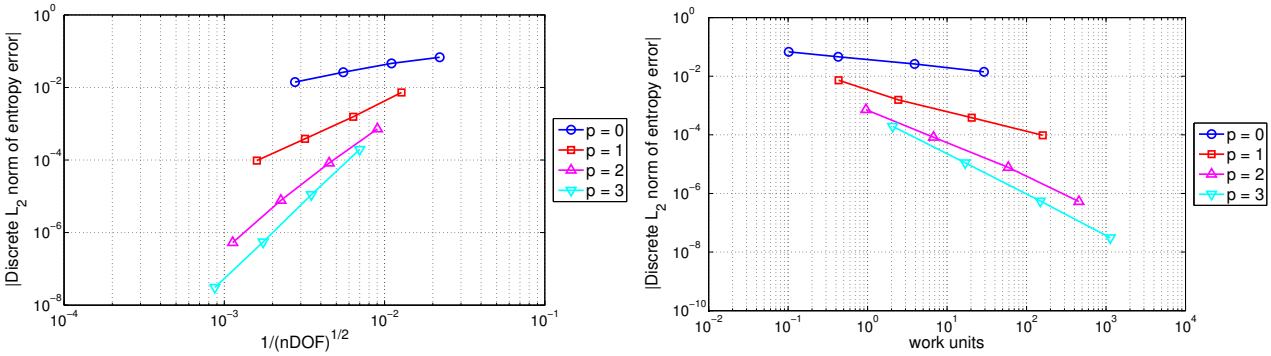


Figure 1: Entropy error convergence with $h$ refinement and work units.

Table 1: Relevant data for the 2D radial expansion case.

| nelem | p = 0 | p = 1 | p = 2 | p = 3 |
|---|---|---|---|---|
| 2048 | 6.7861e-02 | 7.2694e-03 | 7.2066e-04 | 1.9474e-04 |
| *rate* | - | - | - | - |
| 8192 | 4.5995e-02 | 1.5600e-03 | 8.2500e-05 | 1.1100e-05 |
| *rate* | 0.56 | 2.22 | 3.13 | 4.13 |
| 32768 | 2.6251e-02 | 3.8450e-04 | 7.7491e-06 | 5.4975e-07 |
| *rate* | 0.81 | 2.02 | 3.41 | 4.34 |
| 131072 | 1.4096e-02 | 9.6379e-05 | 5.2903e-07 | 3.0751e-08 |
| *rate* | 0.90 | 2.00 | 3.87 | 4.16 |

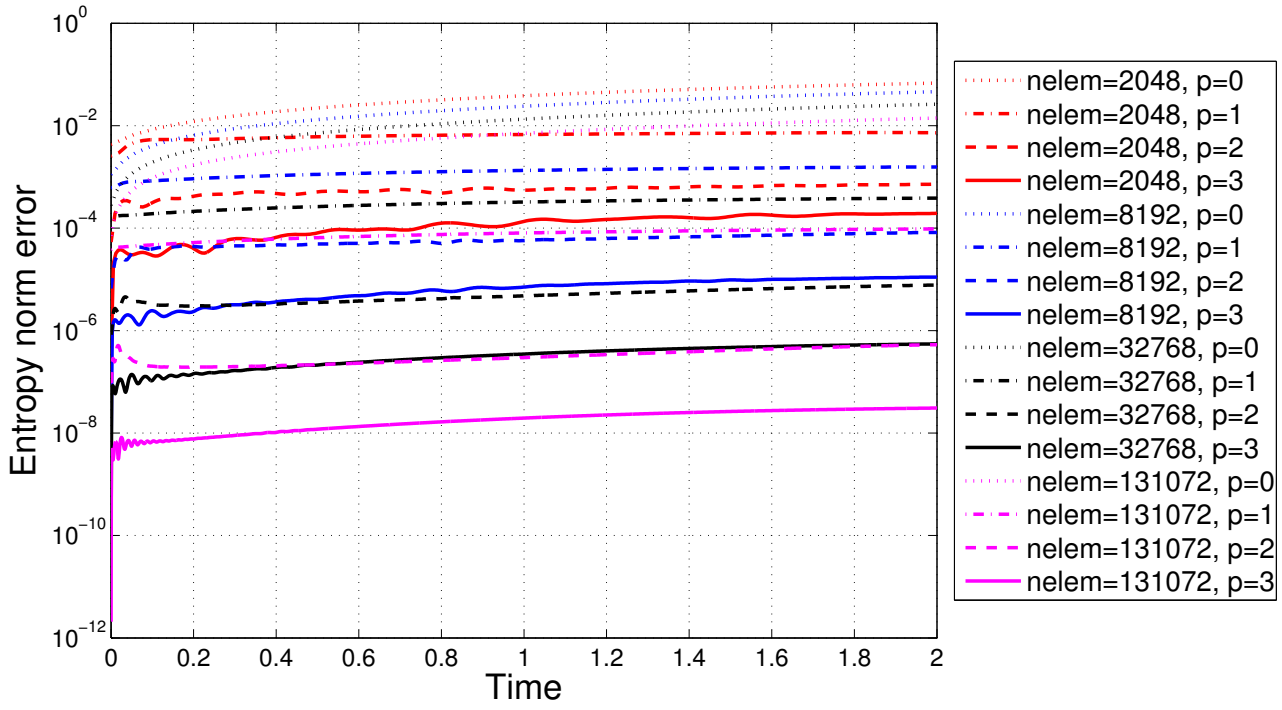


Figure 2: A time history plot for various approximation orders and refinements.