Universal Coding of the Reals: Alternatives to IEEE Floating Point - An Example Application

Improving Numerical Computation with Practical Tools and Novel Computer Arithmetic

SC17 Birds of a Feather Flash Talk

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We consider an application solving the nonlinear hyperbolic Euler equations in 2D

- Shock wave passing through initially quiescent L-shaped chamber
- Ideal gas Euler equations

$$\partial_t u + \nabla \cdot F(u) = 0$$

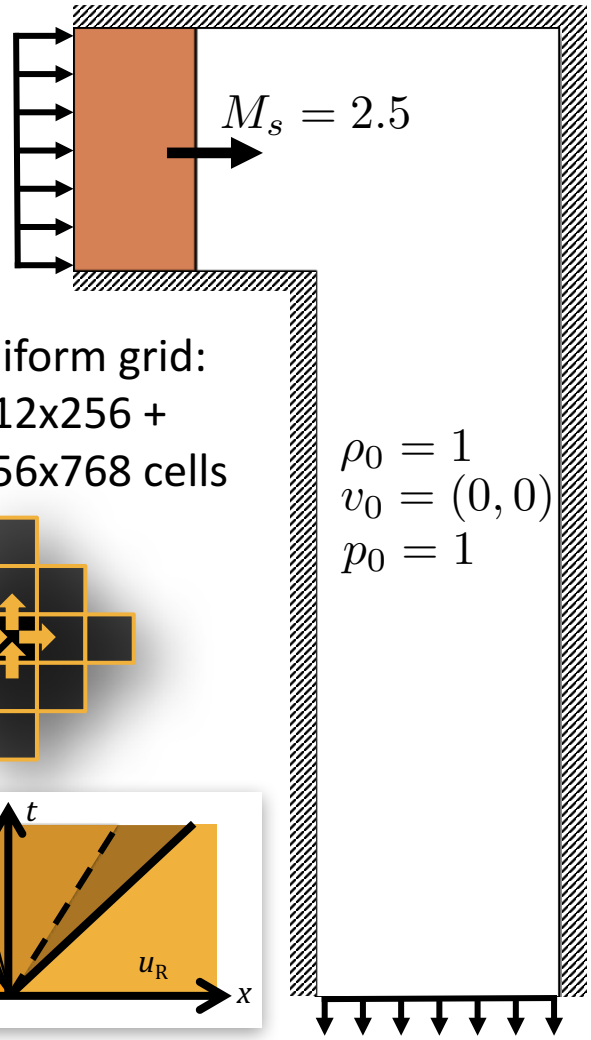
$$u = \begin{pmatrix} \rho \\ \rho v \\ \rho E \end{pmatrix} \qquad F(u) = \begin{pmatrix} \rho v \\ \rho v \otimes v + p \\ \rho v H \end{pmatrix}$$

$$\rho E = \frac{p}{\gamma - 1} + \frac{1}{2}|v|^2 \qquad \rho H = \rho E + p$$

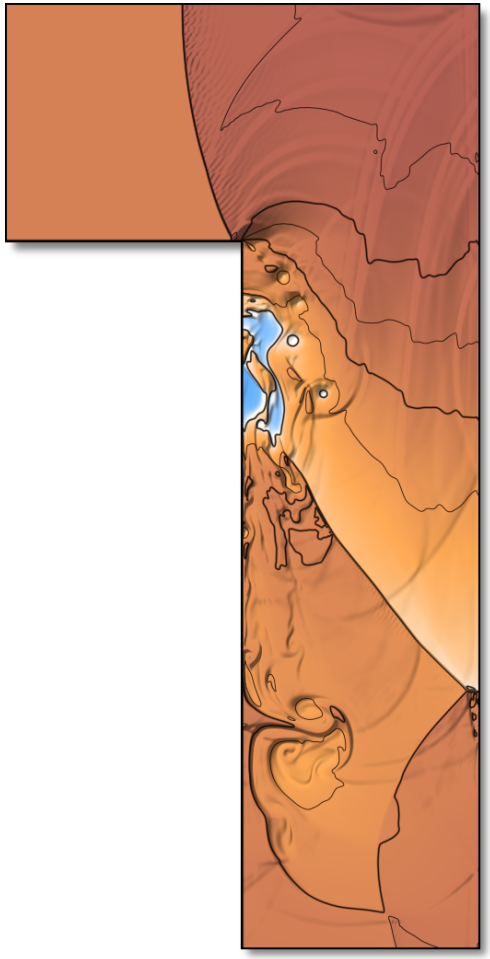
- Explicit finite volume discretization

$$u_{\mathbf{i}}^n = u_{\mathbf{i}}^n - \frac{\Delta t}{\Delta x} \sum_{d=1}^{2} \left[F^d_{\mathbf{i}+\frac{1}{2}\mathbf{e}^d} - F^d_{\mathbf{i}-\frac{1}{2}\mathbf{e}^d} \right]$$

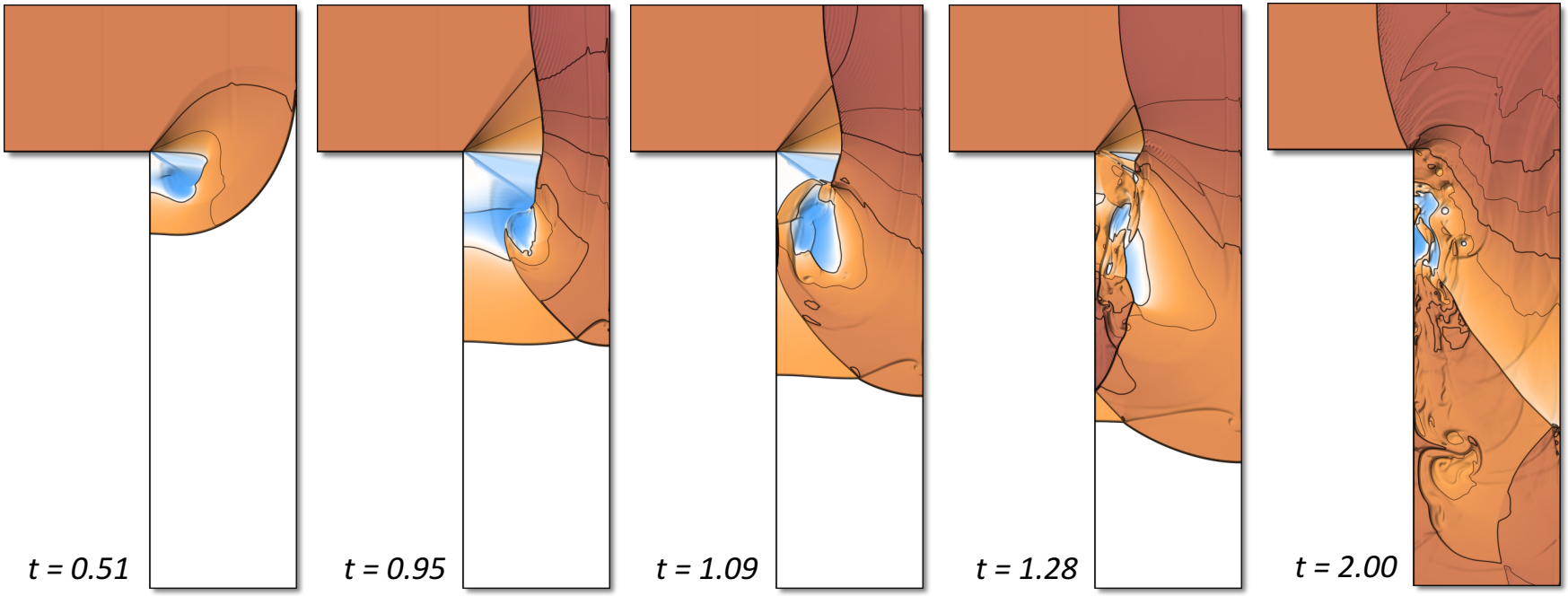
- High-resolution Godunov solver



The solution generates complicated wave interactions



It is useful to understand the solution evolution in order to understand the precision results



Shock reflects off of far wall
Steps 48-89

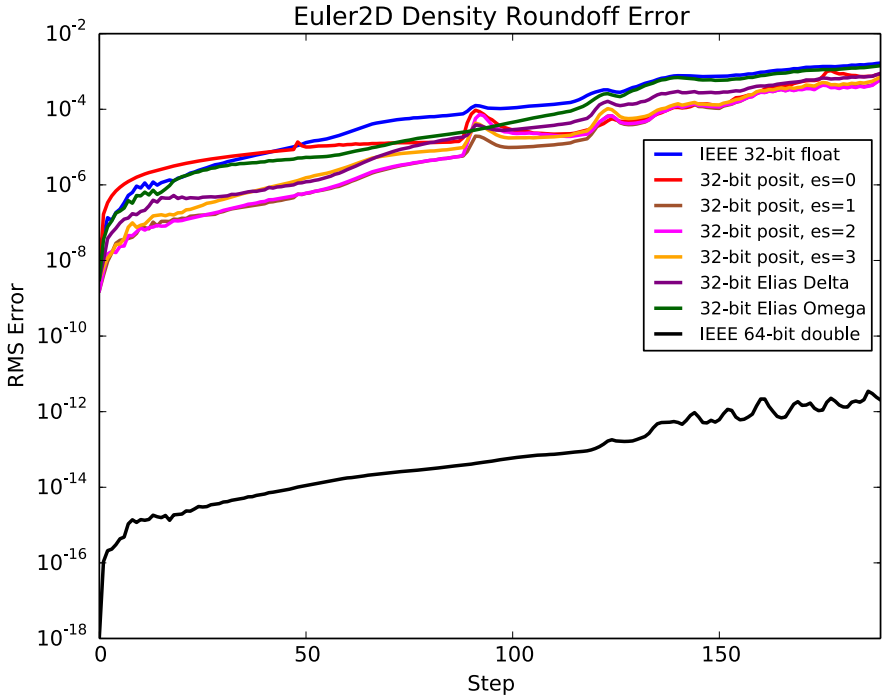
Reflected shock hits vortex
Steps 90-102

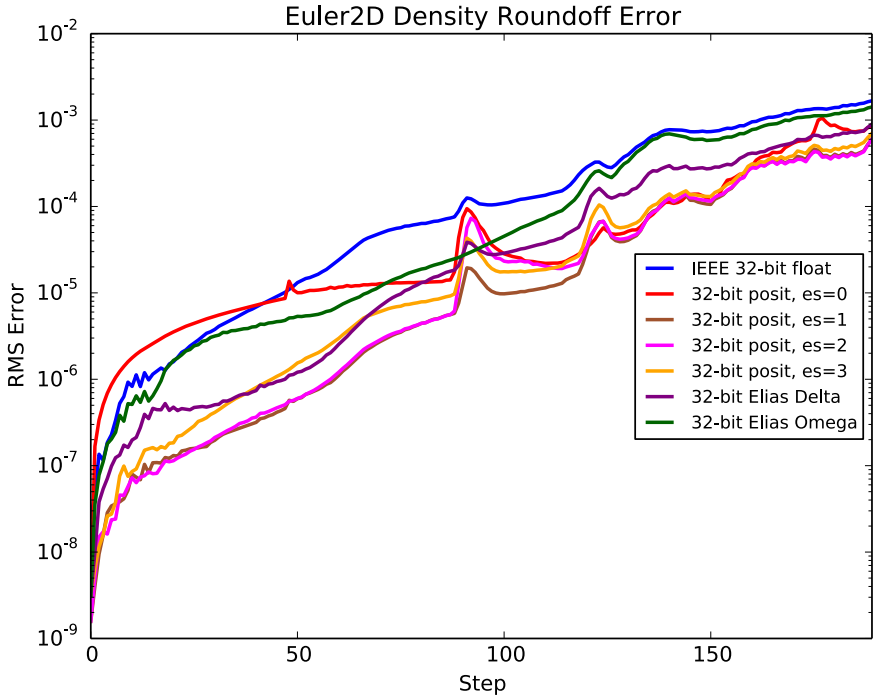
Shock reflects off of near wall
Steps 103-120

Second reflection hits vortex
Steps 121-135

Multiple wave-wave and wave-vortex interactions
Steps 136-189

We have tested numerous types, including posits, using the Euler2D code





- Features in the results correlate to features in the solution data
- The general trend is that you can do better than IEEE float at 32-bits
- It appears 32-bit posit, es=1 performs the best of the 32-bit types tested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