ME 683: Computational Gas Dynamics

Coding Assignment 3: Sod Shock Tube

March 28^{th}-April 24^{th} 2025

Introduction

Sod shock tube is a standard Riemann problem for Euler's equation which is used to validate and test the accuracy of various numerical schemes. An L m long shock tube is separated at the middle $(L/2)$ into two sections: driver section (L) and driven section (R). Let, the initial conditions in the two sections be:

$$\begin{bmatrix} \rho_L \\ P_L \\ u_L \end{bmatrix} = \begin{bmatrix} 1.0 \\ 1.0 \\ 0.0 \end{bmatrix}, \begin{bmatrix} \rho_R \\ P_R \\ u_R \end{bmatrix} = \begin{bmatrix} 0.125 \\ 0.1 \\ 0.0 \end{bmatrix}$$

At time $t = 0$, the diaphragm separating the two section breaks, and (with these initial conditions,) a shock wave moves in the right direction in the driven section, followed by a contact discontinuity and a rarefaction opening up in the left direction in the driver section. The pressure and velocity are constant across the contact discontinuity, and the variables vary continuously in the rarefaction wave.

Goal

The objective of the term project is to write computer program (in any language of your choice $\in$ [C, C++, Fortran, Matlab, Python]) and simulate the standard Sod shock tube problem. Simulation details:

- Simulation Type : 1D
- Domain size : 1 m $(0 \leq x \geq 1)$
- No of cells : 400 minimum
- CFL number : 0.8 (or $\Delta t = 0.8\Delta x/max(|\lambda|)$)
- Total Simulation time : $t = 0.15s$
- Boundary Condition : Zero gradient at the two sides. (Flux = 0)

Numerical Flux Schemes

You have to implement the following Numerical Schemes:

- Roe solver (with and without Entropy fix)
- Steger-Warming flux vector scheme

Submission

Submit 1D line plots of density, pressure, velocity and internal energy (circles as markers, no lines) for each method with underlaying analytical results (in dark line, data is provided). In total, you should have a total of 3×4 plots. The plots should have proper filename, title, labels and legends. In addition to this, compare and conclude which is the best method (among the ones that you have implemented) and why so? (In a separate text/doc file). You have to submit all codes along with these plots. Mail zip/tar file of your plots+doc files+codes to *tapan.mankodi@iitg.ac.in* and *harshal.srivastava@iitg.ac.in* by 9:00 PM, April 24^{th} 2025 (Thursday).

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