229065125 Figures 1 and 2

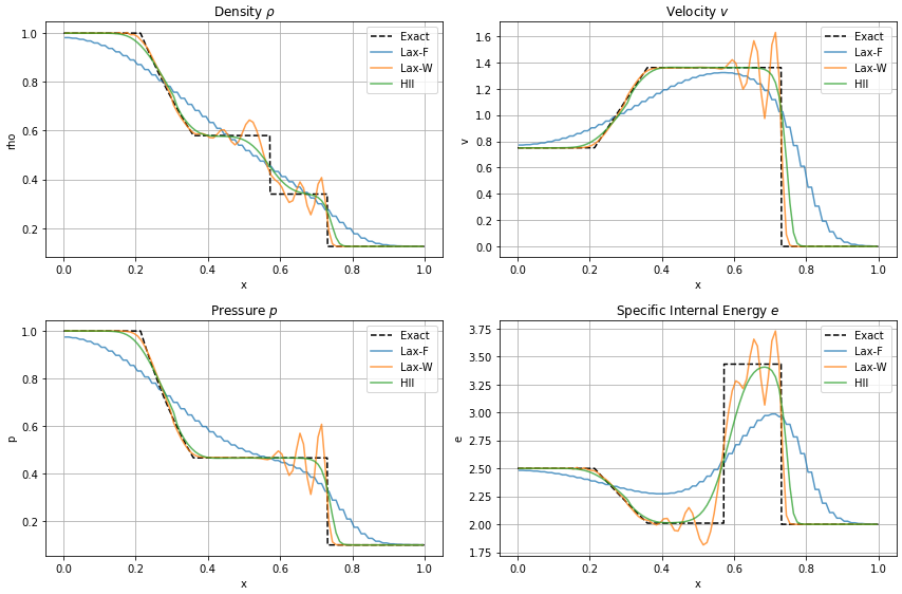


Figure below displays the evolution of three key physical features in Sod's shock tube, computed using the HLL method:

- **Shock Position (blue)** – the furthest right sharp increase in density.
- **Rarefaction Edge (orange)** – the leftmost density drop marking the rarefaction fan.
- **Contact Discontinuity (green)** – tracked using a passive scalar (tracer), located by the maximum gradient of the tracer field.

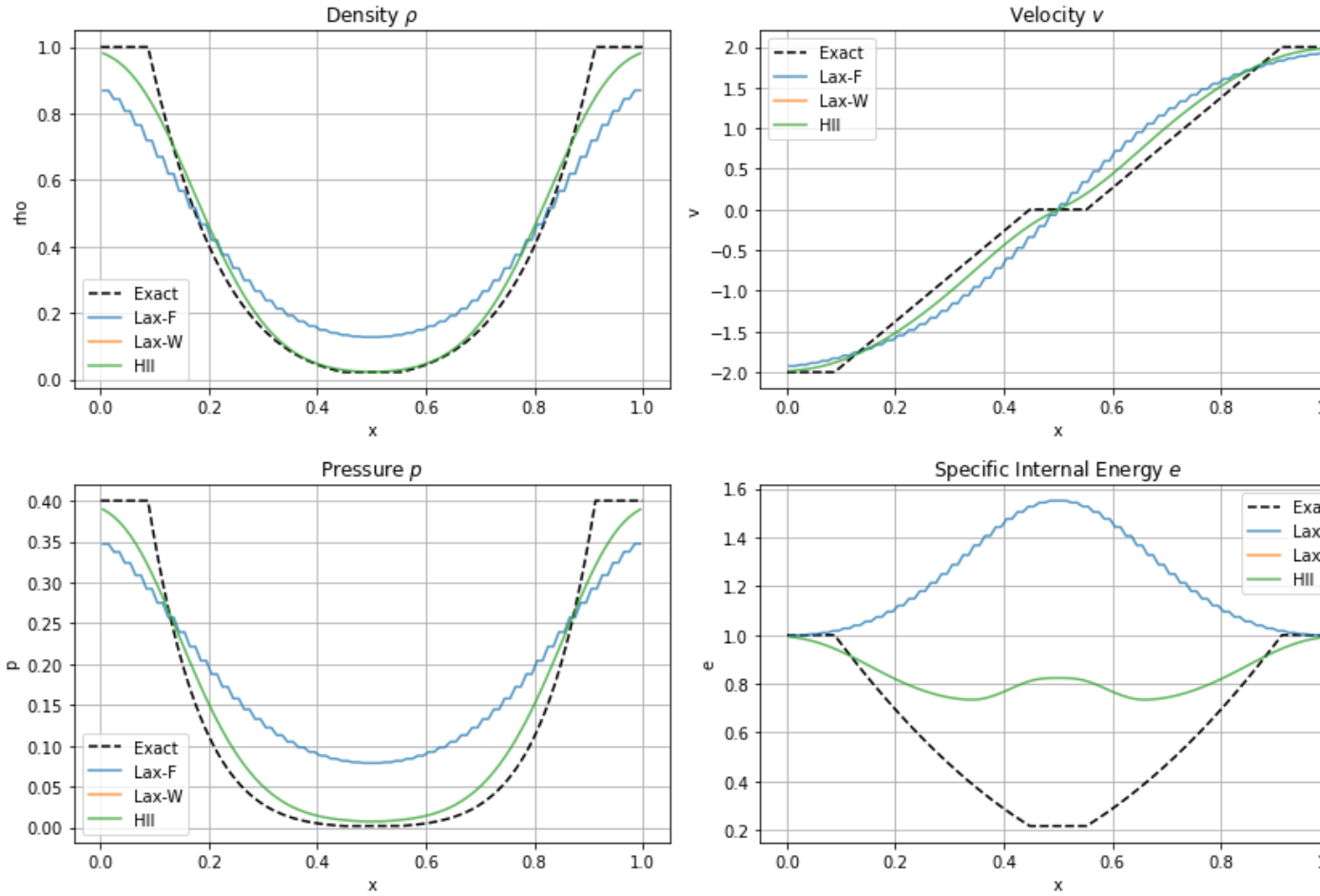
The `run_hll3()` function extracted these locations at every timestep and outputted them to `features_hll.txt` for plotting.

The **HLL method** was chosen for this analysis due to its ability to sharply resolve shocks and interfaces without unphysical oscillations—unlike Lax-Friedrichs or Lax-Wendroff, which tend to diffuse or overshoot. HLL uses estimates of wave speeds and provides robust, accurate fluxes between cells.

This visualization confirms the physically expected evolution:

- The **shock** travels steadily rightward through the low-pressure region.
- The **rarefaction wave** expands leftward.
- The **contact discontinuity** moves slower than the shock and remains distinct throughout.

The clarity and stability of these features using HLL make it an ideal candidate for further studies—especially in cases requiring sharp resolution and feature tracking such as core-collapse supernovae or blast waves. Additionally, HLL could be combined with higher-order spatial reconstructions in future work to improve smooth feature resolution while retaining shock robustness.



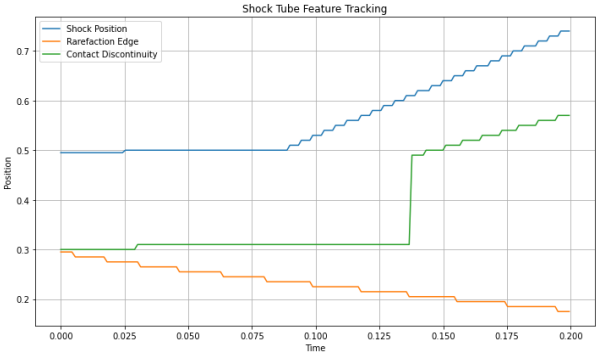


Figure 1: Shock tube evolution showing the tracked positions of the shock front, rarefaction edge, and contact discontinuity over time using the HLL solver.