Multimaterial Simulations using the Ghost Fluid Method

Knut Sverdrup

Cavendish Laboratory, Department of Physics, J J Thomson Avenue, Cambridge. CB3 0HE

Abstract

The unsteady, compressible Euler equations for multimaterial flow in one dimension have been solved numerically by employing a level set method and two versions of the Ghost Fluid Method.

1. Introduction

1.1. Euler equations

The Euler equations govern adiabatic and inviscid flow of a fluid. In one dimension, with density ρ, velocity u, total energy E and pressure p, they are given by

$$\frac{\partial \mathbf{U}}{\partial t} + \frac{\partial \mathbf{F}(\mathbf{U})}{\partial x} = 0\,, \tag{1}$$

where the vectors of conserved quantities $\mathbf{U}$ and their fluxes $\mathbf{F}(\mathbf{U})$ are given by

$$\mathbf{U} = \begin{pmatrix} \rho \\ \rho u \\ E \end{pmatrix}\,, \quad \mathbf{F} = \begin{pmatrix} \rho u \\ \rho u^2 + p \\ u(E+p) \end{pmatrix}\,. \tag{2}$$

It is sometimes convenient to work in terms of the primary variables $\mathbf{W} = \begin{pmatrix} \rho, & u, & p \end{pmatrix}^T$. The total energy is the sum of the kinetic and potential energy of the system, i.e.

$$E = \frac{1}{2}\rho u^2 + \rho e\,, \tag{3}$$

where e is the internal energy, related to the other variables through the equation of state. For an ideal gas, the equation of state is

$$e = \frac{p}{(\gamma - 1)p}\,, \tag{4}$$

where γ denotes the ratio of specific heats for the gas.

1.2. Riemann problem

1.3. Multimaterial flow

2. Numerical methods

2.1. Slope-Limiting Centered scheme (SLIC)

2.2. Level-set method

2.3. Ghost Fluid Methods

2.3.1. Original Ghost Fluid Method

2.3.2. Riemann Ghost Fluid Method

3. Results

3.1. Moving contact discontinuity

3.2. Simple ghost fluid tests

3.3. Multimaterial shock tubes for gases

3.4. Water-gas shock tube test

4. Conclusions

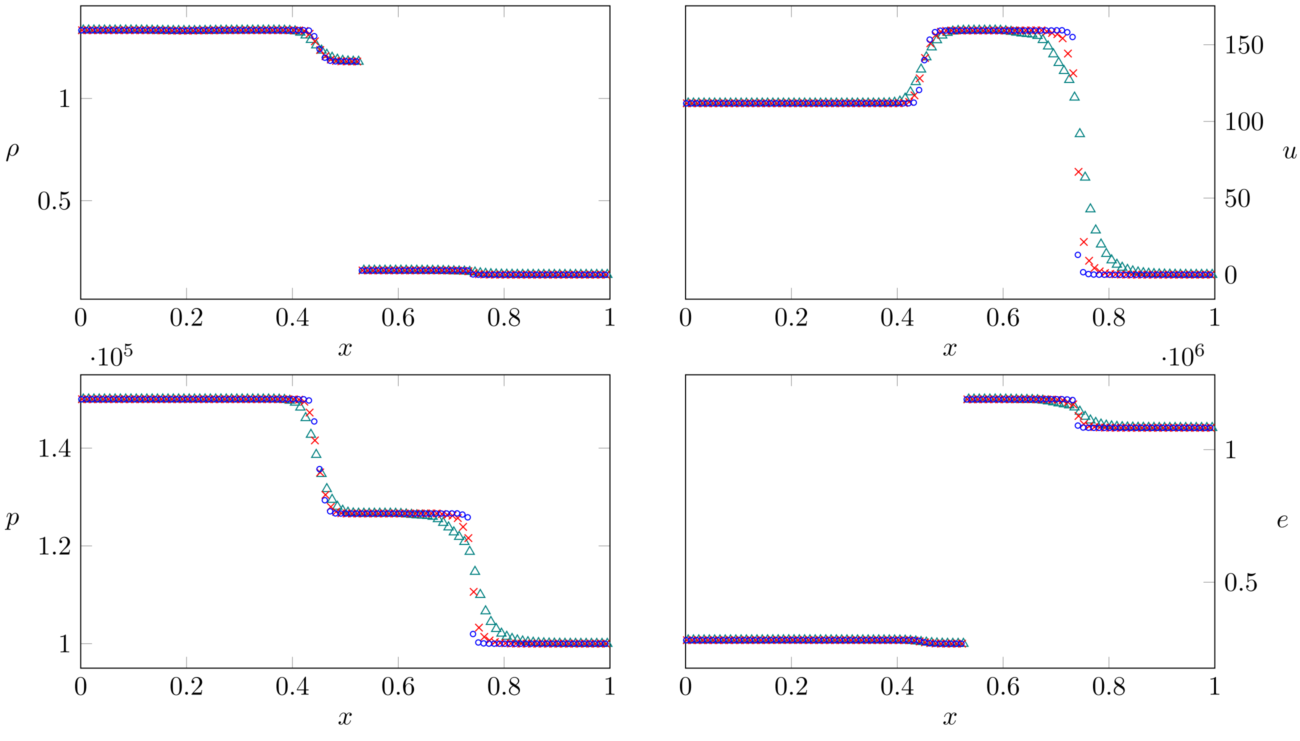

Figure 1: Original Ghost Fluid method for test C. $\triangle N = 100$ $\times N = 200$ $\circ N = 400$

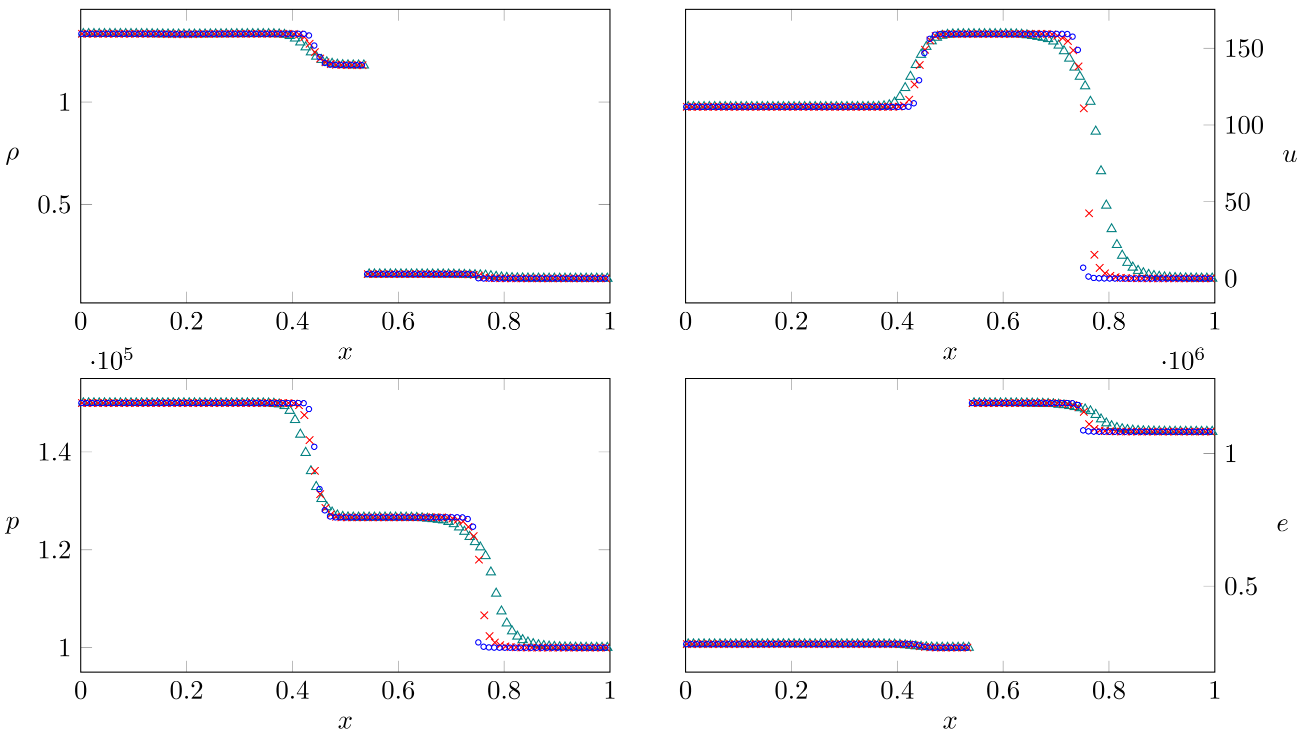

Figure 2: Riemann Ghost Fluid method for test C. $\triangle N = 100$ $\times N = 200$ $\circ N = 400$

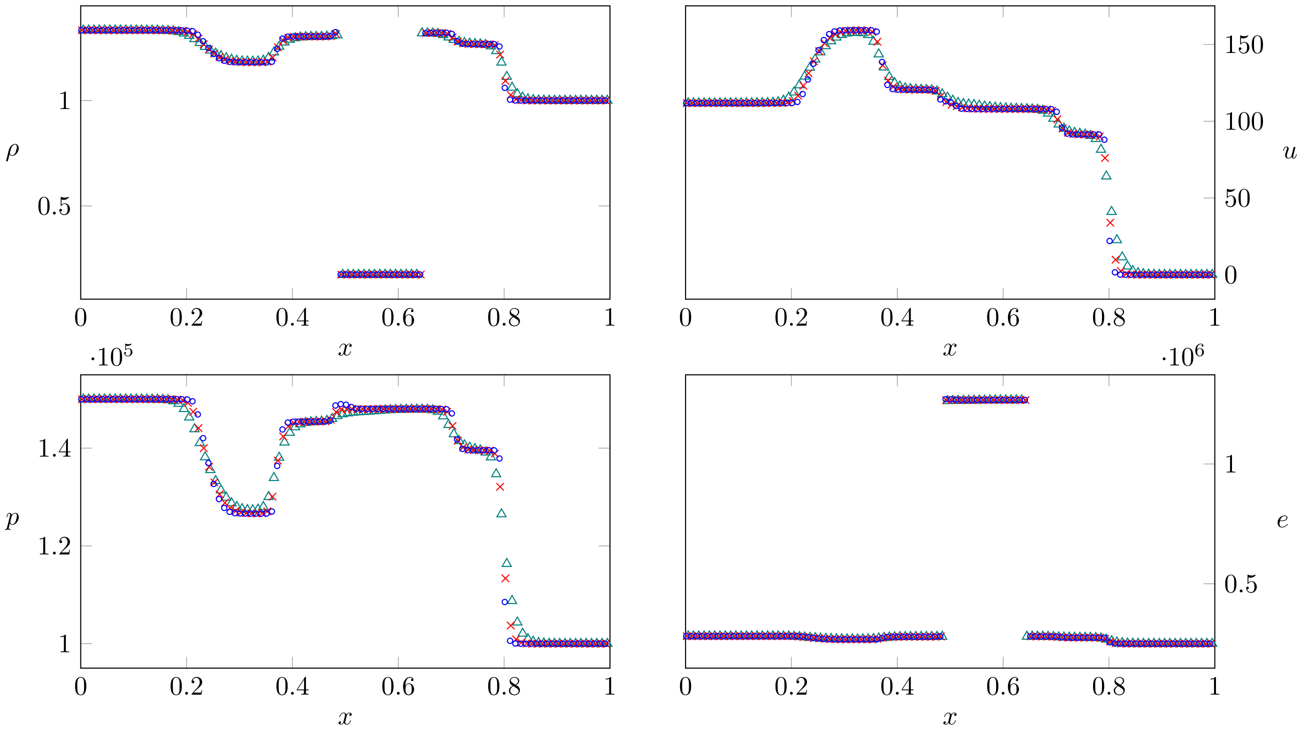

Figure 3: Original Ghost Fluid method for test D. △$N = 100$ ×$N = 200$ ∘$N = 400$

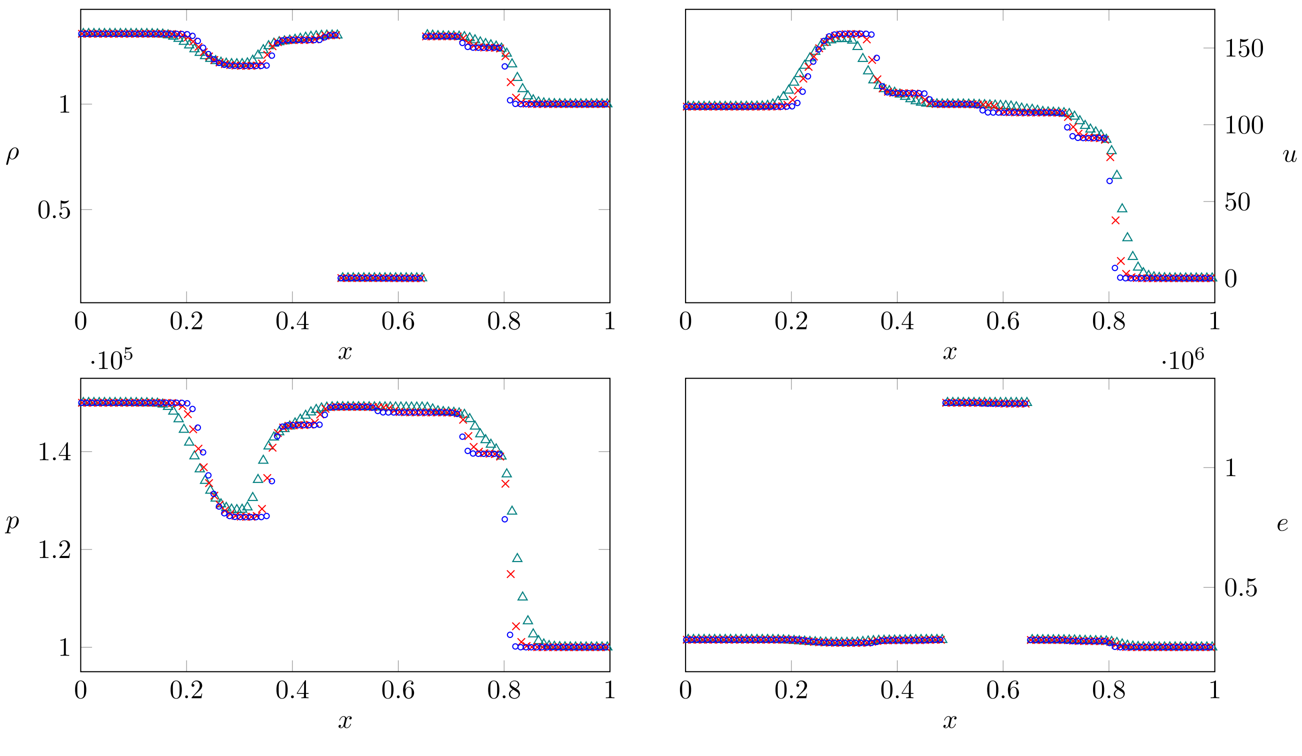

Figure 4: Riemann Ghost Fluid method for test D. △$N = 100$ ×$N = 200$ ∘$N = 400$

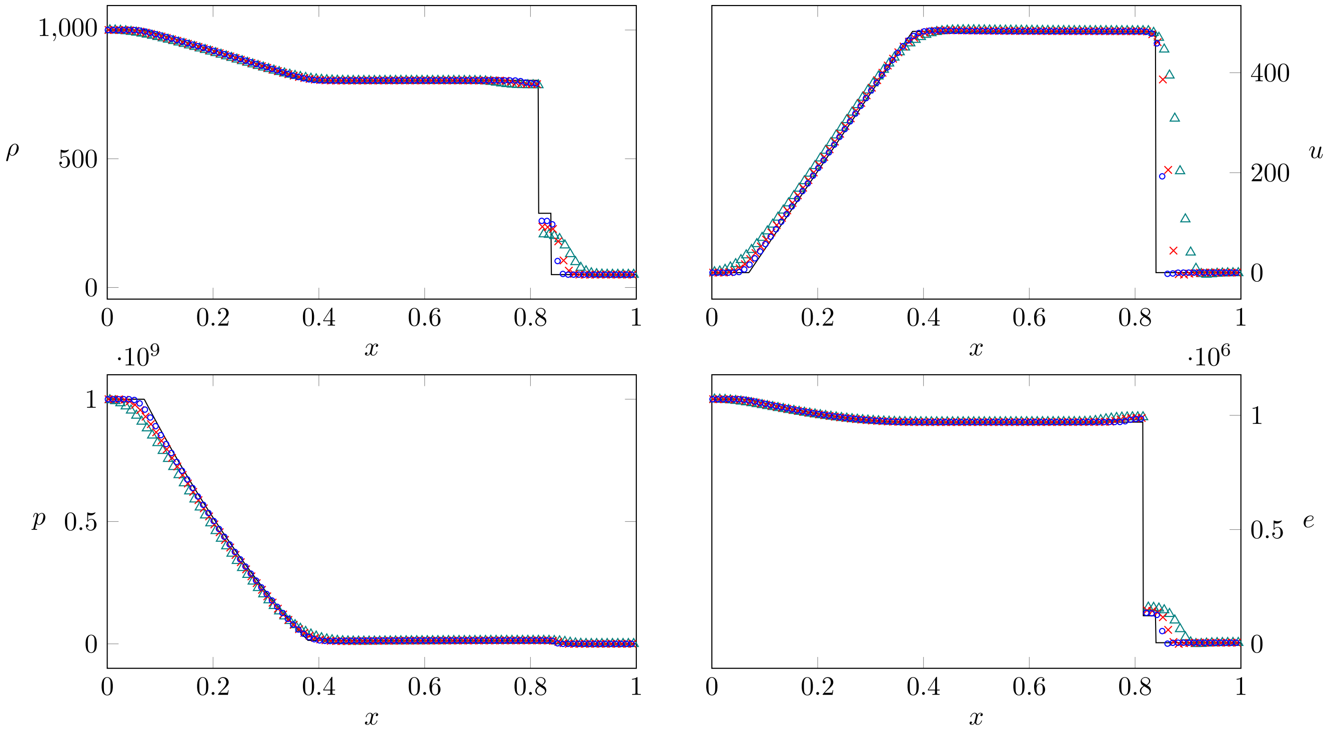

Figure 5: Riemann Ghost Fluid method for test E. △$N = 100$ ×$N = 200$ ○$N = 400$

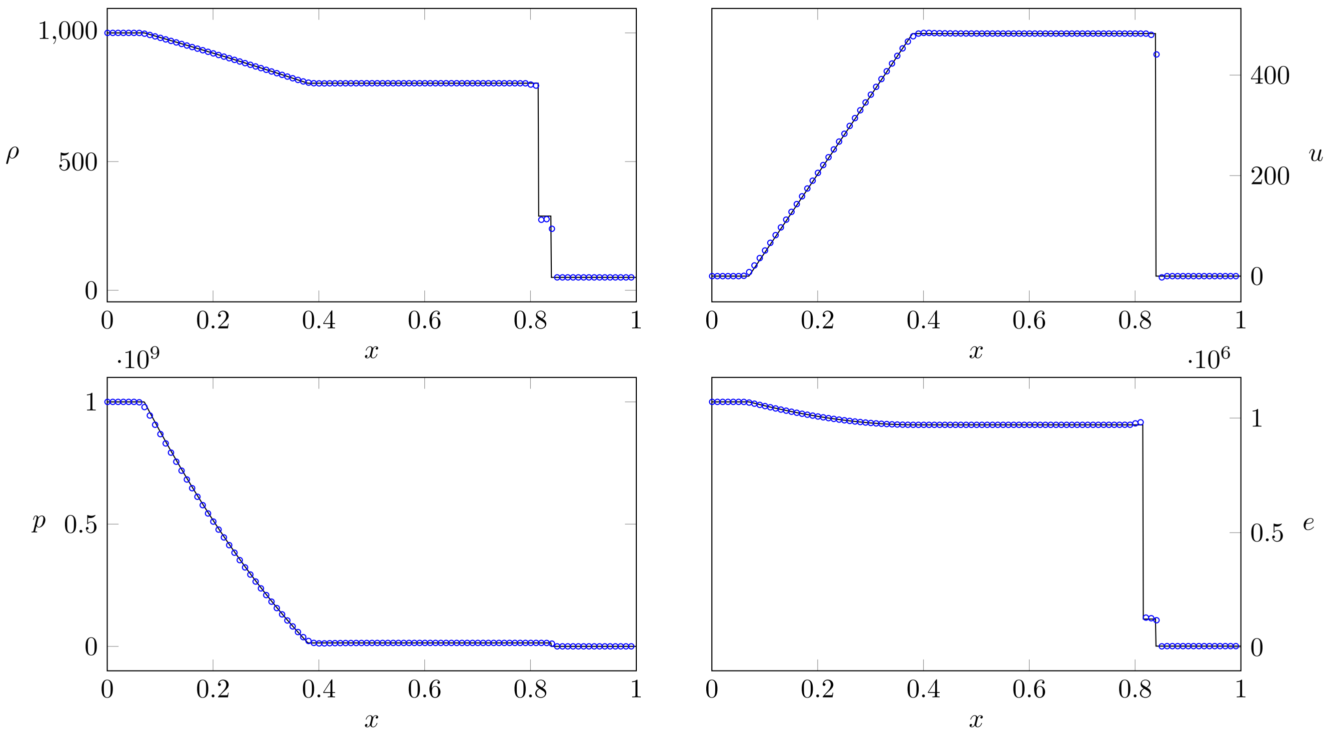

Figure 6: Riemann Ghost Fluid method for test E with higher accuracy ($N = 1000$).