

# SHOCKWAVE

Max Lê

April 23, 2019

# Overview

- Problem Statement
- Methods
- Results
- Conclusions
- Q&A

# Motivation



Figure: Shock cloud F15

- Shockwaves are important in aerodynamics
- In aircraft: when approach speed of sound
- In detonation: blast wave causes very dangerous shock
- Across shocks, properties are chaotic → Need good shock capturing schemes

# The Shocktube

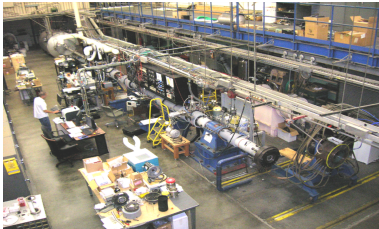


Figure: NASA Ames 9m shocktube

- simple mechanical device with low and high properties at both end
- A diaphragm separates the two fluid.
- Once diaphragm breaks, **shockwave** propagates to the right, expansion wave propagates to the left

# The Shocktube

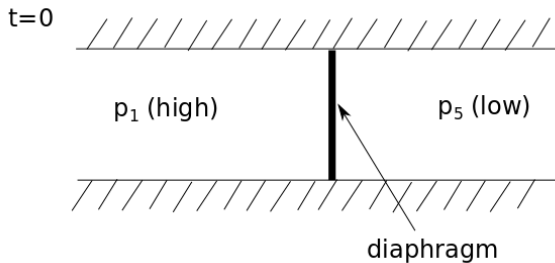


Figure: Initial conditions

# The Shocktube

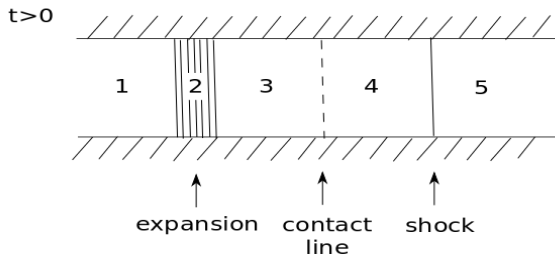


Figure: After diaphragm breaks

# Assumptions

- Ideal gas
- Single phase flow
- Zero gradient boundary conditions at both ends
- No heat transfer, no body force
- Incompressible
- Steady State

# Equations

$$\frac{\partial U}{\partial t} + \frac{\partial F}{\partial x} = 0, \quad U = \begin{bmatrix} \rho \\ \rho u \\ E \end{bmatrix}, \quad F(U) = \begin{bmatrix} \rho u \\ p + \rho u^2 \\ (E + p)u \end{bmatrix}$$

$\rho$  = density,  $u$  = velocity,  $p$  = pressure

$E$  = total energy per unit volume =  $\rho e + \frac{1}{2}\rho u^2$

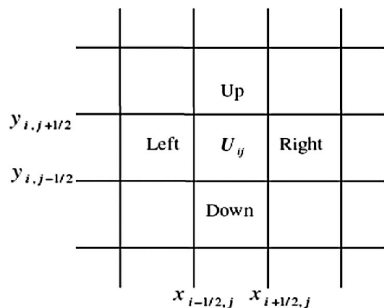
$\rho e$  = internal energy per unit volume

$e$  = internal energy per unit mass

- Conservation of mass, momentum and energy
- Ideal gas equation of state to close the system



# Computational Grid



- Properties at cell's center
- Fluxes on the edge

# Numerical Schemes

$$\frac{\partial U}{\partial t} \approx \frac{U_i^{n+1} - U_i^n}{\Delta t} + \mathcal{O}(\Delta t)$$

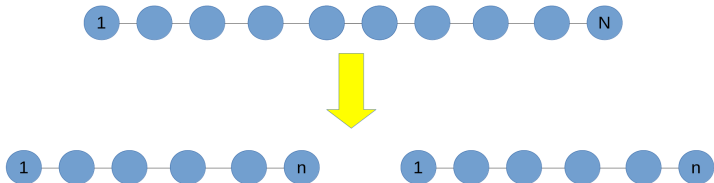
$$\frac{\partial F}{\partial x} \approx \frac{F_{i+1}^n - F_i^n}{\Delta x} + \mathcal{O}(\Delta x)$$

- Temporal discretization: first order forward in time
- Spatial discretization: first order in space
- Fluxes are calculated as **Van Leer** fluxes for subsonic and supersonic case.

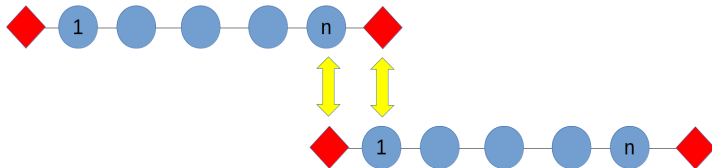
# Numerical Schemes

$$U_i^{n+1} = U_i^n - \frac{\Delta t}{\Delta x} [(F^+ + F^-)_{i+1/2} - (F^+ + F^-)_{i-1/2}]$$

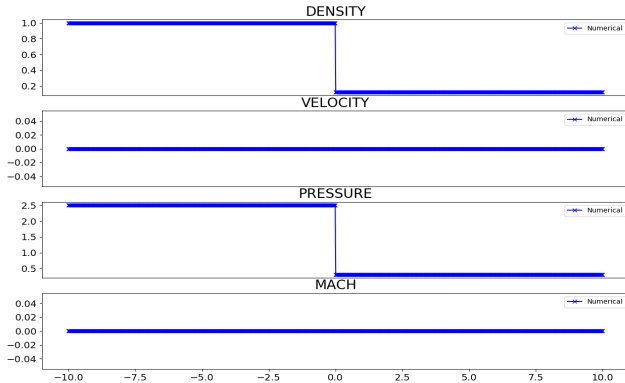
# Parallelization Strategy



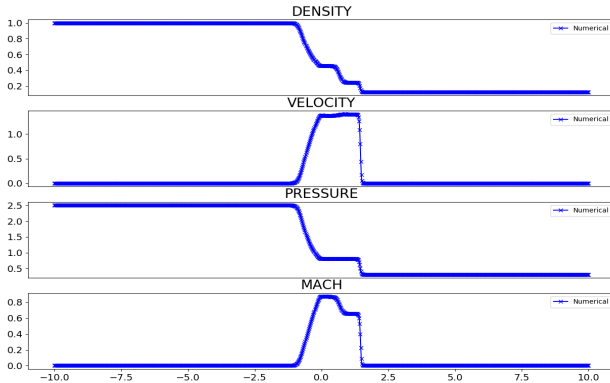
# Optimizations



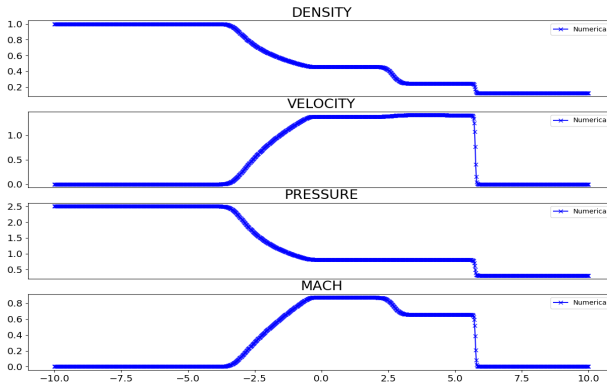
# Numerical evolutions



# Numerical evolutions

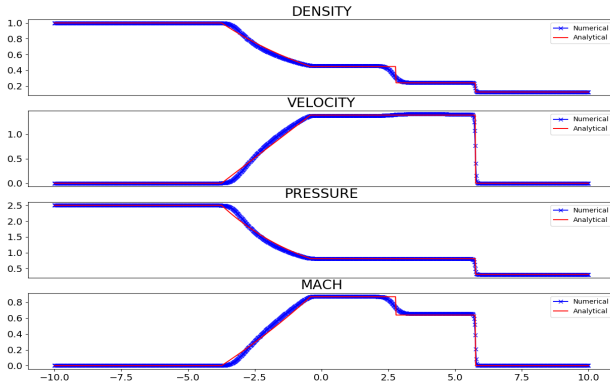


# Numerical evolutions



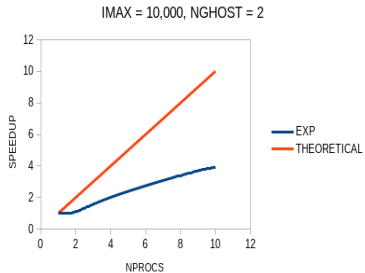


# Analytical comparison



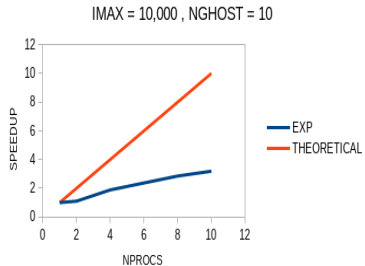
# Speedup

CORE	TIME	EXP	THEORETICAL
1	10.888	1	1
2	9.953	1.093941525	2
4	5.425	2.007004608	4
8	3.207	3.395073277	8
10	2.78	3.916546763	10



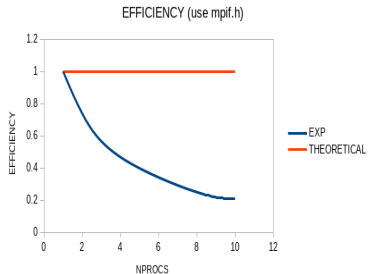
# Ghost Points

CORE	TIME	EXP	THEORETICAL
1	11.237	1	1
2	10.198	1.101882722	2
4	5.962	1.884770211	4
8	3.941	2.851306775	8
10	3.526	3.186897334	10



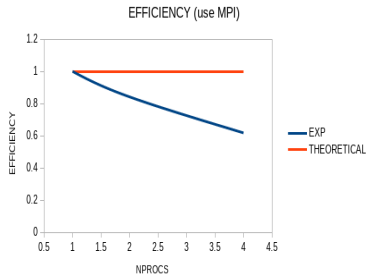
# Scaling

N	CORE	TIME	EXP	THEORETICAL
1000	1	0.778	1	1
2000	2	1.053	0.738841405508	1
4000	4	1.664	0.467548076923	1
8000	8	3.113	0.249919691616	1
10000	10	3.695	0.210554803789	1



# Scaling

N	CORE	TIME	EXP	THEORETICAL
1000	1	0.405	1	1
2000	2	0.481	0.841995841996	1
4000	4	0.655	0.618320610687	1



## Some remarks

- We do see speedup but not great
- Extended ghost layers do not give much speedup
- Improvements: solve cons of mass, momentum, energy individually (instead of grouping everything under 1 U state vector)  $\Rightarrow$  need individual fluxes

Thank You For Listening!  
*(Remember: Go with with the flow)*