High Performance Computing 1b
Parallelization of a 2D Hydro Solver

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Introduction and physics

Our task was to parallelize an existing C code, originally written by Prof. Romain Teyssier in Fortran, which solves the Euler equations in 2D using a Godunov scheme. A hyperbolic PDE in conservation law form is represented as

$$\partial_t \mathbf{U} + \nabla \cdot \mathbf{F}(\mathbf{U}) = 0 \tag{1}$$

The euler equations are a set of equations which basically state the momentum, mass and energy conservation. Discretization on a grid yields

$$\mathbf{U}_i^{n+1} = \mathbf{U}_\mathbf{i}^\mathbf{n} + \frac{\Delta x}{\Delta t}(\mathbf{F}_{\mathbf{i-1/2}} - \mathbf{F}_{\mathbf{i+1/2}}) \tag{2}$$

where $\mathbf{F}_{\mathbf{i\pm 1/2}}$ are the fluxes at the cell boundaries, the Godunov scheme uses various approximations for $\mathbf{F}_{\mathbf{i\pm 1/2}}$, depending on the specific variation of the method, e.g upwind scheme, lax-friedrich, ...

Parallelization strategy

Serial vs. Parallel Processing

We compare the average time step durations for a single process up to approximatly 1500 parallel processses for a fixed problem size (in our case 60994 x 120). As observable in the strong scaling graph (ref figure) we get a super linear scaling up to 800 processes. The super linearity of the scaling can be explained with cache usage effects.

Oprimal cache memory usage only works well for rectangular shaped domains (large x small y for parallelization in x direction). We have compared how a fixed sized problem performs with diffrent x/y ratios (see figure xx). We can cleary see that the performance increases with deacrasing y/x size, up to a ratio, where each processes computing domain gets too small and becomes inefficient.

Scaling and Speedup

sfftrong.png

Figure: Strong scaling for a fixed grid size of 69994 × 120 for 1 to

weffak.png

Figure: Performance comparison of a fixed sized grid with varinyg y/x

Scaling and Speedup

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speehdup.png

Figure:

Output image

To show the power of parallel processing we wanna show an excerpt from our high resolution image (15000 x 500) at simulation time t=600 seconds (corresponds to the 200'000th time step in our simulation)