Turbulent Flow Simulation on HPC Systems
Department of Mechanics and Informatics
Technical University of Munich

Worksheet 2

Haotian Ji, Siva Karthikeya Mandarapu, Hari Surya Charan Mudragada, and Matilde Tozzi

December, 2023

Abstract — This is a short abstract summarizing the main points of your article.

1 Parallelization (30%)

We looked at the `ParallelBoundaryIterator`, which operates on the border of a process domain and operates separately on the top, bottom, left and right faces (in 3D, on the front and back faces too). The stencil used by the iterator needs to have the functions `applyXWall`, where `X` is the various sides respectively. We decided to use this iterator and a similar structure for our stencils `PressureBufferFillStencil`, `PressureBufferReadStencil`, `VelocityBufferFillStencil` and `VelocityBufferReadStencil`.

We then integrated these operations in `PetscParallelManager`, that uses the methods `communicatePressure` and `communicateVelocity` to call `MPI_Sendrecv`. The calls to this class were added in the class `Simulation`.

2 Scaling and Efficiency (20%)

For each scenario, we use the following general setup:

```
<timestep dt="1" tau="0.5" />
  <solver gamma="0.5" />
  <geometry dim="3"
    lengthX="1.0" lengthY="1.0" lengthZ="1.0"
    sizeX="20" sizeY="10" sizeZ="20"
  >
    <mesh>uniform</mesh>
  </geometry>
  <environment gx="0" gy="0" gz="0" />
  <walls>
      <left>
          <vector x="0" y="0" z="0" />
      </left>
      <right>
          <vector x="0" y="0" z="0" />
      </right>
      <top>
          <vector x="1" y="0" z="0" />
      </top>
      <bottom>
          <vector x="0" y="0" z="0" />
      </bottom>
      <front>
          <vector x="0" y="0" z="0" />
      </front>
      <back>
          <vector x="0" y="0" z="0" />
```

```
    </back>
  </walls>
```

As suggested, we also switched off the VTK output because it is not parallelized.

2.1 Cavity 3D

The execution time without `mpirun` is 34039686ns. This is the situation with different parallel domains:

Parallel Domain	Time
1x1x1	19178151ns
2x2x2	18492591ns
3x3x3	17050365ns

There execution time is lower with a more intensive parallel use, so we don't have a strong parallel scaling in this case.

3 Implementation Turbulence Modeling (30%)

4 Testing (5%)

5 Flow Physics (15%)