Introduction to open source CFD

An experimental OpenFOAM course

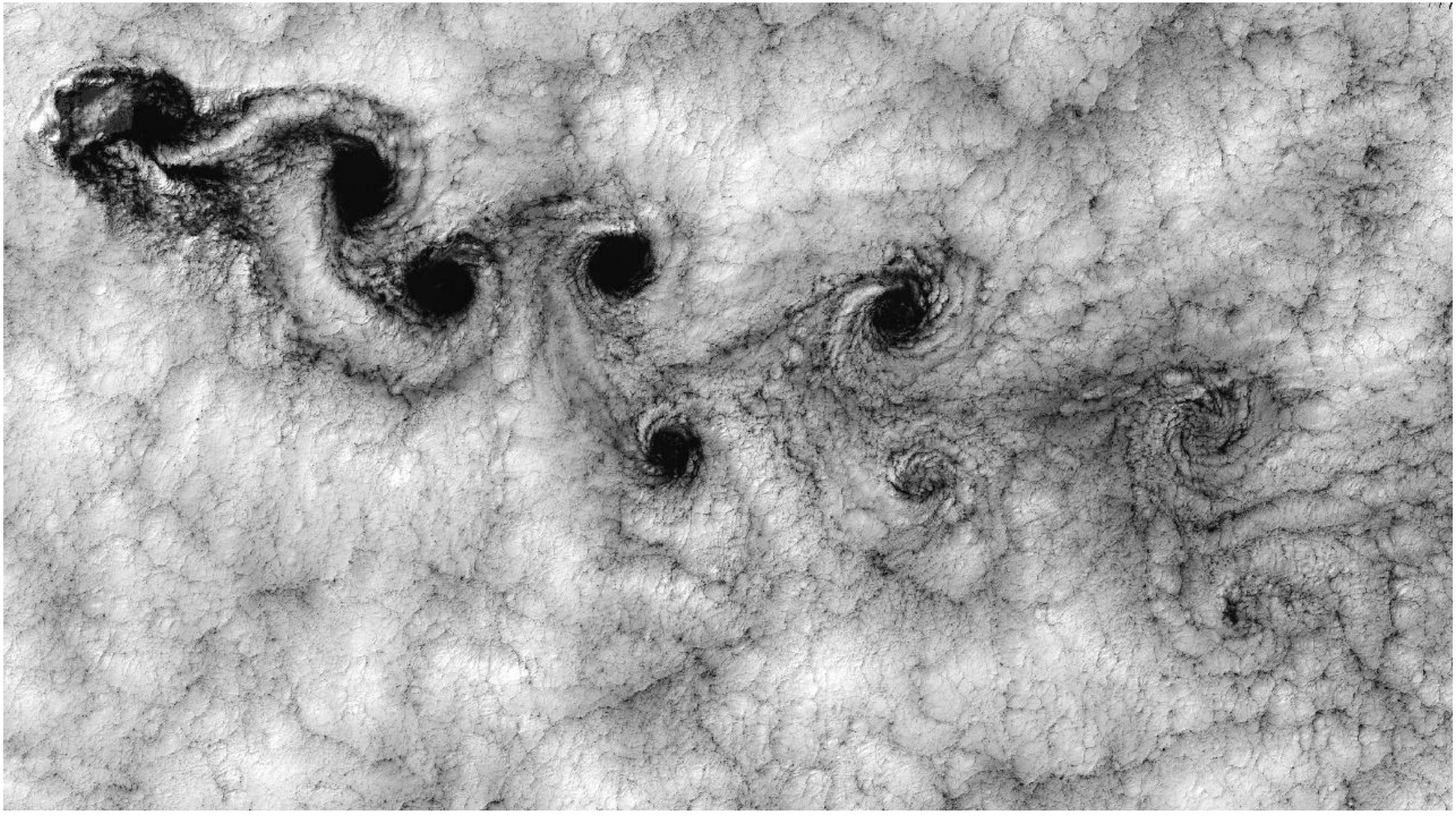
Gerhard Holzinger

November 23, 2016

1. Hands on Karman vortex street
   - Meshing
   - Results
   - Play around

Table of contents

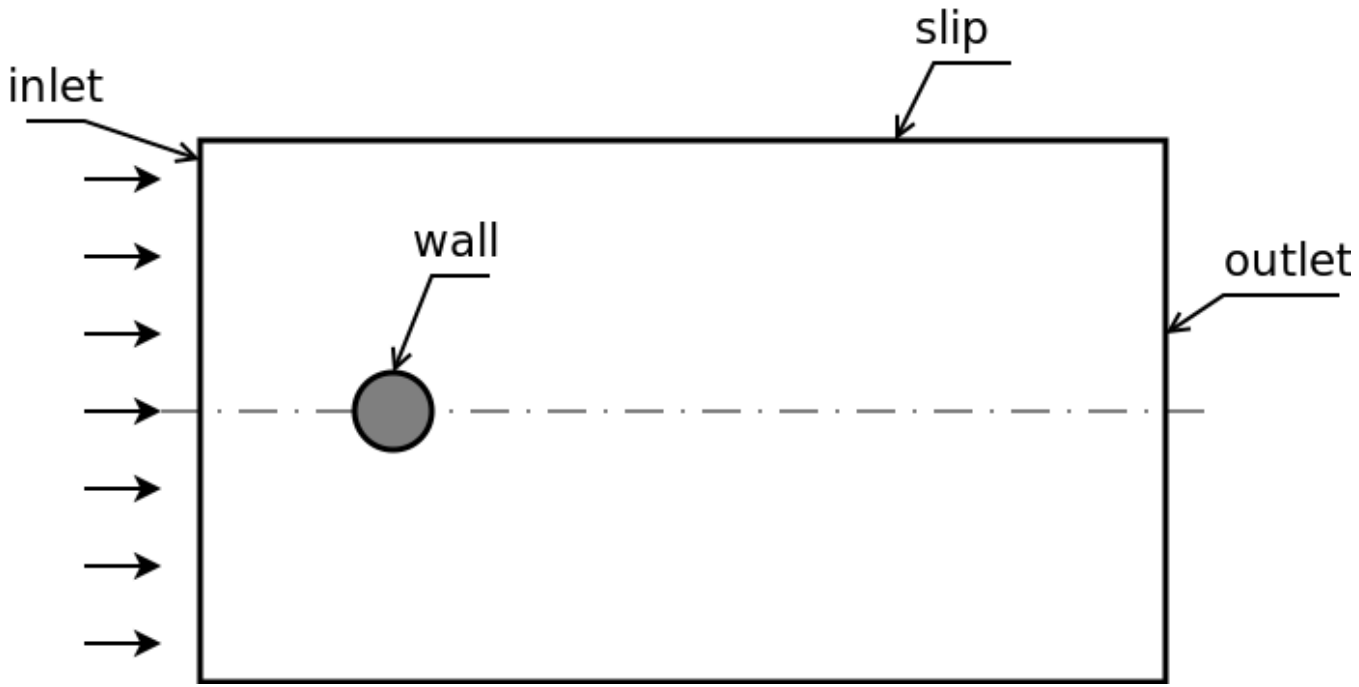
Karman vortex street



https://commons.wikimedia.org/wiki/File:Vortex-street-1-90deg.jpg

Case description

- Simple 2D case
  - We will use several meshing tools



Case description

- Meshes in OpenFOAM
  - Are always three-dimensional
  - So how to we create a 2D case?

Case description

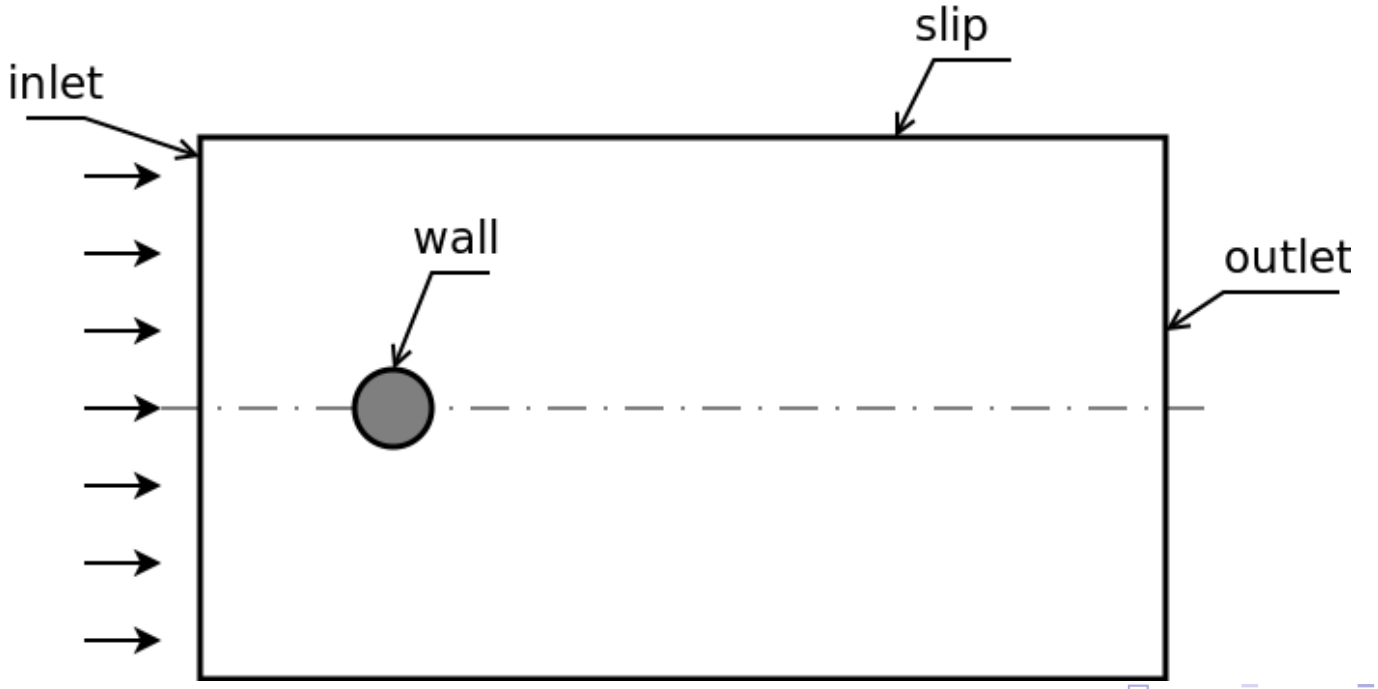
- Meshes in OpenFOAM
  - Are always three-dimensional
  - So how to we create a 2D case?
- OpenFOAM is our friend
  - Build mesh with a single cell in thickness
  - Use special boundary condition for the patches in thickness direction

Case description

- Meshes in OpenFOAM
  - Are always three-dimensional
  - So how to we create a 2D case?
- OpenFOAM is our friend
  - Build mesh with a single cell in thickness
  - Use special boundary condition for the patches in thickness direction
- A single code base for the mesh, the finite volume method, etc. handles every possible case
  - 0D – solve evolution of chemical species content in a single cell (the reactor vessel)
  - 1D – e.g. for simplified pipelines
  - 2D – e.g. for our vortex street, for airfoils
  - full 3D

Influence of mesh fineness

- We need enough cells to resolve our flow features
  - determines the minimum fineness
  - the more features, the more cells
- How many cells are enough to resolve our flow
  - the more cells, the longer the simulation takes
  - we need to be careful not to waste time

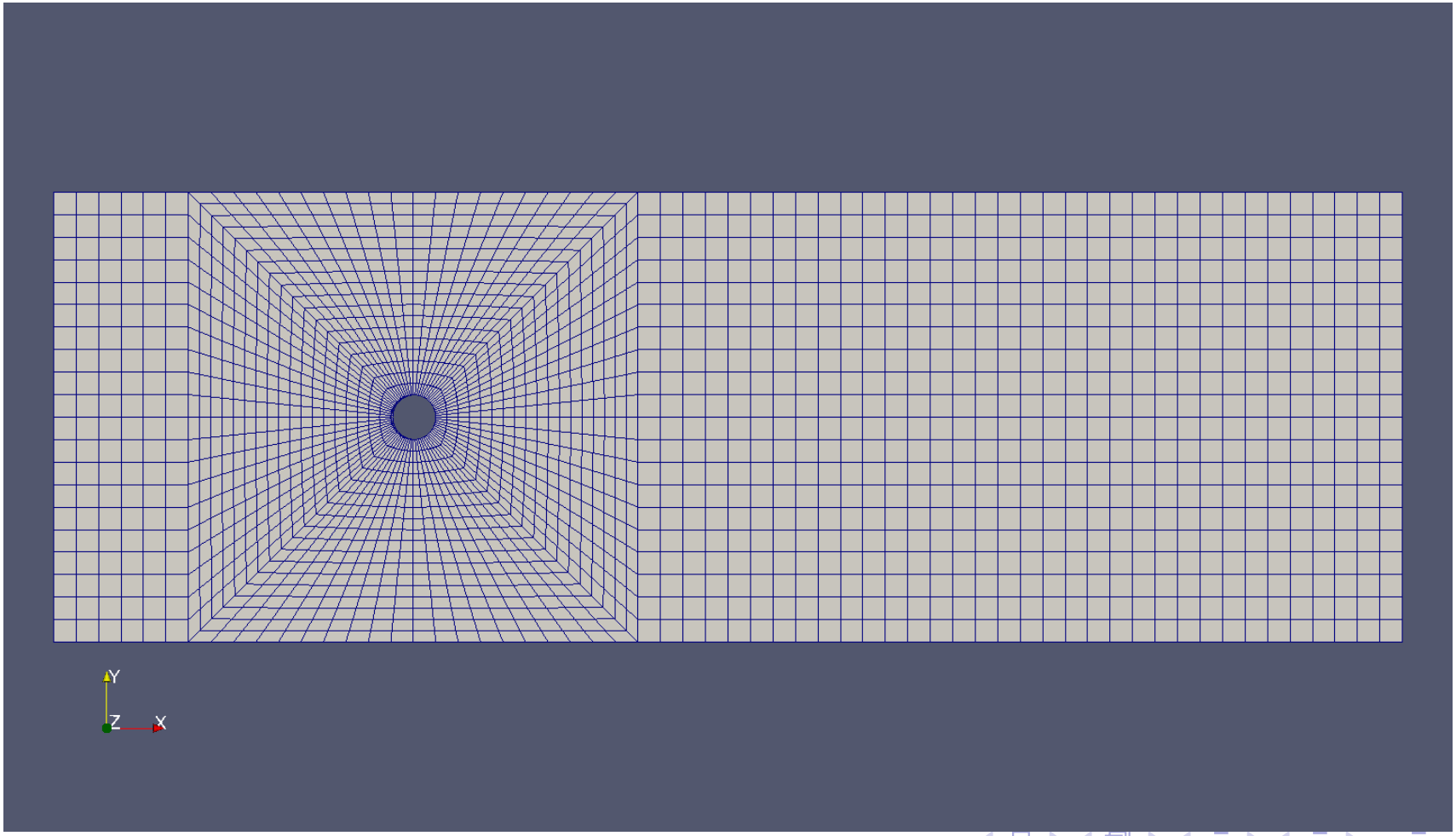


Meshing tools

- blockMesh
  - ~~manual mesh building like an animal~~
  - scripted in two levels of madness
- snappyHexMesh
  - although 2D meshes are a bit cumbersome with snappy
  - snappy is an all-3D meshing tool

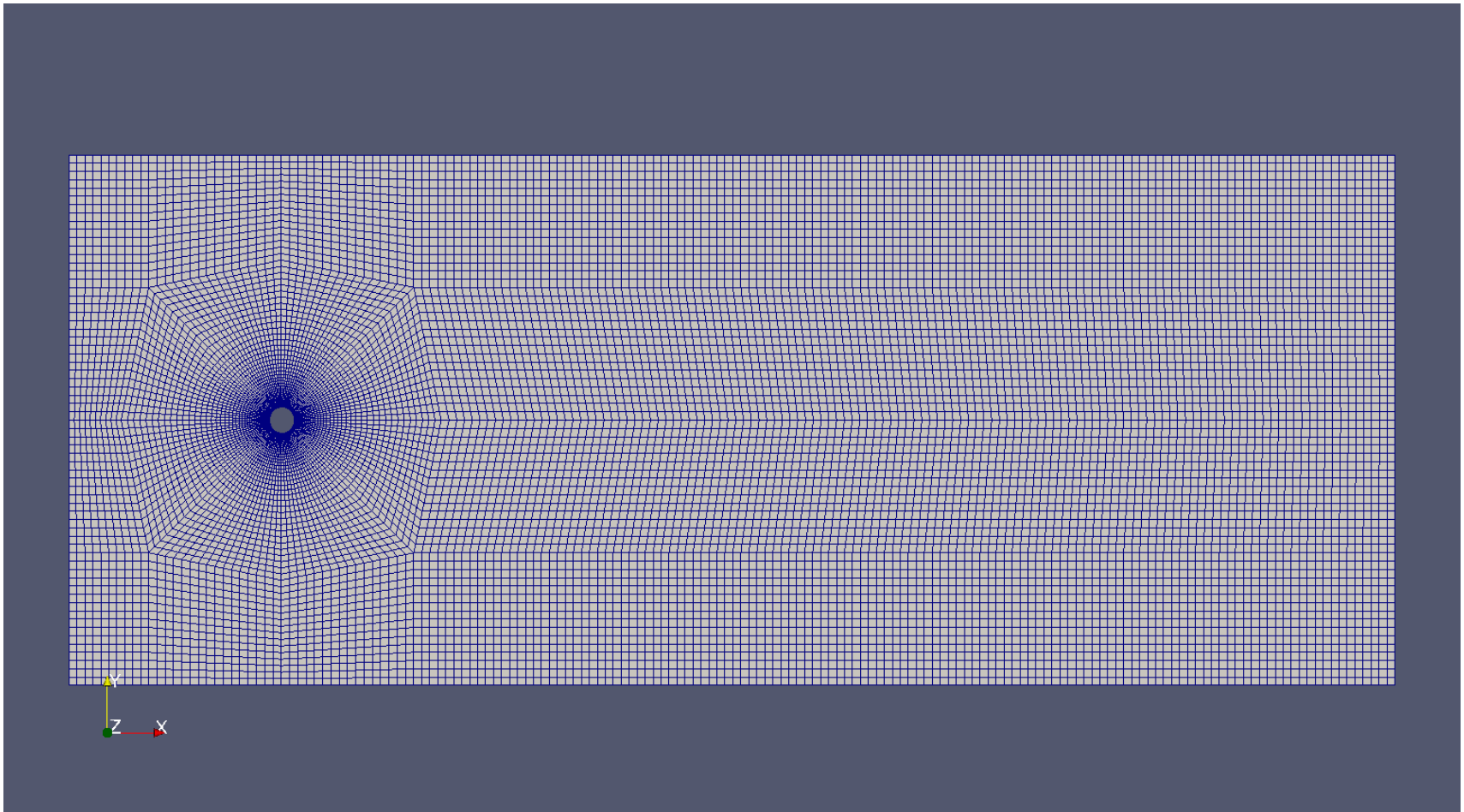
blockMesh

- Simple structure
  - rather straight forwards



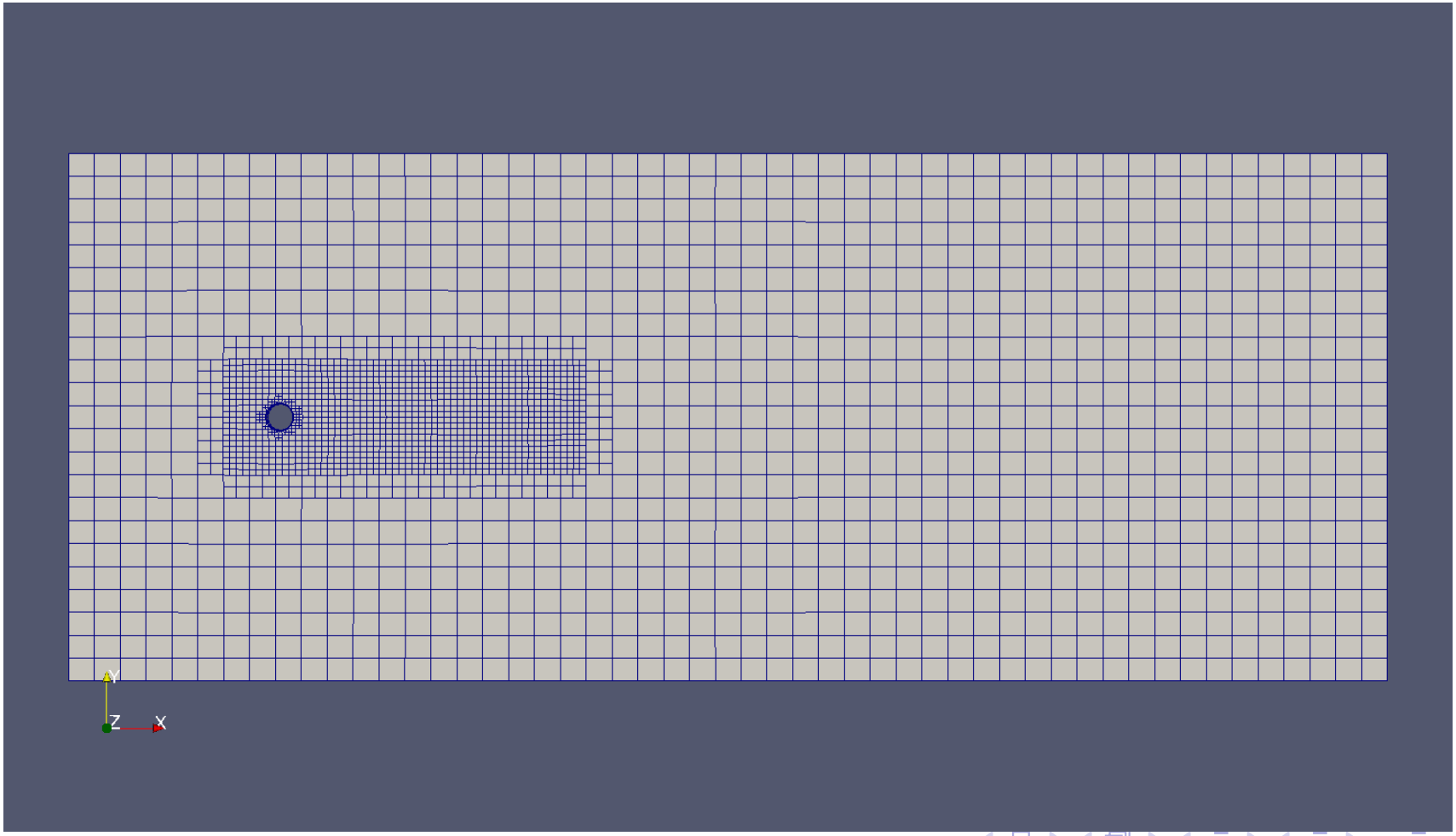
blockMesh

- Give ’em more blocks
  - looks much nicer
  - you might want to script this



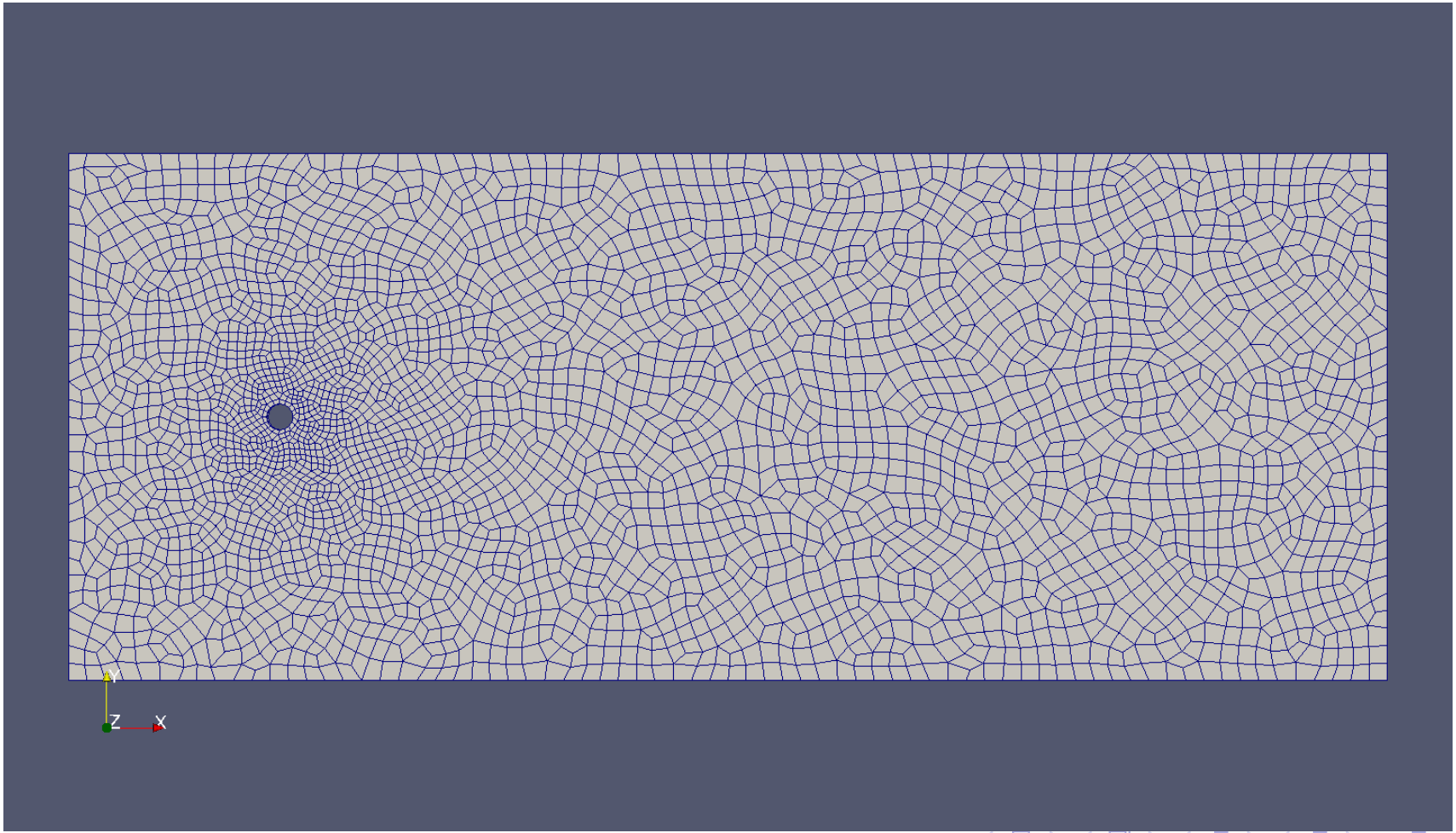
snappyHexMesh

- With some work-arounds for 2D
  - region-wise refinement



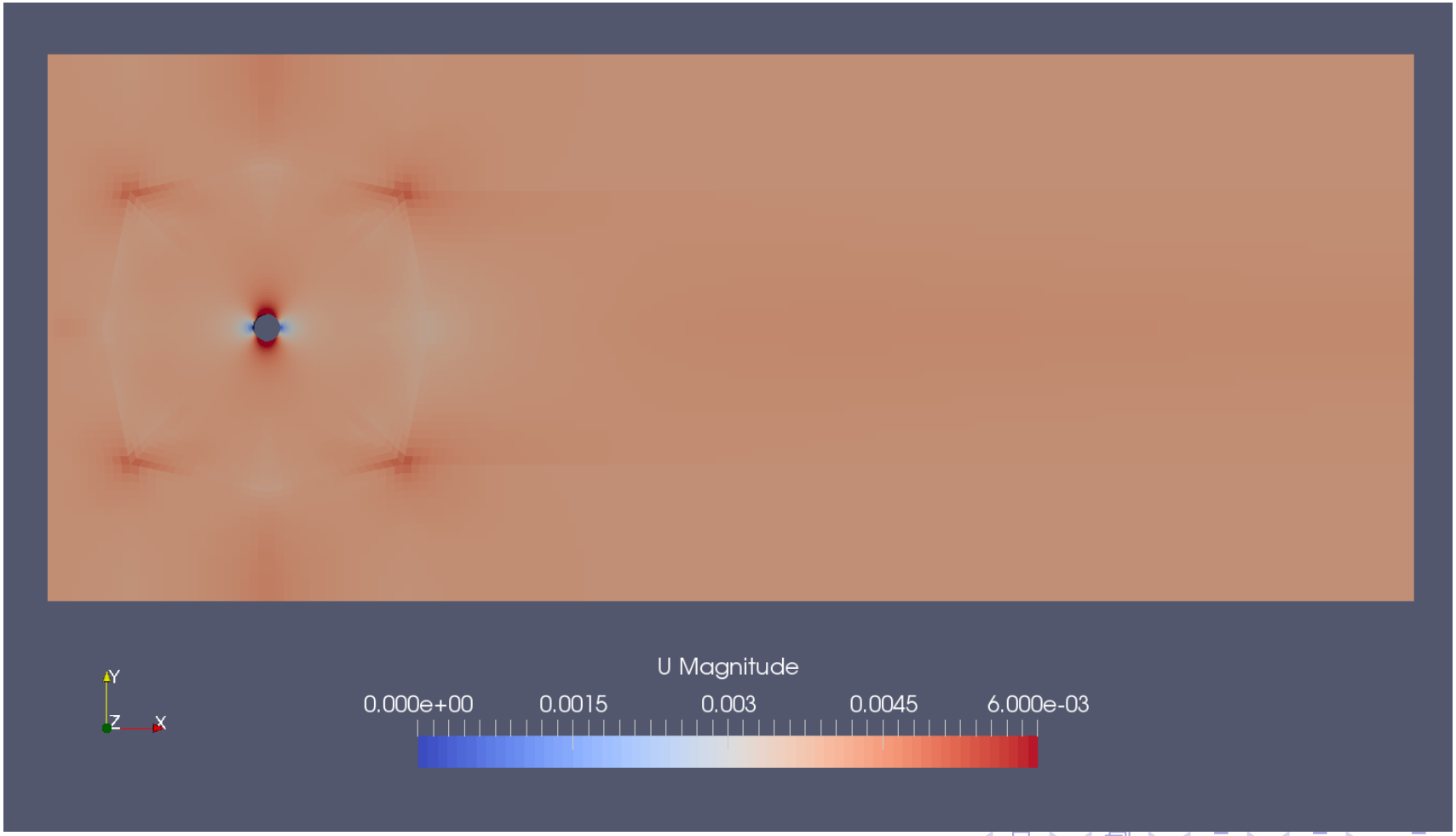
GMSH

- Very simple, limited UI
  - It can however be plugged into other CAD software



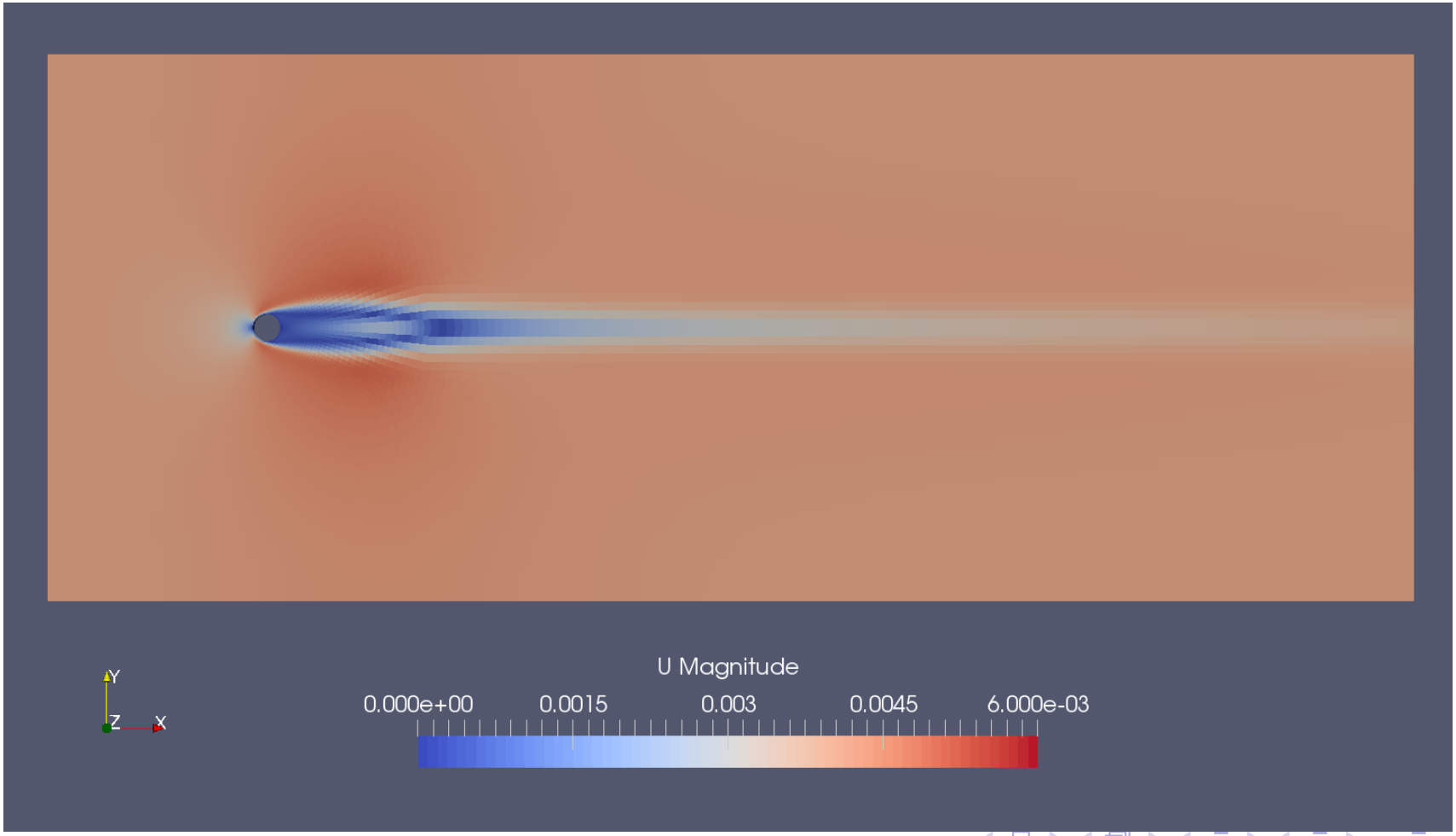
blockMesh

- Initialisation
  - computed with potential theory



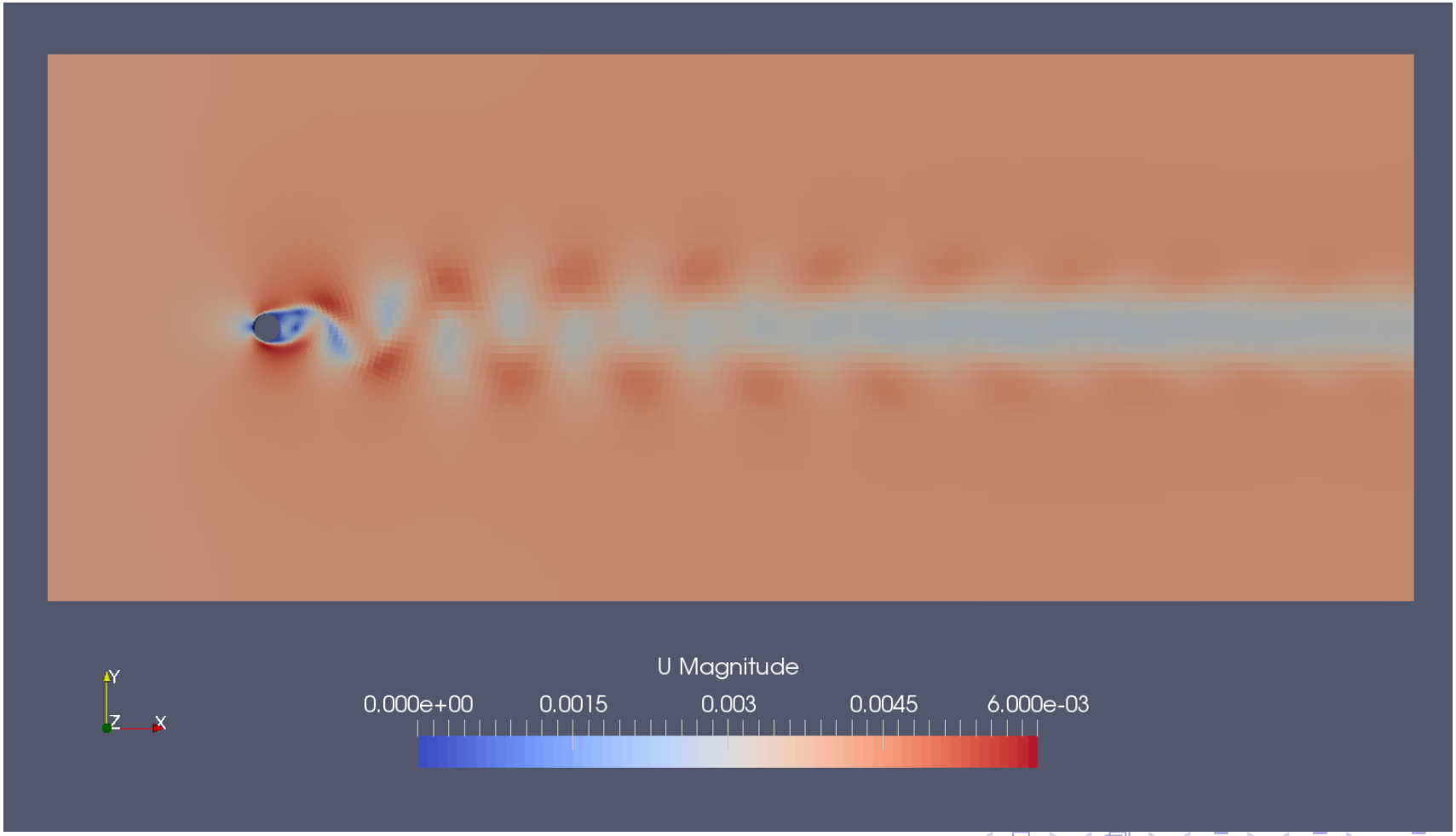
blockMesh

- Intermediate solution
  - very symmetric



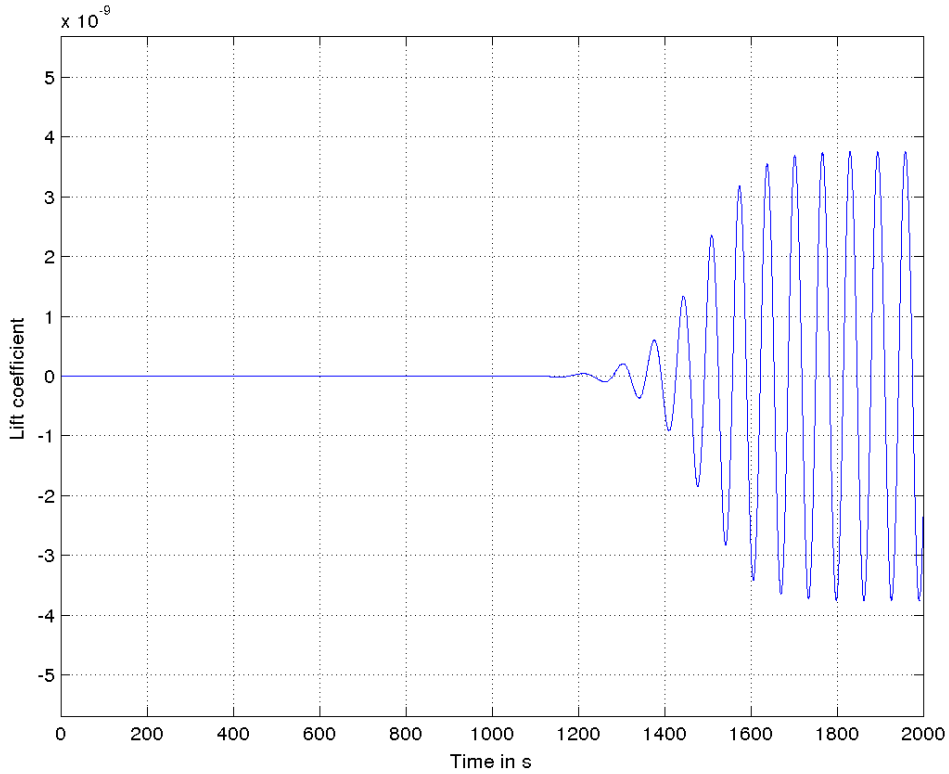
blockMesh

- Fully developed vortex street
  - symmetry is broken at last



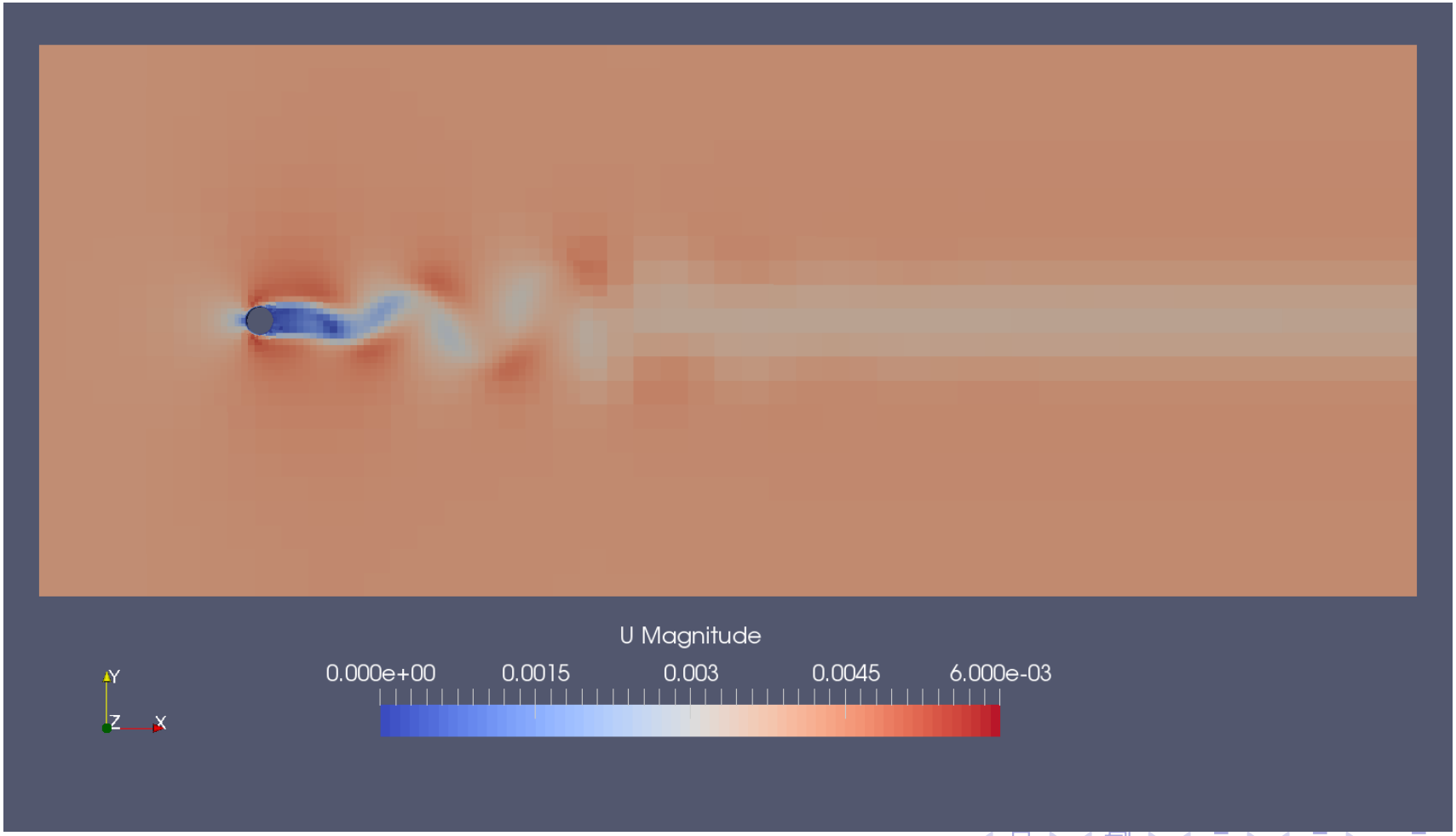
blockMesh

- The solution takes a while to develop
  - most probably due to symmetric mesh



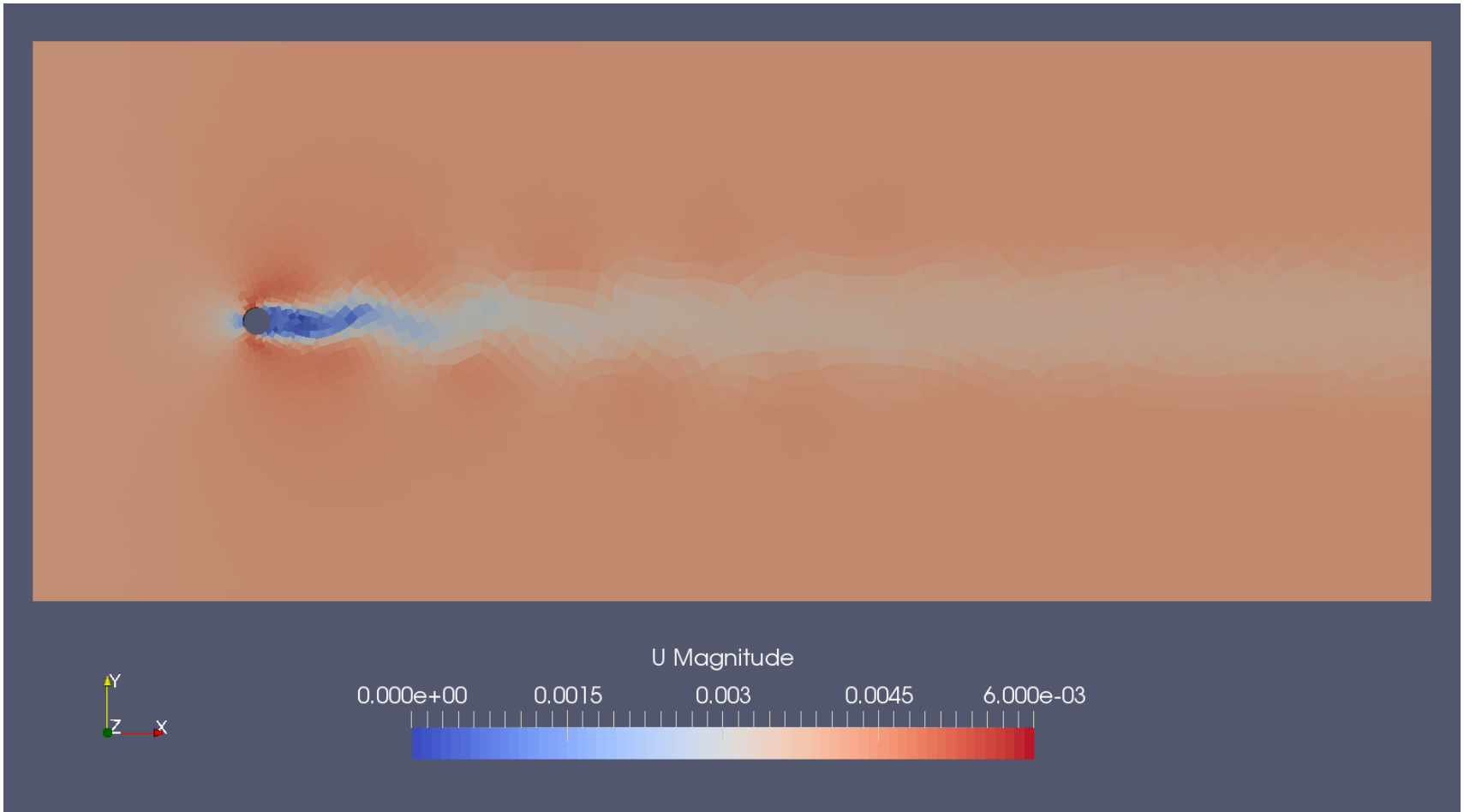
snappyHexMesh

- The refinement region is visible in the solution
  - maybe we should be more generous with cells



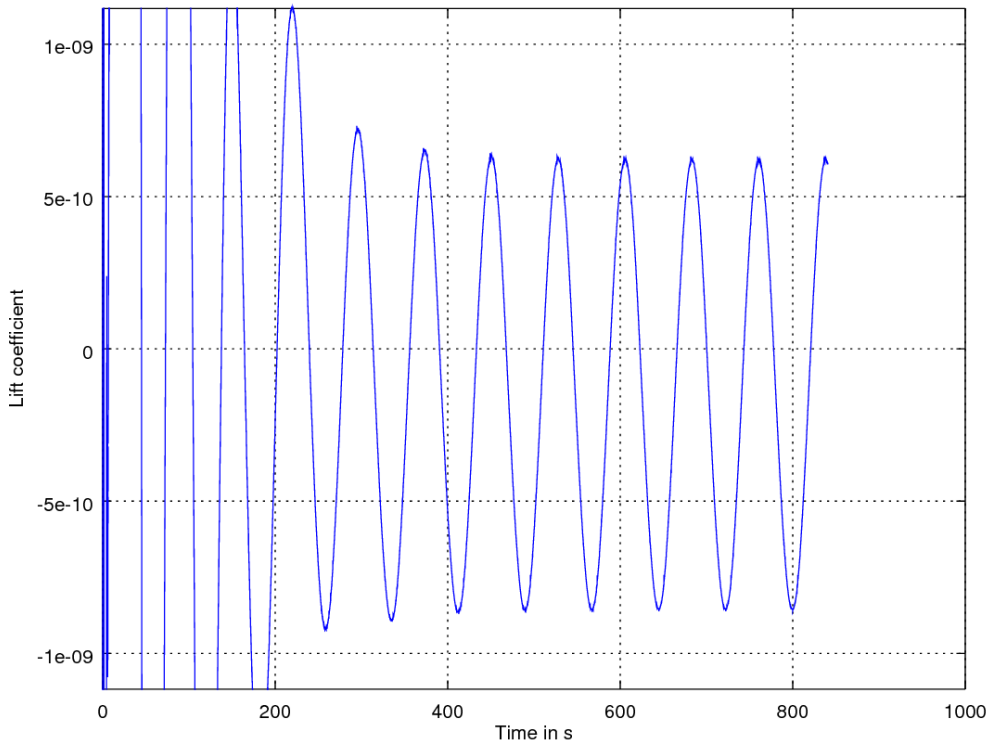
gmsh, coarse mesh

- The mesh is rather coarse
  - the un-symmetric mesh probably helps to break the symmetry



gmsh, coarse mesh

- The solution is oscillating immediately
  - most probably due to non-symmetric mesh



Compare solutions

- There is a relation for the frequency
  - Karman vortex shedding frequency $f = \frac{Sr\,u}{D} = 0.016048$ Hz
  - $Sr = 0.2$ . . . Strouhal number

Mesh	No. of cells	Frequency
blockMesh, simple	2240	0.01500
blockMesh, adv.	14272	0.01545
blockMesh, adv.	22268	0.01621
snappyHexMesh	2439	0.01373
gmsh, coarse	3552	0.01297
gmsh, fine	17691	0.01469

Play around

- What is the influence of the ratio domain width W to cylinder diameter D?
  - a too narrow domain with its frictionless walls will at some point restrict the formation of the vortex street
- What is the influence of numerical discretisation?
  - which settings change the solution for the better or the worse?
  - are there settings that can break the solution
- What happens if you skip the initialisation with potentialFoam?
  - the velocity field computed by potentialFoam is kind of wrong, does it do any good?
- Test alternative means of initialisation
  - map the solution of a coarse-mesh simulation to a fine-mesh simulation
  - use a ramp-up velocity boundary condition

Play around, even more

- Fiddle with post-processing
  - determine the vortex shedding frequency from the data of a velocity probe somewhere downwind of the cylinder