Tailor

unknown

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CONTENTS

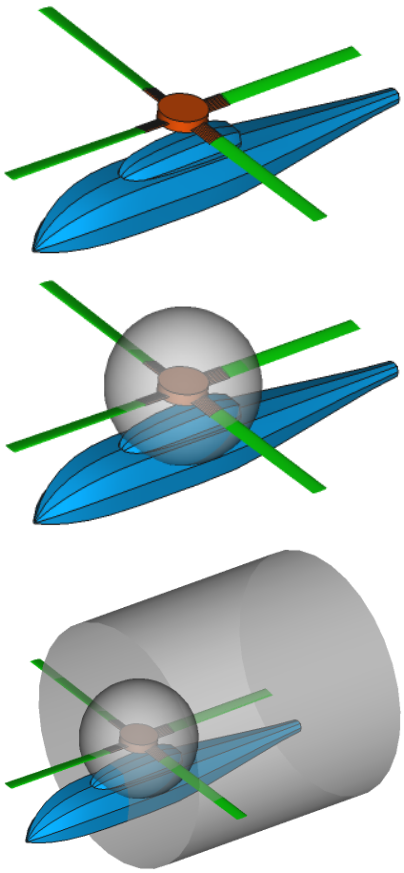
tailor is a spatially load balancing flow solver which can operate on three-dimensional moving overset meshes.

CHAPTER

ONE

WHY USE OVERSET GRID TECHNIQUE

The left-most figure below is a helicopter model consisting of six components: A fuselage, a hub and four blades. It is difficult to generate a single structured grid around all the components. It is possible to generate a single unstructured grid around all the components, however, it is usually desired to have structured mesh especially in the boundary layer of components. Even if the single structured mesh is generated with great difficulties, in moving body problems, the single structured would need to be re-generated. It is possible to avoid mesh re-generation by allowing meshes to deform. However, careful mesh deformation techniques should be applied in order to avoid excessive mesh deformation which causes lower solution accuracy.



CHAPTER

TWO

HOW OVERSET GRID TECHNIQUE WORKS

In overset grid technique, a mesh is generated independently for each component. In the case of helicopter, a spherical mesh can be generated for the hub as shown in center figure above. Note that, only outline of the mesh shown for clarity. Similarly, a cylindrical mesh can be generated for a blade as shown in right-most figure above. For the fuselage, a spherical mesh can be used which would also act as a background mesh containing all other meshes.

CHAPTER

THREE

OVERSET GRID TECHNIQUE VERSUS SLIDING MESH TECHNIQUE

In sliding mesh technique meshes cannot overlap but only slide. It is possible to simulate the helicopter model shown above with sliding mesh technique. However, it is impossible to add a tail rotor to the model in sliding mesh technique but there is no such limitation in overset mesh technique.

CHAPTER

FOUR

DEPENDENCIES

- **Few Boost libraries such as**
  - Boost MPI for parallelization
  - Boost Serialization to save & restore data.
  - Boost Program_options for reading configuration files.
- METIS for load balancing.
- Gmsh for mesh generation in msh format.
- amgcl for solution of linear system of equations if implicit formulation is used.

CHAPTER

FIVE

CONTENTS

5.1 Test cases

5.1.1 Shock tube

Shock tube test case is comprised of a tube containing initially two gases separated by an imaginary membrane at x = 0.

Initial condition

Flow is initizalized by reading flow_init.ini.

Table 1: Initial profile

Variable	Left	Right
Density	1.0	0.125
Pressure	1.0	0.1
Velocity	0.0	0.0

Table 2: Solver parameters

Flow type	Steady
Riemannsolver	HLLC
Temporal discretization	Runge-Kutta (4-stage)
Limiter	Venkatakrishnan (K = 0.3)
CFL	10

Boundary condition

Flow in the tube is made one-dimensional by imposing empty boundary conditions in peripheral surfaces of the tube. At caps of the tube, dirichlet boundary condition is imposed.

Results

5.1.2 Steady transonic airfoil

A single unstructured mesh is used to solve the Euler equations at transonic air speed to steady state. Flow and solver properties are shown in the following tables.

Table 3: Flow properties

Mach	0.8
Angle of attack	1.25°
Freestream pressure	1 / 1.4
Freestream density	1
Ratio of specific heats	1.4

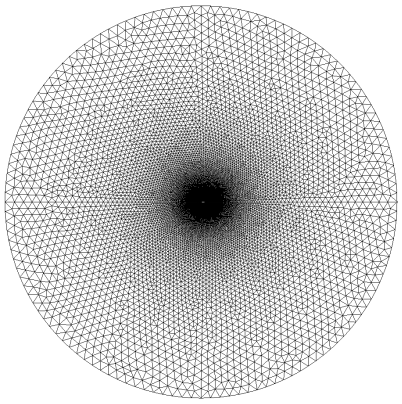
Table 4: Solver parameters

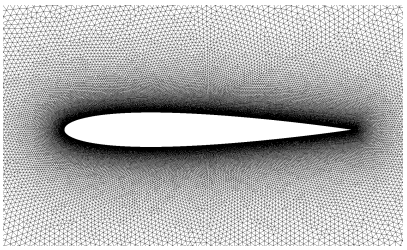
Flow type	Steady
Riemann solver	Roe
Temporal discretization	Backward Euler
Limiter	Venkatakrishnan (K = 0.3)
CFL	10

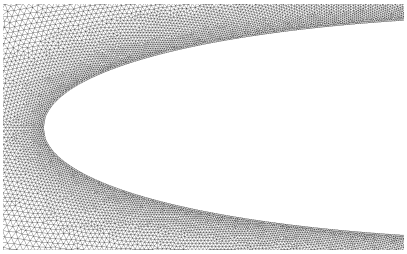
Settings are read from settings.ini.

Mesh properties

Following figures shows the unstructured mesh used for solving transonic airfoil test case.







Cell size is the finest near the airfoil and grows proportional to distance from the airfoil surface. Cell size is controlled with combination of `Field` in NACA0012_O.geo as shown below.:

```
lc = 1;
Field[1] = Distance;
Field[1].FacesList = {wallbc[]};
Field[1].NNodesByEdge = 100;
Field[2] = MathEval;
Field[2].F = Sprintf("F1/20 + %g", lc / 1000);
Background Field = 2;
```

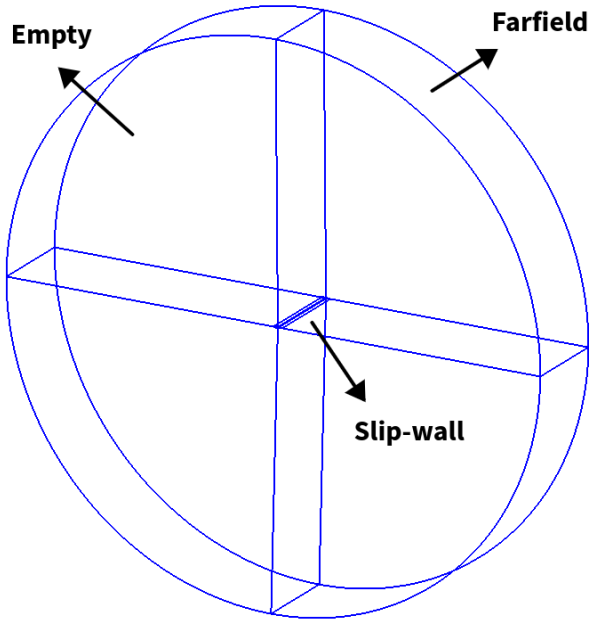
According to the snippet above, cell size is set with equation *distance/20 + 1/1000*. I don't know how cell size is related to cell volume in Gmsh. There 137228 cells with shape of triangular prism in the unstructured mesh. The reason of having three-dimensional (3D) cells in a two dimensional(2D) problem is because Tailor always works in 3D space similar to OpenFOAM. This kind of problems are called 2.5-dimensional. The 3D mesh is obtained by extruding the 2D mesh by one layer.

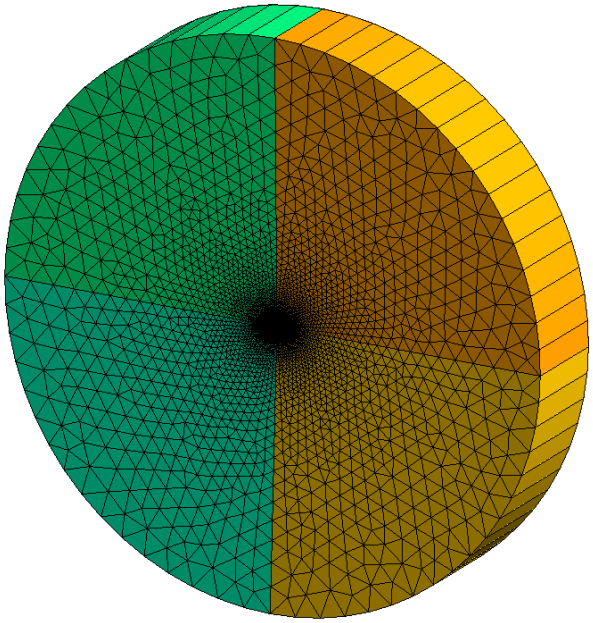
Since there 32 processors, initially the mesh is also partitioned into 32 partitions.

```
gmsh NACA0012_O.geo -3 -oneFilePerPart -part 32 -format msh2
```

Boundary conditions

Boundary conditions on the airfoil and in outer boundary are slip-wall and Riemann, respectively. Riemann boundary condition is based on Riemann invariant equations. Empty boundary conditions are used in z-normal direction. Initially flow is set to freestream values everywhere in the domain.





Job submission

The code works even when CFL is greater than 10 however, residuals do not converge below 1e-2 in that case. The script below is the SLURM script used to submit a job to the cluster.

```
#!/bin/bash
#SBATCH -p short
#SBATCH --ntasks=32
#SBATCH --hint=nomultithread
#SBATCH -t 00-04:00:00
#SBATCH --output=slurm-%j.out
#SBATCH --error=slurm-%j.err
```

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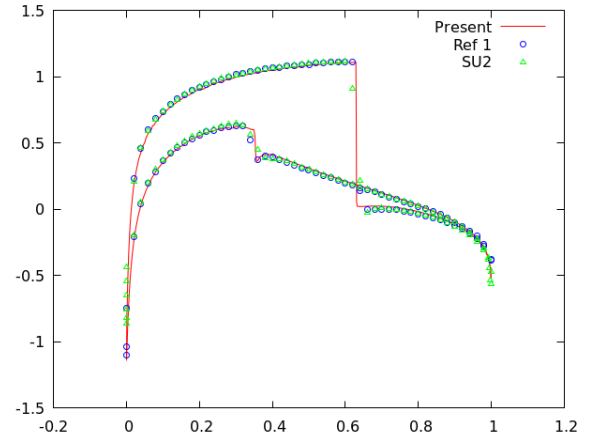
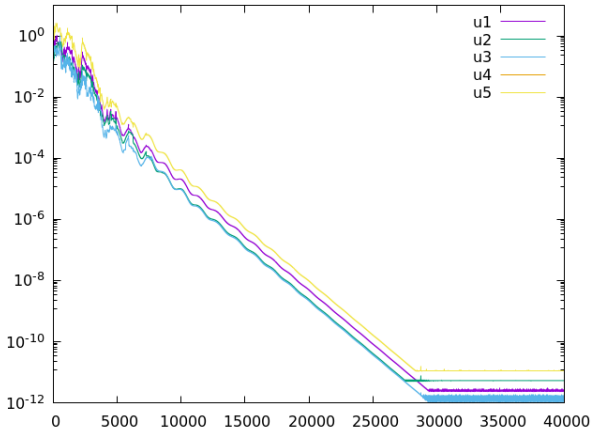
```
mpirun --tag-output --report-bindings /usr/bin/time -f '%e %S %U %P %M' -o "timing.dat
↪" --append ./out
```

Results

Figure below shows pressure coefficients at the airfoil surface and convergence history.





It is useful to have raw pressure coefficient data to compare results, especially when data for upper and lower surfaces are provided separately. This saves time by avoiding plot digitizing. Here are pressure coefficient data for upper_pc.dat and lower_pc.dat airfoil surfaces.

Reference 1: Manzano, Luis, Jason Lassaline, and David Zingg. “A Newton-Krylov algorithm for the Euler equations using unstructured grids.” 41st Aerospace Sciences Meeting and Exhibit. 2003. Reference 2: https://su2code.github.io/tutorials/Inviscid_2D_Unconstrained_NACA0012/

5.1.3 Oscillating airfoil