e3prepToFoam: a mesh generator for OpenFOAM

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Abstract

`e3prepToFoam.py` is a utility to convert structured body-conforming multi-block meshes from the `e3prep`/Eilmer format to the OpenFOAM `foam` format. This report is a user-guide for the mesh conversion tool and provides several examples to help with the conversion. The tool can perform the following tasks:

- Convert 2-D Eilmer mesh into 1 cell deep 2-D OpenFOAM `foam` mesh
- Convert 2-D axysimmetric EIlmer mesh into 1 layer thick wedge shaped OpenFOAM `foam` mesh
- Convert 3-D Eilmer mesh into 3-D OpenFOAM `foam` mesh.

1 Introduction

As part of their code collection the *CFCFD Group* at the University of Queensland distributes the multi-block structured mesh generator `e3prep`. The mesh generator allows the generation of body conforming grids using simple easily scripted python front end. To utilise these capabilities with OpenFOAM, the grid conversion tool `e3prepToFoam` has been created. The tool allows the conversion of structured multi-block `e3prep` meshes into the OpenFOAM `foam` format. The tool also supports the generation of grouped boundary patches to simplify the boundary condition definition in OpenFOAM.

This report acts is a user guide and theory guide for `e3prepToFoam`. It is to be read in conjunction with the Eilmer user guide [1], which describes the mesh generation using `e3prep`.

1.1 Compatibility

`e3prepToFoam` uses functions from the *CFCFD Group* code collection (Eilmer3), the OpenFOAM distribution [2], python, and C++. The following dependencies exist:

Eilmer3 `e3prepToFoam` has been included as part of Eilmer code distribution from November 2014 onwards.

OpenFOAM The utility has been tested with OpenFOAM Vers. 2.3 and OpenFOAM-extended Vers. 3.1.
However it should be compatible with earlier releases also.

python The code has a number of python and C++ dependencies. It is recommended to install the dependencies list from the CFCFD webpage `http://cfcfd.mechmining.uq.edu.au/getting-started.html`

1.2 Citing this tool

When using tho tool in simulations that lead to published works, it is requested that the following works are cited:

- This report to cover the `e3prepToFoam.py` mesh conversion tool.
  Ingo Jahn, Kan Qin (2015), "e3prepToFoam: a mesh generator for OpenFOAM", Mechanical Engineering Technical Report 2015/04, pp 1-66, The University of Queensland
- The following report which covers `e3prep.py` the underlying code used to generate the mesh.
  PA Jacobs, RJ Gollan, DF Potter (2014), "The Eilmer3 code: user guide and example book", Mechanical Engineering Technical Report 2014/04, pp 1-447, The University of Queensland

2 Distribution and Installation

`e3prepToFoam.py` is distributed as part of the code collection maintained by the *CFCFD Group* at the University of Queensland [3]. This collection is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or any later version. This program collection is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details `http://www.gnu.org/licenses/`.

The code will be automatically installed during a typical build of Eilmer3. Download and build instructions are available from the CFCFD webpage `http://cfcfd.mechmining.uq.edu.au/`.

2.1 Modifying the code

The working version of `e3prepToFoam.py` is installed in the `$HOME/e3bin` directory. If you perform modifications or improvements to the code please submit an updated version together with a short description of the changes to the authors. Once reviewed the changes will be included in future versions of the code.

3 Using the Tool

3.1 5-minute version for experienced python, e3prep, and OpenFOAM Users

If you have used `e3prep.py` and OpenFOAM before, this for you.

3.1.1 Creating the directory structure

`e3prepToFoam.py` requires the correct OpenFOAM directory structure to function. Either copy an existing directory structure from an OpenFOAM example or manually create a directory structure. Once created add a folder titled `e3prep` to the root (`/case`) directory of your simulation. The resulting directory and file structure, required for `e3prepToFoam` to run correctly is:

case/

- **0/**
- **constant/**
- **constant/polyMesh**
- **system/**
- **system/** controlDict ← file required
- **system/** fvSchemes ← file required
- **system/** fvSolution ← file required
- **e3prep/** ← added for `e3prepToFoam`

All files and directories are required, to ensure correct operation. The directories can be empty, apart from the 3 files in the `/system` directory listed above.

3.1.2 Creating your job.py file for e3prep

Within the `/case/e3prep/` directory, create your typical `job.py` file as used for `e3prep.py`. See examples in section 5 for more details. The key differences to typical Eilmer meshing are:

- set `gdata.dimensions = X` with `X = 2` or `3`
- set `gdata.axisymetric_flag = X` with `X = 0` or `1`
- setting of gas model is not required. Actual gas model is defined in `case/constant/...`
- define blocks as usual. setting of fill condition is not required, as this is defined in `case/0/...`
- include `identify_block_connections()`
- use following command to label external block faces: `blk0.bc_list[EAST] = ExtrapolateOutBC(label="NAME`
  where `NAME` is one of the following `OF_inlet_nn`, `OF_outlet_nn`, `OF_wall_nn`, `OF_symmetry_nn`.
  In a 2-D mesh only the north, south, west and east faces need to be labelled. See note below for more details.
- include `sketch.prefer_bc_lables_on_faces()` to show face labels in svg sketch.

- For 2-D meshes keep code to draw .svg file

Note about boundary conditions:
`e3prepToFoam` does not define boundary conditions. Instead by labelling the block faces using the names listed above, where `nn` can be the numbers `00`, `01`, ... `10`, thee corresponding block faces are grouped into a single patch consisting of all the faces for OpenFOAM. The correct boundary conditions, corresponding to a given patch are then set in OpenFOAM in the `case/0` directory.

Optionally: Once the `job.py` file has been generated, to run the following sequence of commands to view the mesh in paraview.

```
$ e3prep.py --job=job.py --do-svg --openfoam
$ e3post.py --job=job.py --vtk-xml
$ paraview
```

3.1.3 Running e3prepToFoam.py

The mesh generation and conversion is performed in two steps using the following commands:
`$ e3prep.py --job=job.py --do=svg --openfoam` ← creates mesh
`$ e3prepToFoam.py --job=job.py [--create_0]` ← converts mesh to `foam`
Running the second command, generates the foam mesh, overwriting any mesh that already exists within the `case/constant/polymesh` directory. Adding the `--create_0` option additionally writes files `case/0/U` and `case/0/p` corresponding to the boundary face labels defined in the `job.py` file. Any existing `0/U` and `0/p` files are copied to `/U.bak` and `/p.bak`. Other initial and boundary condition files required by the selected solver (e.g. `0/T`) need to be generated manually.

At this stage the foam mesh can be viewed using the command:

```
$ parafoam
```

Perform the following checks:

- `$ checkMesh` This provides a quick overview of the quality of the mesh and wether error occurred in the conversion.
- If patches with names `t0000`, `b0000`, `n0000`, `s0000`, `w0000` or `e0000` (where `0000` can be any 4-digit number) are listed, this indicates that the t-top (b-bottom, n-north, s-south, w-west, e-east) face of the corresponding block was not labelled in the `job.py` file.
- Open mesh in paraview (`$ paraFoam`).
  - If paraview crashes when loading mesh, this typically indicates that not all boundary conditions/initial conditions have been set. (e.g. when performing compressible and turbulent simulation, files `/0/T`, `/0/nut`, etc need to exist for parafoam to work correctly.)
    Otherwise de-select all `Volume Fields` and the mesh alone should load without errors.
  - In paraview, check mesh quality, check that external faces have been correctly grouped.

3.1.4 Adjusting the initial fill condition, boundary conditions, gas models, and other items for OpenFOAM

After the mesh conversion the OpenFOAM simulation is initialised, set-up and started using the normal OpenFOAM procedure.

- Dimensions, initial conditions, and boundary condition for each simulated variable are defined in respective file in the `case/0/` directory. Boundary conditions for each grouped face name defined in the `job.py` file (e.g. `OF_wall_00`) must have a corresponding definition.
- Gas and transport properties are set in the `case/constant/` directory.
- Simulation properties are set in the `case/system/` directory.

3.2 Detailed Instructions

Read this section if you are new to python, Eilmer3, or OpenFOAM.

3.2.1 Creating the Directory Structure

`e3prepToFoam.py` requires the correct OpenFOAM File directory structure to function. The easiest way approach to generate this is to find an existing OpenFOAM example (or tutorial) that is similar to the simulation you want to run and to copy the directories. For example to perform an incompressible simulation using `icoFoam` you could do the following:
`$ of230` ← load the OpenFOAM commands
`$ tut` ← change to tutorial directroy
`$ cd incompressible/icoFoam` ← change to directory containing the `icoFoam` example
`$ cp -r cavityClipped/. $FOAM_RUN/cavityClipped` ← copy the icoFoam example to your run directory
`$ run` ← change to run directory
`$ cd cavityClipped` ← change to your simulation working directory
`$ mkdir e3prep` ← create the empty `e3prep` directory

At the end of this you should have the following directory and file structure. There may be some extra files in there, but these don't matter

case/

- **0/**
- **constant/**
- **constant/polyMesh**
- **system/**
- **system/** controlDict ← file required
- **system/** fvSchemes ← file required
- **system/** fvSolution ← file required
- **e3prep/** ← added for `e3prepToFoam`

3.2.2 Creating your job.py file for e3prep

Now move to the `e3prep` directory, where you will create your `e3prep` mesh.
`$ cd e3prep`

At this point you can either copy and existing `job.py` (advised) and modify this or create your own file. Detailed instructions for the creation of a `job.py` file and examples are available in the Eilmer user guide [1]. The `job.py` file should contain the following parts:

File Header
The file header must include the following lines of code to define the mesh type:
`gdata.dimensions =X` ← `X=2` 2-D mesh or `X=3` for 3-D mesh
`gdata.axisymetric_flag =X` ← `X=0` for planar 2-D or 3-D or `X=1` for 2-D axi-symmetric

Block Definition

The core part of the `job.py` file is the definition paths, which then can be turned into a 2-D or 3-D block. The Eilmer user guide provides extensive examples for the generation of points and path segments.

The definition of a typical 2-D block, consisting of north, east, south, west edges defined by the respective paths (e.g. `north_path`) is:

```
blk0 = Block2D( make patch(north_path, east_path, south_path, west_path),
nni=2, nnj=2, cf_list=[None,]*4)
```

Do not include definition of boundaries at this point.

After completing the block definitions, include the command
`identify_block_connections()`
This ensures that the blocks are joint correctly at internal faces.

External Boundary Definition

`e3prep` or `e3prepToFoam` does not set boundary conditions for OpenFOAM. Instead it allows multiple block faces, labelled with one of a list of pre-defined names in `job.py` to be grouped into a single boundary patch. The OpenFOAM boundary conditions are then set for each patch in the `case/0` directory after the generation of the `foam` mesh. Currently the following pre-defined labels are recognised by `e3prepToFoam`.

- `OF_inlet_00`, `OF_inlet_01`, ...`OF_inlet_10`
  Suitable for inlets
- `OF_outlet_00`, `OF_outlet_01`, ...`OF_outlet_10`
  Suitable for outlets.
- `OF_wall_00`, `OF_wall_01`, ...`OF_wall_10`
  Suitable for walls.
- `OF_symmetry_00`, `OF_symmetry_01`, ...`OF_symmetry_10`
  Suitable for symmetry planes.

To label faces use the command
`blk0.bc_list[EAST] = ExtrapolateOutBC(label="NAME")`, where `EAST` can be any side of the block and `NAME` any of the labels from above. Possible blcok sides are: `NORTH`, `EAST`, `SOUTH`, `WEST` for 2-D with the addition of `TOP` and `BOTTOM` for 3-D. To group multiple faces, simply give them the same name.
For example add both the north and east face of the block above to the group `OF_wall_03`, use the following lines of code:

```
blk0.bc_list[NORTH] = ExtrapolateOutBC(label="OF_wall_03")
blk0.bc_list[EAST] = ExtrapolateOutBC(label="OF_wall_03")
```

3.2.3 Running `e3prep.py` and `e3prepToFoam.py`

The grid generation and conversion is a 2-stage process.

Step 1: Grid Generation

To generate the mesh run:
`$ e3prep.py --job=job.py --do=svg --openfoam` (from within the `e3prep` directory)
This will create an `e3prep` mesh, stored in `case/e3prep/grid`. If error messages arise in this stage, fix these before proceeding to the next stage.

Optionally to view the mesh, run
```
$ e3post.py --job=job.py --vtk-xml
$ paraview
```
This allows checking of the mesh quality before proceeding to the next step.

Step 2: Grid Conversion

To convert the mesh to the foam format run:
`$ e3prepToFoam.py --job=job.py` (from within the `case/e3prep` or `case` directory)
or `$ e3prepToFoam.py --job=job.py --create_0` to auto-generate template boundary conditions for `p` and `U`.
WARNING: the `--create_0` option replaces existing `p` and `U` files and copies the old files to `p.bak` and `U.bak`.

Should running `e3prepToFoam` fail, a range of on-screen error messages with suggested solutions are provided. Or use the details below:

- Error with mergeMeshes. Try running of230 to load OpenFOAM module
  This is typically caused if the OpenFOAM environment hasn't been loaded and thus OpenFOAM commands are not recognised. Run `$ of230` or equivalent command to load the OpenFOAM environment.

- WARNING: Not all external boundaries were defined in e3prep
  The list of block faces (e.g. `b0001` is bottom face of block 1) indicate faces on the mesh external boundaries that have not been given names as described in section 3.2.2.

- WARNING: labels used to define boundary faces do not follow standard OF_names
  External boundaries were labelled with names that do not match the predefined list. Check for spelling mistakes and/or change names.

- WARNING: Problem during execution of renumberMesh.
  Fixing this error is optional. This error arises if the files in the `case/0` directory are missing or if the patch labels do not match the labels of the the newly generated mesh. The easiest fix is to re-run with the `--create_0` option.

3.2.4 Checking mesh and boundary faces

To check the mesh and the boundary conditions, execute the `$ checkMesh` command from the `case` directory.
The on screen output provides an overview of the mesh. The list of faces should reflect the external mesh boundaries defined in the `job.py` file. If there are faces listed with names consisting of a the letters t, b, n, s, w, e followed by a 4 digit number, this indicates that the corresponding face of the block identified by the number was not labelled using one of the OpenFOAM names. If the faces are internal to the mesh, check that `identify_block_connections()` was included in `job.py`.

Further mesh checking is possible using paraview by running the `$ paraFoam` command from the `case` directory.
Before loading the mesh in the paraview GUI, de-select all `Volume Fields` (e.g. p and U). Then

by selecting specific mesh features (E.g. OF_wall_00) the corresponding faces that form this patch can be visualised.

3.2.5 Setting boundary conditions

Boundary conditions for the OpenFOAM simulation are set in the `case/0/` directory. In most cases it is possible to copy file templates from existing OpenFOAM examples.

Incompressible, laminar (e.g. icoFoam)
Running `e3prepToFoam` with the `--create_0` option creates the `p` or `U` file required for an incompressible laminar flow solver, such as icoFoam. The resulting files contain template entries for all the patches (group of external faces) that were defined using the `OF_name_nn` labels. To set up the simulation, simply change the boundary condition to the correct type (e.g. change `zeroGradient` to `FixedValue`) and set the correct boundary values as required.

Other solvers, using more than `p` and `U` variable
When using more complex solvers form the OpenFOAM collection initial condition and boundary conditions for additional variables have to be defined. Either modify existing files in `case/0` or create new files for each variable. The files must `boundaryField` definitions for all the external patches grouped using the `OF_name_nn` names (and `FrontBack`, `Front`, `Back`, `Centreline` if present). The `p` or `U` files created using `--create_0` can be sued as templates.

3.2.6 Adjusting gas models and other items for OpenFOAM

After the mesh conversion the OpenFOAM simulation is set-up and started using the normal OpenFOAM procedure.

- Gas and transport properties are set in the `case/constant/` directory.
- Simulation properties are set in the `case/system/` directory.

3.2.7 Running the simulation

At this point you should be ready to run you OpenFOAM simulation.

4 Theory behind code

The following sections describe in more detail the theory and steps of the code. As an overview, the mesh conversion by `e3prpToFoam` is performed by the following steps:

1. check that suitable directory structure exists
2. execute `e3post.py` to write individual foam meshes, corresponding to each block generated by e3prep. Different approaches are used for 3-D, 2-D and axi-symmetric meshes. See 4.1 for details.
3. use OpenFOAM `mergeMesh` utility to combine individual blocks into single mesh
4. (optional) For axisymmetric meshes, remove zero area faces along centreline
5. use OpenFOAM `stichMesh` utility to link blocks and remove internal faces
6. (optional) For axisymmetric meshes, automatically group all faces that fall on Centreline
7. (optional) For 2-D meshes automatically group top and bottom faces in group `FrontBack` with type `empty`
8. (optional) For axisymmetric meshes, automatically group top faces in group `Front` and bottom faces in group `Back` with type `wedge` and faces along x-axis in group `Centreline` with type `empty`.
9. group external faces into patches according to the labels: `OF_inlet_nn`, `OF_outlet_nn`, `OF_wall_nn`, `OF_symmetry_nn`, where `nn` can be numbers `00`, `01`, ... `10`. See 4.2 for details.
10. (optional) if `--create_0` option is used, create `/0/p` and `/0/p` files. See 4.3 for details.
11. use OpenFOAM `renumberMesh` utility to reorder faces and cells for numerical efficiency.

4.1 e3prep → foam block conversion

The conversion of individual e3prep blocks to corresponding foam meshes is carried out by invoking the `--OpenFOAM` option of `e3post.py`. The corresponding code is shown in section 7.1. Depending on mesh type the following procedures are applied to convert the mesh.

4.1.1 3-D meshes

Eilmer uses a body-fitting structured mesh. A simple $3 \times 1 \times 2$ grid is shown in Figure 1, which results in 24 vertices (labelled from 0 to 23) and 6 cells (labelled from 0 to 5). This figure is used to explain how the Eilmer mesh is converted to OpenFOAM format. The OpenFOAM `foam` mesh contains 5 files, namely, `points`, `faces`, `owner`, `neighbour`, and `boundary`, which are defined as:

- `points`
  A list of vectors describing the cell vertices, where the first vector in the list represents vertex 0, the second vector represents vertex 1, etc. Since a structured mesh is used in Eilmer, the `points` file is created by sequentially going through the mesh, first in the i direction, next the j direction and then k direction and writing a corresponding file.

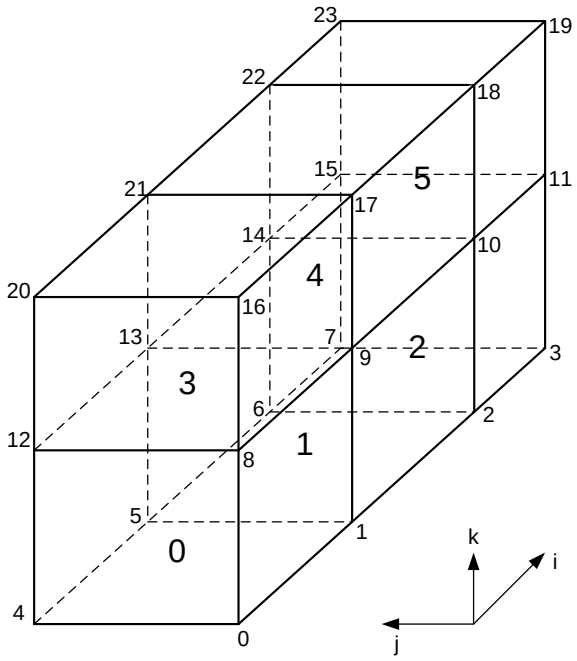


Figure 1: Simple structured mesh in Eilmer3.

- `faces`
  A face is an ordered list of points, where a point is referred to by its label. The ordering of point labels in a face is such that each two neighbouring points are connected by an edge. Faces are compiled into a list and each face is referred to by its label, representing its position in the list. The direction of the face normal vector is defined by the right-hand rule. There are two types of faces within the `foam` format which must be treated differently

  1. `Internal face`: All faces that connect two cells (and it can never be more than two). The order of points is selected such, that each face normal points in the positive i, j or k direction. For example, for the internal face between block 0 and 1 (created by the four points: 1, 5, 13 and 9) is defined as (1 5 13 9) to ensure that the face normal vector points in the positive i direction.
  2. `Boundary face`: All faces that belonging to one cell only, since they coincide with the boundary of the domain. A boundary face is therefore addressed by one cell (only) and a boundary patch. The ordering of the point labels is such that the face normal points outside of the computational domain. For example, for the boundary face which is created by the points: 0 1 9 8, to make sure that the normal vector of this boundary face points outside of computational domain, the order of points in the label is (0 1 9 8).

  Using the above convention all the face labels are written to the `faces` file.

- `owner` and `neighbour`
  owner and neighbour files define which cell owns and neighbours each face, respectively.

From the definition, owners exist for both internal and boundary faces, but neighbours only exist for internal face. In Eilmer, cells are numbered in order of i direction first, j direction next and then k direction. The owner of the specific internal face is defined as the starting cell based on the right hand rule. For example, for the internal face of (1 5 13 9), its normal vector points from cell 0 to cell 1, in this case, cell 0 is the owner while cell 1 neighbour and corresponding entries are written to the `owner` and `neighbour` files. For the boundary face of (0 1 9 8), cell 0 is the owner, and there is no neighbour. Here an entry is only added to the `owner` file.

- `boundary`
  A list of patches, containing a dictionary entry for each patch. The number of faces and the starting face for this boundary is provided. Corresponding entries are created for the six sides of the structured mesh.

These are the typical steps for 3-D mesh conversion from Eilmer3 to OpenFOAM, however, what if 2-D mesh is generated in Eilmer, how do we convert it into OpenFOAM format since only 3-D mesh is accepted in OpenFOAM, this will be discussed below.

4.1.2 2-D meshes

Eilmer 2-D meshes are created in the west, east, north, south plane (corresponding to the x-y plane). To allow conversion of 2-D meshes for simulations in OpenFOAM, which requires a 3-D mesh, the mesh is first extruded in the downwards direction by 1×10^{-3} m to form a 1 cell deep 3-D mesh. This mesh is then converted as outlined above.

4.1.3 2-D axi-symmetric meshes

Eilmer 2-D axi-symmetric meshes are created in the west, east, north, south plane (corresponding to the x-y plane). To generate 3-D axi-symmetric mesh as required by OpenFOAM, the Eilmer mesh is then rotated by ± 0.04 rad ($2.3°$) about the x-axis, to create a wedge shaped, 1 cell wide mesh centred on the x-y plane. This mesh is then converted as outlined above.

4.2 Grouping of external faces

`e3prep` or `e3prepToFoam` does not set boundary conditions. Instead it allows multiple block faces, labelled with one of a list of pre-defined names in `job.py` to be grouped into a single boundary patch. In OpenFOAM boundary conditions are then set for each patch. Currently the following pre-defined labels are recognised by `e3prepToFoam`. Depending on type, different patch types are set.

- `OF_inlet_00`, `OF_inlet_01`, ... `OF_inlet_10`
  Patch is defined with type `patch`.
- `OF_outlet_00`, `OF_outlet_01`, ... `OF_outlet_10`
  Patch is defined with type `patch`.
- `OF_wall_00`, `OF_wall_01`, ... `OF_wall_10`
  Patch is defined with type `wall`.
- `OF_symmetry_00`, `OF_symmetry_01`, ... `OF_symmetry_10`
  Patch is defined with type `symmetry`.

The type of the individual patches can be changed retrospectively by editing the `case/constan/polymesh/boundary` file. The names of the individual patches can be changed by editing `case/constan/polymesh/boundary` and the respective `boundaryField` names in the files within the `case/0/` directory.

4.3 Creation of boundary conditions (`--create_0` option)

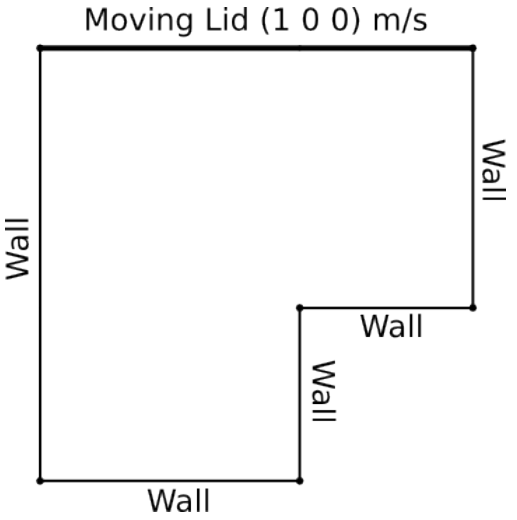
If the `$ e3prepToFoam.py --job=job.py --create_0` is executed, in addition to converting the mesh, the initial and boundary condition files for pressure (`p`) and velocity (`U`) are created in the `case/0` directory. These files contain dimensions, initial conditions, pre-populated boundary condition entries for all the labeled external faces, and boundary condition entries for empty front and rear faces in 2-D meshes.
The `p` file is initialised as:

- `dimensions` `[0 2 -2 0 0 0 0]` ($m^2\ s^{-2}$) ← needs to be altered for compressible
- `internalField` `uniform 0` ← needs to be altered for compressible
- `boundaryField` template generated based on label type
  - `OF_inlet`, `OF_outlet`, `OF_wall` → `zeroGradient`
  - `OF_symmetry` → `symmetry`
  - `FrontBack` (automatically set for 2-D) → `empty`
  - `Front`, `Back` (automatically set for axi-symmetric) → `wedge`
  - `Centreline` (automatically set for axi-symmetric) → `empty`

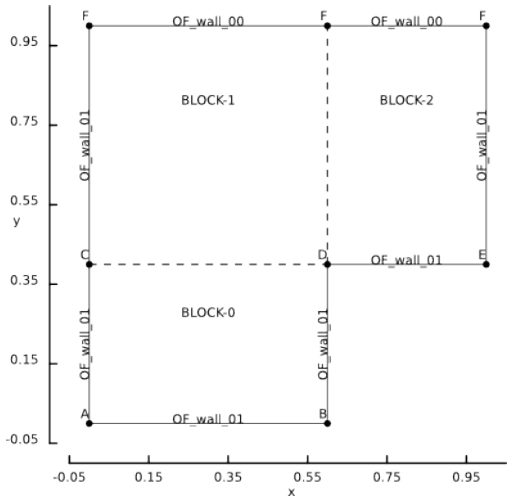
The `U` file is initialised as:

- `dimensions` `[0 1 -1 0 0 0 0]` ($m\ s^{-1}$)
- `internalField` `uniform (0 0 0)`
- `boundaryField` template generated based on label type
  - `OF_inlet` , `OF_wall $\rightarrow$ \verb`fixedValue'
  - `OF_outlet'` → `zeroGradient`
  - `OF_symmetry` → `symmetry`
  - `FrontBack` (automatically set for 2-D) → `empty`
  - `Front`, `Back` (automatically set for axi-symmetric) → `wedge`
  - `Centreline` (automatically set for axi-symmetric) → `empty`

If the extra variables are solved, additional files need to be created in the `case/0/` directory. The `p` and `U` files can be used as templates.



(a) Domain used for 2-D example and corresponding boundary conditions.



(b) Blocking strategy for mesh and labels as applied by e3prep.

Figure 2: Domain, boundary conditions, blocking strategy, and boundary labels for 2-D example.

5 Examples

5.1 2-D mesh

This example is based on the *clippedCavity* example (Section 2.1.9 and 2.1.10) from the OpenFOAM Manual [2]. The first step is to copy the existing OpenFOAM `cavityClipped` example and to create the `e3prep` directory (see section 3.2.1).

Meshing

The domain is a rectangle with a quarter missing as shown in Figure 2(a). All lower walls are stationary and the top wall is moving to the right with a velocity of 1 m /s. For meshing using `e3prep` the mesh is split into 3 blocks as shown in Figure 2(b). The external walls are split into 2 groups:
`OF_wall_00` for the moving lid
`OF_wall_01` for the remaining walls.
The corresponding grid generation file `cavityClipped.py` is

```
# cavityClipped.py
# Simple job-specification file for e3prep.py and e3prepToFoam.py
# IJ, 27-Apr-2015

job_title = "cavityClipped example for e3prepToFoam."
print job_title

# We can set individual attributes of the global data object.
gdata.dimensions = 2
gdata.title = job_title
gdata.axisymmetric_flag = 0

# Set up 3 rectangles in the (x,y)-plane by first defining
```

```
# the corner nodes, then the lines between those corners.
a = Node(0.0, 0.0, label="A")
b = Node(0.6, 0.0, label="B")
c = Node(0.0, 0.4, label="C")
d = Node(0.6, 0.4, label="D")
e = Node(1.0, 0.4, label="E")
f = Node(0.0, 1.0, label="F")
g = Node(0.6, 1.0, label="F")
h = Node(1.0, 1.0, label="F")

# Define Lines connecting blocks
ab = Line(a, b)  # horizontal lines (lowest level)
cd = Line(c, d); de = Line(d, e) # horizontal lines (mid level)
fg = Line(f, g); gh = Line(g, h) # horizontal lines (top level)
ac = Line(a, c); cf = Line(c, f) # vertical lines (left)
bd = Line(b, d); dg = Line(d, g) # vertical lines (mid)
eh = Line(e, h) # vertical lines (right)

# Define the blocks, with particular discretisation.
nx0 = 12; nx1 = 8; ny0 = 8; ny1 = 12
blk_0 = Block2D(make_patch(cd, bd, ab, ac), nni=nx0, nnj=ny0,
                label="BLOCK-0")
blk_1 = Block2D(make_patch(fg, dg, cd, cf), nni=nx0, nnj=ny1,
                label="BLOCK-1")
blk_2 = Block2D(make_patch(gh, eh, de, dg), nni=nx1, nnj=ny1,
                label="BLOCK-2")

# Command to identify internal face connections
identify_block_connections()

# Set boundary conditions.
blk_1.bc_list[WEST] = ExtrapolateOutBC(label="OF_wall_01") # labelling wall B/C
blk_0.bc_list[WEST] = ExtrapolateOutBC(label="OF_wall_01")
blk_0.bc_list[SOUTH] = ExtrapolateOutBC(label="OF_wall_01")
blk_0.bc_list[EAST] = ExtrapolateOutBC(label="OF_wall_01")
blk_2.bc_list[SOUTH] = ExtrapolateOutBC(label="OF_wall_01")
blk_2.bc_list[EAST] = ExtrapolateOutBC(label="OF_wall_01")
blk_1.bc_list[NORTH] = ExtrapolateOutBC(label="OF_wall_00")
blk_2.bc_list[NORTH] = ExtrapolateOutBC(label="OF_wall_00")

# command to write BC labels
sketch.prefer_bc_labels_on_faces()

# plot .svg
sketch.xaxis(-0.05, 1.05, 0.2, -0.05)
sketch.yaxis(-0.05, 1.05, 0.2, -0.05)
sketch.window(-0.05, -0.05, 1.05, 1.05, 0.05, 0.05, 0.17, 0.17)
```

The grid generation and grid conversion is performed using the commands (from the `e3prep` directory):

```
e3prep.py --job=cavity3.py --do=svg --openfoam
e3prepToFoam.py --job=cavity3.py --create_0
```

Running `checkMesh` provides following summary of the grid:

```
Create polyMesh for time = 0

Time = 0

Mesh stats
```

```
    points:           754
    internal points:  0
    faces:            1384
    internal faces:   632
    cells:            336
    faces per cell:   6
    boundary patches: 3
    point zones:      0
    face zones:       2
    cell zones:       0

Overall number of cells of each type:
    hexahedra:     336
    prisms:        0
    wedges:        0
    pyramids:      0
    tet wedges:    0
    tetrahedra:    0
    polyhedra:     0

Checking topology...
    Boundary definition OK.
    Cell to face addressing OK.
    Point usage OK.
    Upper triangular ordering OK.
    Face vertices OK.
    Number of regions: 1 (OK).

Checking patch topology for multiply connected surfaces...
    Patch              Faces    Points   Surface topology
    FrontBack          672      754      ok (non-closed singly connected)
    OF_wall_00         20       42       ok (non-closed singly connected)
    OF_wall_01         60       122      ok (non-closed singly connected)

Checking geometry...
    Overall domain bounding box (0 0 0) (1 1 0.001)
    Mesh (non-empty, non-wedge) directions (1 1 0)
    Mesh (non-empty) directions (1 1 0)
    All edges aligned with or perpendicular to non-empty directions.
    Boundary openness (1.36813e-19 -2.01195e-19 -3.88871e-17) OK.
    Max cell openness = 8.67362e-17 OK.
    Max aspect ratio = 1 OK.
    Minimum face area = 5e-05. Maximum face area = 0.0025.  Face area magnitudes
        OK.
    Min volume = 2.5e-06. Max volume = 2.5e-06.  Total volume = 0.00084.  Cell
        volumes OK.
    Mesh non-orthogonality Max: 0 average: 0
    Non-orthogonality check OK.
    Face pyramids OK.
    Max skewness = 1e-09 OK.
    Coupled point location match (average 0) OK.

Mesh OK.

End
```

As can be seen the external faces of the mesh are defined by 3 patches:
`FrontBack` → front and back face of single cell deep 3-D mesh used by OpenFOAM for 2-D simulations
`OF_wall_00` → moving lid

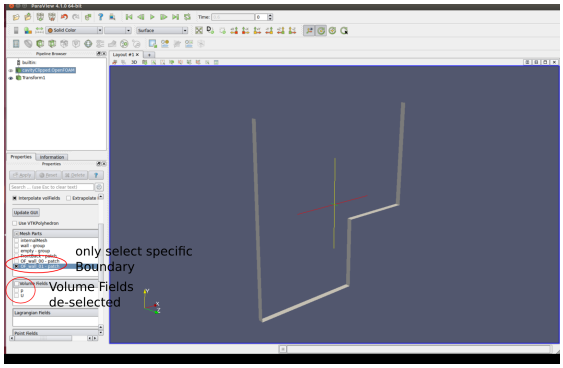


Figure 3: Parts of the mesh visualised in Paraview.

`OF_wall_01` → stationary walls at left, bottom, right.

Figure 3 shows visualisation of various mesh components in paraview.

Boundary Conditions

Next the boundary conditions are set in the `p` and `U` files. Templates with the correct patch names have already been create by running the `--create_0` option. For the `p` file all faces are set to `zeroGradient`. For the `U` file the moving lid is set to `(1 0 0)` and the stationary walls are set to `(0 0 0)`. The corresponding files are:

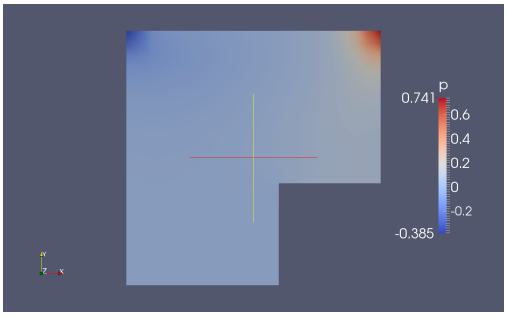
```
/*--------------------------------*- C++ -*----------------------------------*\
| =========                 |                                                 |
| \\      /  F ield         | OpenFOAM: The Open Source CFD Toolbox           |
|  \\    /   O peration     | Version:  2.3.0                                 |
|   \\  /    A nd           | Web:      www.OpenFOAM.org                      |
|    \\/     M anipulation  |                                                 |
\*---------------------------------------------------------------------------*/
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      p;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //

dimensions      [0 2 -2 0 0 0 0];

internalField   uniform 0;

boundaryField
{
    FrontBack
    {
        type            empty;
    }
    OF_wall_00
    {
        type            zeroGradient;
    }
```

```
    OF_wall_01
    {
        type            zeroGradient;
    }
}


// ************************************************************************* //
```

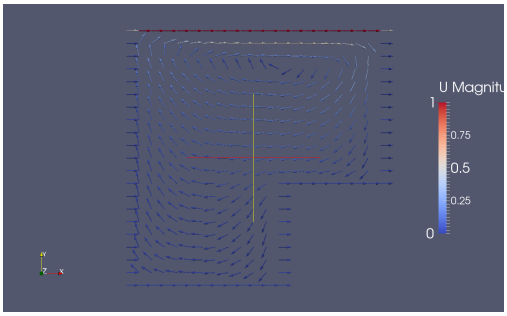
```
/*--------------------------------*- C++ -*----------------------------------*\
| =========                 |                                                 |
| \\      /  F ield         | OpenFOAM: The Open Source CFD Toolbox           |
|  \\    /   O peration     | Version:  2.3.0                                 |
|   \\  /    A nd           | Web:      www.OpenFOAM.org                      |
|    \\/     M anipulation  |                                                 |
\*---------------------------------------------------------------------------*/
FoamFile
{
    version     2.0;
    format      ascii;
    class       volVectorField;
    location    "0";
    object      U;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //

dimensions      [0 1 -1 0 0 0 0];

internalField   uniform (0 0 0);

boundaryField
{
    FrontBack
    {
        type            empty;
    }
    OF_wall_00
    {
        type            fixedValue;
        value           uniform (1 0 0);
    }
    OF_wall_01
    {
        type            fixedValue;
        value           uniform (0 0 0);
    }
}


// ************************************************************************* //
```

Running the simualtion

The simulation can now be run using the `$ icoFoam` command. The pressure and velocity field obtained from the simulation are shown in Figure 4



(a) Pressure Field.



(b) Velocity Vectors coloured by magnitude.

Figure 4: Solution of the clippedCavity 2-D example.

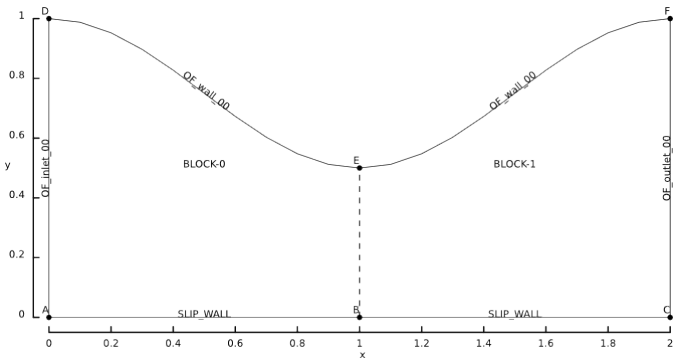


Figure 5: Fluid domain and block structure for 2-D axi-symmetric convergent-divergent nozzle

5.2 2-D axi-symmetric mesh

This example is based on a convergent divergent nozzle with sinusoidal shape as shown in Figure 5. The nozzle has a length of $2 \times L_0 = 2\,\mathrm{m}$ and starting radius of $R_0 = 1\,\mathrm{m}$. The nozzle contour is defined as $R = R_0\ (0.75 + 0.25\cos(x\,\pi))$

Meshing

The external walls are split into 3 groups:
`OF_wall_00` for the outer radius
`OF_inlet_00` for inlet (left end)
`OF_oulet_00` for inlet (right end)
The corresponding grid generation file `condiv.py` is

```
# condiv.py
# Simple job-specification file for e3prep.py and e3prepToFoam.py
# IJ, 27-Apr-2015

job_title = "condiv a Convergent-Divergent Nozzle example for e3prepToFoam."
print job_title

# We can set individual attributes of the global data object.
gdata.dimensions = 2
gdata.title = job_title
gdata.axisymmetric_flag = 1 # set equal 1 as axi-symmetric

# Define variables for parametric geometry definition
R0 = 1.
L0 = 1.
# Set up the corner nodes, then the lines between those corners.
a = Node(0.0     , 0.0, label="A")
b = Node(L0      , 0.0, label="B")
c = Node(2. *L0  , 0.0, label="C")
d = Node(0.0     , R0, label="D")
e = Node(L0      , 0.5*R0, label="E")
f = Node(2.0*L0  , R0, label="F")

# Define straight Lines
ab = Line(a, b); bc = Line(b,c )  # Centreline
ad = Line(a, d); be = Line(b, e); cf = Line(c, f) # vertical lines

```

```
# use PyFunctionPath to define nozzle contour
import numpy as np
def path0(t):
    global R0
    global L0
    x = t * L0
    y = R0 * (0.75 + 0.25 * np.cos(t * np.pi))
    return x,y,0.

def path1(t):
    global R0
    global L0
    x = (1+t) * L0
    y = R0 * (0.75 + 0.25 * np.cos((t+1.) * np.pi))
    return x,y,0.

# Define Nozzle Contours
de = PyFunctionPath(path0); ef = PyFunctionPath(path1)

# Define the blocks, with particular discretisation.
nx0 = 10; nx1 = 10; ny0 = 10
blk_0 = Block2D(make_patch(de, be, ab, ad), nni=nx0, nnj=ny0,
                fill_condition = initial, label="BLOCK-0")
blk_1 = Block2D(make_patch(ef, cf, bc, be), nni=nx1, nnj=ny0,
                fill_condition = initial, label="BLOCK-1")

# Command to identify internal face connections
identify_block_connections()

# Set boundary conditions.
blk_0.bc_list[WEST] = ExtrapolateOutBC(label="OF_inlet_00") # labelling wall B/C
blk_0.bc_list[NORTH] = ExtrapolateOutBC(label="OF_wall_00")
blk_1.bc_list[NORTH] = ExtrapolateOutBC(label="OF_wall_00")
blk_1.bc_list[EAST] = ExtrapolateOutBC(label="OF_outlet_00")

# command to write BC labels
sketch.prefer_bc_labels_on_faces()

# plot .svg
sketch.xaxis(0.0, 2.0, 0.2, -0.05)
sketch.yaxis(0.0, 1.0, 0.2, -0.05)
sketch.window(-0.05, -0.05, 1.05, 2.05, 0.05, 0.05, 0.17, 0.27)
```

The grid generation and grid conversion is performed using the commands (from the `e3prep` directory):

```
e3prep.py --job=condiv.py --do=svg
e3prepToFoam.py --job=condiv.py --create_0
```

Running `checkMesh` provides following summary of the grid faces/patches:

```
Checking patch topology for multiply connected surfaces...
    Patch               Faces     Points    Surface topology
    Back                200       231       ok (non-closed singly connected)
    Front               200       231       ok (non-closed singly connected)
    OF_inlet_00         10        21        ok (non-closed singly connected)
    OF_outlet_00        10        21        ok (non-closed singly connected)
    OF_wall_00          20        42        ok (non-closed singly connected)
```

As can be seen from the output, a `Front` and `Back` patch has been added.

Boundary Conditions

Next the boundary conditions are set in the `p` and `U` files. Templates with the correct patch names have already been create by running the `--create_0` option. For the `p` file all faces are set to `zeroGradient`. For the `U` file the inlet is set to `uniform (1 0 0)`, the stationary walls are set to `uniform (0 0 0)` and the outlet is set to `zeroGradient`. The corresponding files are:

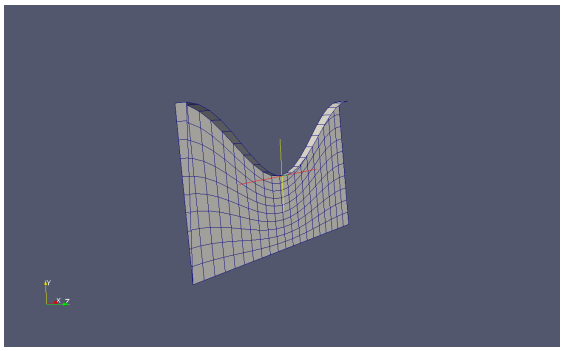
```
/*--------------------------------*- C++ -*----------------------------------*\
| =========                 |                                                 |
| \\      /  F ield         | OpenFOAM: The Open Source CFD Toolbox           |
|  \\    /   O peration     | Version:  2.3.0                                 |
|   \\  /    A nd           | Web:      www.OpenFOAM.org                      |
|    \\/     M anipulation  |                                                 |
\*---------------------------------------------------------------------------*/
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      p;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //

dimensions      [0 2 -2 0 0 0 0];

internalField   uniform 0;

boundaryField
{
    Back
    {
        type            wedge;
    }
    Front
    {
        type            wedge;
    }
    OF_inlet_00
    {
        type            zeroGradient;
    }
    OF_outlet_00
    {
        type            zeroGradient;
    }
    OF_wall_00
    {
        type            zeroGradient;
    }
}


// ************************************************************************* //
```

```
/*--------------------------------*- C++ -*----------------------------------*\
| =========                 |                                                 |
| \\      /  F ield         | OpenFOAM: The Open Source CFD Toolbox           |
```

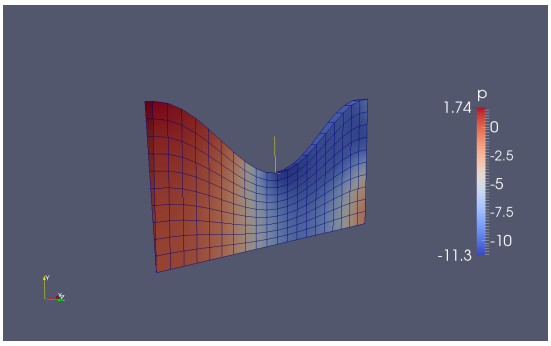
```
|  \\    /   O peration     | Version:  2.3.0                                 |
|   \\  /    A nd           | Web:      www.OpenFOAM.org                      |
|    \\/     M anipulation  |                                                 |
\*---------------------------------------------------------------------------*/
FoamFile
{
    version     2.0;
    format      ascii;
    class       volVectorField;
    location    "0";
    object      U;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //

dimensions      [0 1 -1 0 0 0 0];

internalField   uniform (0 0 0);

boundaryField
{
    Back
    {
        type            wedge;
    }
    Front
    {
        type            wedge;
    }
    OF_inlet_00
    {
        type            fixedValue;
        value           uniform (1 0 0);
    }
    OF_outlet_00
    {
        type            zeroGradient;
    }
    OF_wall_00
    {
        type            fixedValue;
        value           uniform (0 0 0);
    }
}


// ************************************************************************* //
```

Mesh and Results

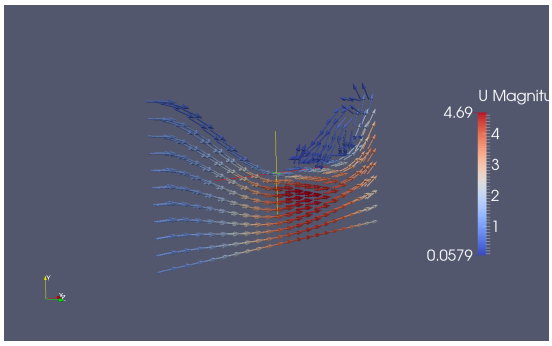
The resulting mesh and solution, as viewed in paraview is shown in Figure 6.



(a) Mesh showing inlet, back wegde face, and outer wall.



(b) Pressure Field.



(c) Velocity Vectors coloured by magnitude.

Figure 6: Mesh and resulting Flow Field of the Convergent-Divergent Nozzle 2-D Axisymmetric example.

5.3 3-D mesh

This example is the heat conduction analysis through a thrust disk. This disk has a inner radius of 25.4 mm and an outer radius of 50.8 mm, and the fixed temperature is set to west and east boundary patch, while others are regarded as adiabatic wall.

5.3.1 Meshing

The external wall boundaries are splited into 3 groups:
`OF_wall_00` for the adiabatic wall
`OF_wall_01` for the west boundary patch
`OF_wall_02` for the east boundary patch
The corresponding grid generation file `rotor.py` is

```
# Mesh generation of rotor
# for OpenFOAM simulation

from math import pi, sin, cos, sqrt
import numpy

# Control Parameter
gdata.dimensions = 3
gdata.title = "Foil thrust bearing--Rotor"

# Define Geometry
r_omega = 2*pi*21000.0/60.0
theta0 = 0.0
theta1 = 15.0/180.0*pi
theta2 = 60.0/180.0*pi

r1 = 0.0510/2.0     # inner radius
r2 = 0.1016/2.0     # outer radius
h1 = 0.0
h2 = 3.0e-3

# Define parametric volume
def makeSimpleBox(ini_angular1, ini_angular2, ini_h1, ini_h2, r_1, r_2):

    inih1 = ini_h1
    inih2 = ini_h2
    ini1 = ini_angular1
    ini2 = ini_angular2
    center_b = Node(0.0, 0.0, inih1)
    center_t = Node(0.0, 0.0, inih2)

    up0 = Vector(r_1*cos(ini1), r_1*sin(ini1), inih1)
    up1 = Vector(r_2*cos(ini1), r_2*sin(ini1), inih1)
    up2 = Vector(r_2*cos(ini2), r_2*sin(ini2), inih1)
    up3 = Vector(r_1*cos(ini2), r_1*sin(ini2), inih1)
    up4 = Vector(r_1*cos(ini1), r_1*sin(ini1), inih2)
    up5 = Vector(r_2*cos(ini1), r_2*sin(ini1), inih2)
    up6 = Vector(r_2*cos(ini2), r_2*sin(ini2), inih2)
    up7 = Vector(r_1*cos(ini2), r_1*sin(ini2), inih2)

    up01 = Line(up0, up1)
    up12 = Arc(up1, up2, center_b)
    up32 = Line(up3, up2)
    up03 = Arc(up0, up3, center_b)
    up45 = Line(up4, up5)
```

```
    up56 = Arc(up5, up6, center_t)
    up76 = Line(up7, up6)
    up47 = Arc(up4, up7, center_t)
    up04 = Line(up0, up4)
    up15 = Line(up1, up5)
    up26 = Line(up2, up6)
    up37 = Line(up3, up7)

    return WireFrameVolume(up01, up12, up32, up03, up45, up56,
                           up76, up47, up04, up15, up26, up37)

# set cluster functions
c_x = RobertsClusterFunction(1,1,1.0)
c_y = RobertsClusterFunction(1,1,1.0)
c_z = RobertsClusterFunction(1,1,1.0)

## block 0
pvolume0 = makeSimpleBox(theta0, theta2, h1, h2, r1, r2)
cflist0 = [c_x,c_y,c_x,c_y,c_x,c_y,c_x,c_y,c_z,c_z,c_z,c_z];
nx0 = 48 ; ny0= 48; nz0= 10;
blk0= Block3D(label="rotor-0", nni=nx0, nnj=ny0, nnk=nz0,
              parametric_volume=pvolume0,
              cf_list=cflist0)

# label Boundary Conditions
blk0.bc_list[NORTH] = ExtrapolateOutBC(label='OF_wall_00')
blk0.bc_list[EAST] = ExtrapolateOutBC(label='OF_wall_01')
blk0.bc_list[SOUTH] = ExtrapolateOutBC(label='OF_wall_00')
blk0.bc_list[WEST] = ExtrapolateOutBC(label='OF_wall_02')
blk0.bc_list[TOP] = ExtrapolateOutBC(label='OF_wall_00')
blk0.bc_list[BOTTOM] = ExtrapolateOutBC(label='OF_wall_00')

sketch.prefer_bc_labels_on_faces()

identify_block_connections()
```

The command generatating mesh file is shown in `prep-simulation.sh`, please note that this is a 3-D mesh case, the option of `--do-svg` is only woking for 2-D using `e3prep.py`. Also, this 3-D mesh is for the heat conduction analysis, the temperature boundary field is only needed in this case, so the option of `--create_0` using `e3prepToFoam.py` is ignored here.

```
#!/bin/bash -l

e3prep.py --job=rotor --openfoam

e3prepToFoam.py --job=rotor
```

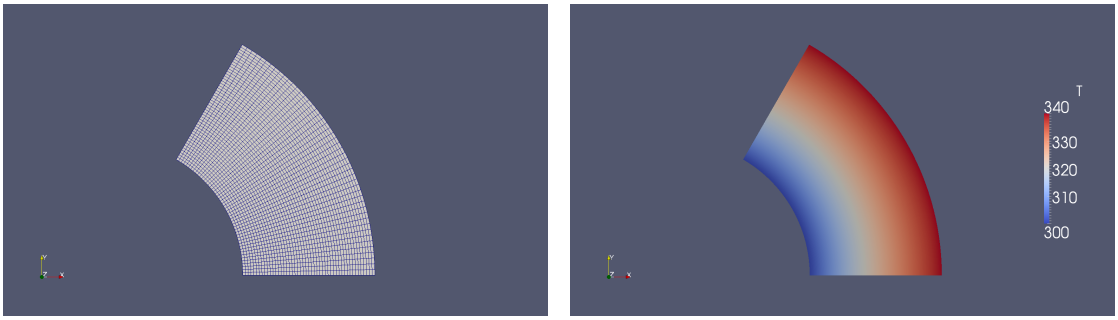
5.3.2 Boundary Conditions

Next the boundary conditions are set in the `T` file. Since the `--create_0` option can only generate `p` and `U` for pressure and velocity, respectively, the temperature `T` file needs to be added manually, which is shown below. For this `T` file, the adiabatic wall are set to `zeroGradient`, the west boundary patch is set to a fixed temperature of 300 K, while the east boundary patch is set to a fixed temperature of 340 K.

```
/*--------------------------------*- C++ -*----------------------------------*\
| =========                      |                                            |
| \\      /  F ield              | OpenFOAM: The Open Source CFD Toolbox      |
|  \\    /   O peration          | Version:  2.2.2                            |
|   \\  /    A nd                | Web:      www.OpenFOAM.org                 |
|    \\/     M anipulation       |                                            |
\*---------------------------------------------------------------------------*/
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    location    "0";
    object      T;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //

dimensions      [0 0 0 1 0 0 0];

internalField   uniform 300;

boundaryField
{
    OF_wall_00
    {
        type            zeroGradient;
    }
    OF_wall_01
    {
        type            fixedValue;
        value           uniform 340;
    }
    OF_wall_02
    {
        type            fixedValue;
        value           uniform 300;
    }
}


// ************************************************************************* //
```

5.3.3 Mesh and Results

For the heat conduction analysis of this thrust disk, the solver called `laplacianFoam` is used, and the resulting mesh and solution, as viewed in paraview is shown in Figure 7.



(a) Mesh for thrust disk.

(b) Temperature field for thrust disk.

Figure 7: Mesh and resulting temperature field of the thrust disk: 3-D example.

6 References

References

[1] P.A. Jacobs, R.J. Gollan, D.F. Potter, 2014, *The Eilmer3 Code: User Guide and Example-Book*, Mechanical Engineering Report 2014/05, The University of Queensland

[2] OpenFOAM The Open Source CFD Toolbox, *Userguide*, Version 2.3.1, 3r December 2014, `www.foam.sourceforge.net/docs/Guides-a4/UserGuide.pdf` OpenFOAM Foundation

[3] CFCFD, *The Compressible Flow Project* `http://cfcfd.mechmining.uq.edu.au` The University of Queensland

7 Appendix

7.1 Addition to e3post.py

Following function has been added to `e3post.py` to enable conversion of `e3prep` blocks to corresponding individual foam meshes.

Additions to `e3_post.py`. This part calls the `write_OpenFOAM_files()` function to perform the mesh conversion.

```
if uoDict.has_key("--OpenFOAM"):
            configFileName = rootName + ".config"
            cp = ConfigParser.ConfigParser()
            cp.read(configFileName)
            axisymmetric_flag = cp.get("global_data", "axisymmetric_flag")
            if verbosity_level > 0:
                print "writing OpenFOAM grid, 2-D or 3-D"
                if axisymmetric_flag == 1:
                    print "creating axisymmetric OpenFOAM grid"
            grid, flow, dimensions = read_all_blocks(rootName, nblock,
                tindx, zipFiles, movingGrid)
            add_auxiliary_variables(nblock, flow, uoDict, omegaz,
                aux_var_names, compute_vars)
            write_OpenFOAM_files(rootName, nblock, grid, flow,
                axisymmetric_flag)
```

Additions to `e3_flow.py`. This part converts the `e3prep` block into an unstructured `foam` mesh and writes the corresponding mesh files.

```
#
    ------------------------------------------------------------------------

# OpenFOAM-related functions by Jason (Kan) Qin, July 2014.

def write_general_OpenFOAM_header(fp):
    fp.write("/*--------------------------------*- C++
        -*----------------------------------*\\\n")
```

```
    fp.write("  | =========                 |
                                              |\n")
    fp.write("  | \\\      /  F ield         | OpenFOAM: The Open Source CFD
        Toolbox           |\n")
    fp.write("  |  \\\    /   O peration     | Version:  2.2.2
                                          |\n")
    fp.write("  |   \\\  /    A nd           | Web:      www.OpenFOAM.org
                            |\n")
    fp.write("  |    \\\/     M anipulation  | This file generated by e3post.
        py                  |\n")
    fp.write("
        \*---------------------------------------------------------------------------*/\
        n")
    fp.write("FoamFile\n")
    fp.write("{\n")
    fp.write("    version     2.0;\n")
    fp.write("    format      ascii;\n")
    return

def write_general_OpenFOAM_bottom(fp):
    fp.write(")\n")
    fp.write("\n")
    fp.write("//
        ************************************************************************
         //\n")
    return

def write_OpenFOAM_unstructured_file(fp0, fp1, fp2, fp3, fp4, jb, grid,
    flow, axi_flag):
    """
    Write the OpenFOAM format data from a single block
    as an unstructured grid of finite-volume cells.
    Since OpenFOAM only accept 3D grid, this tool can be operated in the
        following 3 modes:
    a) 3D grid from Eilmer --> 3D foam grid
    b) 2D grid from Eilmer --> 3D foam grid with width 0.001 meter
    c) 2D axi-symmetric grid from Eilmer --> 3D foam grid with angle
        +/-0.04 radians

    :param fp0: reference to the file object: points
    :param fp1: reference to the file object: faces
    :param fp2: reference to the file object: owner
    :param fp3: reference to the file object: neighbour
    :param fp4: reference to the file object: boundary
    :param grid: single-block grid of vertices
    :param flow: single-block of cell-centre flow data
    :param axi_flag: integr
    """
    nio = grid.ni; njo = grid.nj; nko = grid.nk
    nif = flow.ni; njf = flow.nj; nkf = flow.nk
    two_D = (nko == 1)
    if two_D:
        nko = 2
```

```
    z_set = [0, 0.001]
SumOfPoints = nio * njo * nko
SumOfCells = nif * njf * nkf
#
# cells
cells_number = 0
cells_id = {}
for k in range(nko-1):
    for j in range(njo-1):
        for i in range(nio-1):
            cells_id[(i,j,k)] = cells_number
            cells_number += 1
# points
vtxs_number = 0
vtxs_id = {}
for k in range(nko):
    for j in range(njo):
        for i in range(nio):
            vtxs_id[(i,j,k)] = vtxs_number
            vtxs_number += 1
# faces
face_number = 0
# searching internal faces at k-direction
if two_D == False:
    for k in range(1,nko-1):
        for j in range(njo-1):
            for i in range(nio-1):
                face_number += 1
# searching internal faces at j-direction
for j in range(1,njo-1):
    for k in range(nko-1):
        for i in range(nio-1):
            face_number += 1
# searching internal faces at i-direction
for i in range(1,nio-1):
    for k in range(nko-1):
        for j in range(njo-1):
            face_number += 1

SumOfInternalFaces = face_number
# searching boundary faces at NORTH faces
NF_start = face_number
for i in range(nio-1):
    for k in range(nko-1):
        face_number += 1
NF_end = face_number
SumOfNF = NF_end - NF_start
# searching boundary faces at WEST faces
WF_start = face_number
for k in range(nko-1):
    for j in range(njo-1):
        face_number += 1
WF_end = face_number
```

```
SumOfWF = WF_end - WF_start
# searching boundary faces at EAST faces
EF_start = face_number
for k in range(nko-1):
    for j in range(njo-1):
        face_number += 1
EF_end = face_number
SumOfEF = EF_end - EF_start
# searching boundary faces at SOUTH faces
SF_start = face_number
for i in range(nio-1):
    for k in range(nko-1):
        face_number += 1
SF_end = face_number
SumOfSF = SF_end - SF_start
# searching boundary faces at BOTTOM faces
BF_start = face_number
for i in range(nio-1):
    for j in range(njo-1):
        face_number += 1
BF_end = face_number
SumOfBF = BF_end - BF_start
# searching boundary faces at TOP faces
TF_start = face_number
for i in range(nio-1):
    for j in range(njo-1):
        face_number += 1
TF_end = face_number
SumOfTF = TF_end - TF_start
SumOfFaces = face_number
#
# ---------------------- writing files now ------------------------------
# points
fp0.write("    class        vectorField;\n")
fp0.write("    location     \"constant/polyMesh\";\n")
fp0.write("    object       points;\n")
fp0.write("}\n")
fp0.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
    * * * * * * * * //\n")
fp0.write("\n")
fp0.write("\n")
fp0.write("%d\n" % (SumOfPoints))
fp0.write("(\n")
for k in range(nko):
    for j in range(njo):
        for i in range(nio):
            if two_D:
                if float(axi_flag) == 1:
                    x,y,z = uflowz(grid.x[i,j,0]), uflowz(grid.y[i,j
                        ,0]), uflowz(grid.z[i,j,0])
                    if k == 0:
                        y = y * 0.99920010666097792 # = cos(0.04)
                        z = y * -0.039989334186634161 # = sin(0.04)
```

```
                    else:
                        y = y * 0.99920010666097792 # = cos(0.04)
                        z = y * 0.039989334186634161 # = sin(0.04)
                else:
                    x,y,z = uflowz(grid.x[i,j,0]), uflowz(grid.y[i,j
                        ,0]), uflowz(grid.z[i,j,0])
                    if k == 1:
                        z = z_set[1]
            else:
                x,y,z = uflowz(grid.x[i,j,k]), uflowz(grid.y[i,j,k]),
                    uflowz(grid.z[i,j,k])
            fp0.write("(%e %e %e)\n" % (x,y,z))
# faces, owner and neighbour
# faces header
fp1.write("     class          faceList;\n")
fp1.write("     location       \"constant/polyMesh\";\n")
fp1.write("     object         faces;\n")
fp1.write("}\n")
fp1.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
    * * * * * * * * //\n")
fp1.write("\n")
fp1.write("\n")
fp1.write("%d\n" % (SumOfFaces))
fp1.write("(\n")
# owner header
fp2.write("     class          labelList;\n")
fp2.write("     note           \"nPoints: %d nCells: %d nFaces: %d
    nInternalFaces: %d\";\n" %
          (SumOfPoints, SumOfCells, SumOfFaces, SumOfInternalFaces))
fp2.write("     location       \"constant/polyMesh\";\n")
fp2.write("     object         owner;\n")
fp2.write("}\n")
fp2.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
    * * * * * * * * //\n")
fp2.write("\n")
fp2.write("\n")
fp2.write("%d\n" % (SumOfFaces))
fp2.write("(\n")
# neighbour header
fp3.write("     class          labelList;\n")
fp3.write("     note           \"nPoints: %d nCells: %d nFaces: %d
    nInternalFaces: %d\";\n" %
          (SumOfPoints, SumOfCells, SumOfFaces, SumOfInternalFaces))
fp3.write("     location       \"constant/polyMesh\";\n")
fp3.write("     object         neighbour;\n")
fp3.write("}\n")
fp3.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
    * * * * * * * * //\n")
fp3.write("\n")
fp3.write("\n")
fp3.write("%d\n" % (SumOfInternalFaces))
fp3.write("(\n")
#
```

```
# searching internal faces at i-direction
for i in range(1,nio-1):
    for j in range(njo-1):
        for k in range(nko-1):
            fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],vtxs_id[(i
                ,j+1,k)],vtxs_id[(i,j+1,k+1)],vtxs_id[(i,j,k+1)]))
            owner_id = cells_id[(i-1,j,k)]
            neighbour_id = cells_id[(i,j,k)]
            fp2.write("%d\n" % (owner_id))
            fp3.write("%d\n" % (neighbour_id))
# searching internal faces at j-direction
for j in range(1,njo-1):
    for i in range(nio-1):
        for k in range(nko-1):
            fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],vtxs_id[(i
                ,j,k+1)],vtxs_id[(i+1,j,k+1)],vtxs_id[(i+1,j,k)]))
            owner_id = cells_id[(i,j-1,k)]
            neighbour_id = cells_id[(i,j,k)]
            fp2.write("%d\n" % (owner_id))
            fp3.write("%d\n" % (neighbour_id))
# searching internal faces at k-direction
if two_D == False:
    for k in range(1,nko-1):
        for i in range(nio-1):
            for j in range(njo-1):
                fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],
                    vtxs_id[(i+1,j,k)],vtxs_id[(i+1,j+1,k)],vtxs_id[(i,
                    j+1,k)]))
                owner_id = cells_id[(i,j,k-1)]
                neighbour_id = cells_id[(i,j,k)]
                fp2.write("%d\n" % (owner_id))
                fp3.write("%d\n" % (neighbour_id))
#
# searching boundary faces at NORTH
j = njo-1
for i in range(nio-1):
    for k in range(nko-1):
        fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],vtxs_id[(i,j,k
            +1)],vtxs_id[(i+1,j,k+1)],vtxs_id[(i+1,j,k)]))
        owner_id = cells_id[(i,j-1,k)]
        fp2.write("%d\n" % (owner_id))
# searching boundary faces at WEST faces
i = 0
for k in range(nko-1):
    for j in range(njo-1):
        fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],vtxs_id[(i,j,k
            +1)],vtxs_id[(i,j+1,k+1)],vtxs_id[(i,j+1,k)]))
        owner_id = cells_id[(i,j,k)]
        fp2.write("%d\n" % (owner_id))
# searching boundary faces at EAST faces
i = nio-1
for k in range(nko-1):
    for j in range(njo-1):
```

```
            fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],vtxs_id[(i,j
                +1,k)],vtxs_id[(i,j+1,k+1)],vtxs_id[(i,j,k+1)]))
            owner_id = cells_id[(i-1,j,k)]
            fp2.write("%d\n" % (owner_id))
# searching boundary faces at SOUTH faces
j = 0
for i in range(nio-1):
    for k in range(nko-1):
            fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],vtxs_id[(i+1,j
                ,k)],vtxs_id[(i+1,j,k+1)],vtxs_id[(i,j,k+1)]))
            owner_id = cells_id[(i,j,k)]
            fp2.write("%d\n" % (owner_id))
# searching boundary faces at BOTTOM faces
k = 0
for i in range(nio-1):
    for j in range(njo-1):
            fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],vtxs_id[(i,j
                +1,k)],vtxs_id[(i+1,j+1,k)],vtxs_id[(i+1,j,k)]))
            owner_id = cells_id[(i,j,k)]
            fp2.write("%d\n" % (owner_id))
# searching boundary faces at TOP faces
k = nko-1
for i in range(nio-1):
    for j in range(njo-1):
            fp1.write("4(%d %d %d %d)\n" % (vtxs_id[(i,j,k)],vtxs_id[(i+1,j
                ,k)],vtxs_id[(i+1,j+1,k)],vtxs_id[(i,j+1,k)]))
            owner_id = cells_id[(i,j,k-1)]
            fp2.write("%d\n" % (owner_id))
#
# Boundaries
fp4.write("    class        polyBoundaryMesh;\n")
fp4.write("    location     \"constant/polyMesh\";\n")
fp4.write("    object       boundary;\n")
fp4.write("}\n")
fp4.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
    * * * * * * * * //\n")
fp4.write("\n")
fp4.write("\n")
fp4.write("6\n")
fp4.write("(\n")
# North boundary
fp4.write("    n%04d\n" % (jb))
fp4.write("    {\n")
fp4.write("        type             wall;\n")
fp4.write("        nFaces           %d;\n" % (SumOfNF))
fp4.write("        startFace        %d;\n" % (NF_start))
fp4.write("    }\n")
# West boundary
fp4.write("    w%04d\n" % (jb))
fp4.write("    {\n")
fp4.write("        type             wall;\n")
fp4.write("        nFaces           %d;\n" % (SumOfWF))
fp4.write("        startFace        %d;\n" % (WF_start))
```

```
    fp4.write("    }\n")
    # East boundary
    fp4.write("    e%04d\n" % (jb))
    fp4.write("    {\n")
    fp4.write("        type            wall;\n")
    fp4.write("        nFaces          %d;\n" % (SumOfEF))
    fp4.write("        startFace       %d;\n" % (EF_start))
    fp4.write("    }\n")
    # South boundary
    fp4.write("    s%04d\n" % (jb))
    fp4.write("    {\n")
    fp4.write("        type            wall;\n")
    fp4.write("        nFaces          %d;\n" % (SumOfSF))
    fp4.write("        startFace       %d;\n" % (SF_start))
    fp4.write("    }\n")
    # Bottom boundary
    fp4.write("    b%04d\n" % (jb))
    fp4.write("    {\n")
    fp4.write("        type            wall;\n")
    fp4.write("        nFaces          %d;\n" % (SumOfBF))
    fp4.write("        startFace       %d;\n" % (BF_start))
    fp4.write("    }\n")
    # Top boundary
    fp4.write("    t%04d\n" % (jb))
    fp4.write("    {\n")
    fp4.write("        type            wall;\n")
    fp4.write("        nFaces          %d;\n" % (SumOfTF))
    fp4.write("        startFace       %d;\n" % (TF_start))
    fp4.write("    }\n")
    return

def write_OpenFOAM_files(rootName, nblock, grid, flow, axi_flag):
    """
    Writes the grid files for OpenFOAM, support 2-D and 3-D cases.

    :param rootName: specific file names are built by adding bits to this
        name
    :param nblock: integer
    :param grid: list of StructuredGrid objects
    :param flow: list of StructuredGridFlow objects
    :param axi_flag: integer
    """
    plotPath = "foam"
    if not os.access(plotPath, os.F_OK):
        os.makedirs(plotPath)
    for jb in range(nblock):
        subplotPath = plotPath+("/b%04d" % (jb))
        if not os.access(subplotPath, os.F_OK):
            os.makedirs(subplotPath)
        #
        fileName0 = "points"
        fileName0 = os.path.join(subplotPath, fileName0)
        OFFile0 = open(fileName0, "wb")
```

```
        fileName1 = "faces"
        fileName1 = os.path.join(subplotPath, fileName1)
        OFFile1 = open(fileName1, "wb")
        fileName2 = "owner"
        fileName2 = os.path.join(subplotPath, fileName2)
        OFFile2 = open(fileName2, "wb")
        fileName3 = "neighbour"
        fileName3 = os.path.join(subplotPath, fileName3)
        OFFile3 = open(fileName3, "wb")
        fileName4 = "boundary"
        fileName4 = os.path.join(subplotPath, fileName4)
        OFFile4 = open(fileName4, "wb")
        #
        write_general_OpenFOAM_header(OFFile0)
        write_general_OpenFOAM_header(OFFile1)
        write_general_OpenFOAM_header(OFFile2)
        write_general_OpenFOAM_header(OFFile3)
        write_general_OpenFOAM_header(OFFile4)
        #
        write_OpenFOAM_unstructured_file(OFFile0, OFFile1, OFFile2, OFFile3
            , OFFile4, jb, grid[jb], flow[jb], axi_flag)
        #
        write_general_OpenFOAM_bottom(OFFile0)
        write_general_OpenFOAM_bottom(OFFile1)
        write_general_OpenFOAM_bottom(OFFile2)
        write_general_OpenFOAM_bottom(OFFile3)
        write_general_OpenFOAM_bottom(OFFile4)
        #
        OFFile0.close()
        OFFile1.close()
        OFFile2.close()
        OFFile3.close()
        OFFile4.close()
    return
```

7.2 Source Code e3prepToFoam.py

```
#!/usr/bin/env python
"""
Function to automatically convert e3prep output to OpenFoam mesh.
Can perform following 3 mesh conversions:
    - 2D Eilmer to equivalent 2D OpenFoam mesh
    - 2D Eilmer axisymetric, to equivalent OpenFoam axisymmetric mesh
    - 3D Eilmer to equivalent 3D OpenFoam mesh

The script performs the following tasks:
1) check appropriate OpenFoam File Structure exits
2) execute e3post.py --openFoam to generate individual unstructured OF
    meshes for each Eilmer block. These meshes are stored in /foam/bxxxx
    corresponding to respective blocks
```

```
12 3) combines the individual blocks into a single unstructured OpenFoam mesh
13 4) stitch internal faces
14 5) for 2D combine front and back faces of mesh (Top and Bottom in the
      e3prep blocks) to form "empty" or "wedge" type pacthes
15 6) group boundaries defined in job.py based on the respective names. The
      following boundary names are recognised (replace XX by 01, 02, 03, 04,
      05,06, 07, 08, 09, 10):
16     - OF_inlet_XX
17     - OF_outlet_XX
18     - OF_wall_XX
19     - OF_symmetry_XX
20     - Anything else will retain its name and be set as "patch". Duplicate
         names may cause errors.
21 7) optionally a /0/p and /0/U file containing pressure and velocity
      boundary conditions is created.
22
23 Author: Ingo Jahn 03/02/2015
24 """
25
26 import os as os
27 import numpy as np
28 import shutil as sh
29 from getopt import getopt
30 import sys as sys
31
32 shortOptions = ""
33 longOptions = ["help", "job=", "create_0"]
34
35 def printUsage():
36     print ""
37     print "Usage: e3prepToFoam.py [--help] [--job=<jobFileName>] [--
          create_0]"
38     return
39
40
41 def get_folders():
42     print 'Obtaining directory from which code is executed'
43     start_dir = os.getcwd()
44     str2 = start_dir.split('/')
45     n = len(str2)
46     str3 = str2[n-1]
47     if str3 == 'e3prep':
48         case_dir = os.path.dirname(start_dir)
49         root_dir = os.path.dirname(case_dir)
50         case_name = str2[n-2]
51     else:
52         case_dir = start_dir
53         root_dir = os.path.dirname(case_dir)
54         case_name = str2[n-1]
55     return root_dir, case_dir, start_dir, case_name
56
57 def check_case_structure(case_dir,root_dir):
58     print 'Checking if correct OpenFOAM case structure exists \n'
```

```
59      flag = 0
60      if os.path.exists(case_dir+'/0') is not True:
61          flag = 1
62          print "Missing /0 directory"
63      if os.path.exists(case_dir+'/system') is not True:
64          flag = 1
65          print"Missing /system directory"
66      if os.path.exists(case_dir+'/constant') is not True:
67          flag = 1
68          print "Missing /constant directory"
69
70      if os.path.exists(case_dir+'/constant/polyMesh') is not True:
71          flag = 1
72          print "Missing /constant/polyMesh directory"
73      if os.path.exists(root_dir+'/slave_mesh') is True:
74          flag = 1
75          print "Folder ../slave_mesh/ already exists \n Delete this folder
                and try again"
76      print'\n'
77      return flag
78
79
80  def face_index_to_string(ind):
81      if ind == 0:
82          return 'n'
83      elif ind == 1:
84          return 'e'
85      elif ind == 2:
86          return 's'
87      elif ind == 3:
88          return 'w'
89      elif ind == 4:
90          return 't'
91      elif ind == 5:
92          return 'b'
93      else:
94          print 'Error'
95      return
96
97  def get_job_config_data(job):
98      print 'Extracting required variables from job.config'
99      f = open((job + '.config'),'r')
100     # find dimensions
101     for line in f:
102         if "dimensions" in line:
103             temp = line.split()
104             dimensions = int(temp[2])
105             break
106     # differentiate between axisymmetric and 2-D cases
107     for line in f:
108         if "axisymmetric_flag" in line:
109             temp = line.split()
110             axisymmetric_flag = int(temp[2])
```

```
111             break
112     # find number of blocks
113     for line in f:
114         if "nblock" in line:
115             temp = line.split()
116             nblock = int(temp[2])
117             break
118 
119     other_block = np.zeros((nblock,6))
120     other_face = np.zeros((nblock,6))
121     # find connecting blocks
122     f.seek(0,0)
123     block = 0
124     face = 0
125     for line in f:
126         if "other_block" in line:
127             temp = line.split()
128             other_block[block,face] = int(temp[2])
129             face = face + 1
130             if dimensions == 2:
131                 if face == 4:
132                     other_block[block,4] = -1
133                     other_block[block,5] = -1
134                     face = 0
135                     block = block + 1
136             elif dimensions == 3:
137                 if face == 6:
138                     face = 0
139                     block = block + 1
140     # find connecting faces
141     f.seek(0,0)
142     block = 0
143     face = 0
144     for line in f:
145         if "other_face" in line:
146             temp = line.split()
147             if temp[2] == "none":
148                 other_face[block,face] = -1
149             elif temp[2] == "north":
150                 other_face[block,face] = 0
151             elif temp[2] == "east":
152                 other_face[block,face] = 1
153             elif temp[2] == "south":
154                 other_face[block,face] = 2
155             elif temp[2] == "west":
156                 other_face[block,face] = 3
157             elif temp[2] == "top":
158                 other_face[block,face] = 4
159             elif temp[2] == "bottom":
160                 other_face[block,face] = 5
161             else:
162                 print "Error"
163             face = face + 1
```

```
164             if dimensions == 2:
165                 if face == 4:
166                     other_face[block,4] = -1
167                     other_face[block,5] = -1
168                     face = 0
169                     block = block + 1
170             elif dimensions == 3:
171                 if face == 6:
172                     face = 0
173                     block = block + 1
174     # find boundary labels
175     f.seek(0,0)
176     Label = [[None for i in range(6)] for i in range(nblock)]
177     for block in range(nblock):
178         if dimensions == 2:
179             for face in range(4):
180                 temp = find_boundary_info(f,block,face,"label")
181                 temp = temp.split()
182                 if len(temp) == 3:
183                     Label[block][face] = temp[2]
184                     # print "I was here", block, face, temp[2]
185                 else:
186                     Label[block][face] = "EMPTY"
187             Label[block][4] = "EMPTY"
188             Label[block][5] = "EMPTY"
189         if dimensions == 3:
190             for face in range(6):
191                 temp = find_boundary_info(f,block,face,"label")
192                 temp = temp.split()
193                 if len(temp) == 3:
194                     Label[block][face] = temp[2]
195                     # print "I was here", block, face, temp[2]
196                 else:
197                     Label[block][face] = "EMPTY"
198     f.close()
199     return (nblock, dimensions, axisymmetric_flag, other_block, other_face,
          Label)
200
201
202 def find_boundary_info(fp,block,face,lookup):
203     if face == 0:
204         phrase = ("[block/"+str(block)+"/face/north]")
205     elif face == 1:
206         phrase = ("[block/"+str(block)+"/face/east]")
207     elif face == 2:
208         phrase = ("[block/"+str(block)+"/face/south]")
209     elif face == 3:
210         phrase = ("[block/"+str(block)+"/face/west]")
211     elif face == 4:
212         phrase = ("[block/"+str(block)+"/face/top]")
213     elif face == 5:
214         phrase = ("[block/"+str(block)+"/face/bottom]")
215     else:
```

```
216         print "wrong face_index"
217     fp.seek(0,0)
218     for num, line in enumerate(fp, 1):
219         if phrase in line:
220             break
221     for line in fp:
222         if lookup in line:
223             break
224     return line
225 
226 
227 def write_general_OpenFoam_header(fp):
228     fp.write("/*---------------------------------*- C++
        -*----------------------------------*\\\n")
229     fp.write(" | ========                 |
                                                |\n")
230     fp.write(" | \\      /  F ield         | OpenFOAM: The Open Source CFD
        Toolbox           |\n")
231     fp.write(" |  \\    /   O peration     | Version:  2.2.2
                                    |\n")
232     fp.write(" |   \\  /    A nd           | Web:      www.OpenFOAM.org
                                |\n")
233     fp.write(" |    \\/     M anipulation  | This file generated by e3post.
        py                  |\n")
234     fp.write("
        \*---------------------------------------------------------------------------*/\
        n")
235     fp.write("FoamFile\n")
236     fp.write("{\n")
237     fp.write("    version     2.0;\n")
238     fp.write("    format      ascii;\n")
239     return
240 
241 def write_general_OpenFoam_bottom_round(fp):
242     fp.write(");\n")
243     fp.write("\n")
244     fp.write("//
        ************************************************************************
        //\n")
245     return
246 
247 def write_general_OpenFoam_bottom_curly(fp):
248     fp.write("};\n")
249     fp.write("\n")
250     fp.write("//
        ************************************************************************
        //\n")
251     return
252 
253 def write_createPatch_header(fp):
254     #
255     # ---------------------- writing files now ------------------------------
256     # points
```

```python
    fp.write("     class         dictionary;\n")
    fp.write("     object        createPatchDict;\n")
    fp.write("}\n")
    fp.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //\n")
    fp.write("\n")
    fp.write("pointSync false;\n")
    fp.write("// Patches to create. \n")
    fp.write("patches \n")
    fp.write("(\n")
    return

def write_collapseDict_header(fp):
    #
    # ------------------- writing files now ----------------------------
    # points
    fp.write("     class         dictionary;\n")
    fp.write("     object        collapseDict;\n")
    fp.write("}\n")
    fp.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //\n")
    fp.write("\n")
    fp.write("collapseEdgesCoeffs\n")
    fp.write("{\n")
    fp.write("// Edges shorter than this absolute value will be merged\n")
    fp.write("     minimumEdgeLength    1e-10;\n")
    fp.write("\n")
    fp.write("// The maximum angle between two edges that share a point attached to\n")
    fp.write("// no other edges\n")
    fp.write("maximumMergeAngle    5;\n")
    return


def write_p_header(fp):
    #
    # ------------------- writing files now ----------------------------
    # points
    fp.write("     class         volScalarField;\n")
    fp.write("     location      \"0\";\n")
    fp.write("     object        p;\n")
    fp.write("}\n")
    fp.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //\n")
    fp.write("\n")
    fp.write("dimensions         [0 2 -2 0 0 0 0];\n")
    fp.write("\n")
    fp.write("internalField    uniform 0;\n")
    fp.write("\n")
    fp.write("boundaryField \n")
    fp.write("{ \n")
    return

```

```
def write_U_header(fp):
    #
    # ---------------------- writing files now ------------------------------------
    # points
    fp.write("    class        volVectorField;\n")
    fp.write("    location     \"0\";\n")
    fp.write("    object       U;\n")
    fp.write("}\n")
    fp.write("// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //\n")
    fp.write("\n")
    fp.write("dimensions      [0 1 -1 0 0 0 0];\n")
    fp.write("\n")
    fp.write("internalField   uniform (0 0 0);\n")
    fp.write("\n")
    fp.write("boundaryField \n")
    fp.write("{ \n")
    return

def write_patches(fp,input_patch_str,output_name,output_type):
    fp.write("    {\n")
    fp.write(("        name " + output_name +";\n"));
    fp.write("        patchInfo\n")
    fp.write("        {\n")
    fp.write(("            type "+output_type+";\n"))
    fp.write("        }\n")
    fp.write("        constructFrom patches;\n")
    fp.write("        patches ("+input_patch_str+");\n")
    fp.write("    }\n")
    return

def write_p_Boundary(fp,bname,btype):
    fp.write("    "+bname+"\n")
    fp.write("    {\n")
    if btype == "zeroGradient":
        fp.write("        type   zeroGradient; \n")
    elif btype == "empty":
        fp.write("        type   empty; \n")
    elif btype == "wedge":
        fp.write("        type   wedge; \n")
    elif btype == "symmetry":
        fp.write("        type   symmetry; \n")
    elif btype == "fixedValue":
        fp.write("        type   fixedValue; \n")
        fp.write("        value   0; \n")
    else:
        print ("Boundary type, " + btype + " not recognised. Setting empty")
    fp.write("    }\n")
    return

def write_U_Boundary(fp,bname,btype):
    fp.write("    "+bname+"\n")
```

```
357     fp.write("     {\n")
358     if btype == "zeroGradient":
359         fp.write("         type    zeroGradient; \n")
360     elif btype == "empty":
361         fp.write("         type    empty; \n")
362     elif btype == "wedge":
363         fp.write("         type    wedge; \n")
364     elif btype == "symmetry":
365         fp.write("         type    symmetry; \n")
366     elif btype == "fixedValue":
367         fp.write("         type    fixedValue; \n")
368         fp.write("         value    uniform (0 0 0); \n")
369     else:
370         print ("Boundary type, " + btype + " not recognised. Setting empty"
              )
371     fp.write("     }\n")
372     return
373
374 def combine_faces(case_dir,start_dir,patch_str,patch_name,patch_type):
375     file_createPatchDict = "createPatchDict"
376     file_createPatchDict = os.path.join((case_dir+ '/system'),
          file_createPatchDict)
377     OFFile0 = open(file_createPatchDict, "wb")
378
379     write_general_OpenFoam_header(OFFile0)
380     write_createPatch_header(OFFile0)
381     write_patches(OFFile0,patch_str,patch_name,patch_type)
382     write_general_OpenFoam_bottom_round(OFFile0)
383     OFFile0.close()
384     print "createPatchDict has been written. \n"
385     # execute createPatch
386     os.chdir(case_dir)
387     flag = os.system('createPatch -overwrite')
388     # move back to starting_directory
389     os.chdir(start_dir)
390     if flag == 0:
391         print ("The following boundaries" +patch_str+ " have been combined
              to form Patch: " +patch_name+ " with the type: " + patch_type)
392     else:
393         raise MyError("Problem during execution of createPaatch.")
394     return
395
396 def check_for_undefined_faces(case_dir,nblock):
397     file_name = "boundary"
398     file_name = os.path.join((case_dir+ '/constant/polyMesh/'), file_name)
399     File = open(file_name, "r")
400     String = []
401     for n in range(nblock):
402         for line in File:
403             if ('n'+'%04d' % n) in line:
404                 String.append(line + '; ')
405             if ('e'+'%04d' % n) in line:
406                 String.append(line + '; ')
```

```
407             if ('s'+'%04d' % n) in line:
408                 String.append(line + '; ')
409             if ('w'+'%04d' % n) in line:
410                 String.append(line + '; ')
411         File.seek(0,0)
412     File.close()
413     return String
414 
415 
416 def check_for_undefined_labels(patch_Label):
417     A = [item for sublist in patch_Label for item in sublist]
418     A = set(A)
419     String = ['EMPTY', 'Centreline']
420     for i in range(10):
421         String.append("OF_inlet_"+'%02d' % i)
422         String.append("OF_outlet_"+'%02d' % i)
423         String.append("OF_wall_"+'%02d' % i)
424         String.append("OF_symmetry_"+'%02d' % i)
425     String = set(String)
426 
427     return list(A.difference(String))
428 
429 
430 def collapse_faces(case_dir,start_dir):
431     fn = "collapseDict"
432     fn = os.path.join((case_dir+ '/system'), fn)
433     OFFile0 = open(fn, "wb")
434 
435     write_general_OpenFoam_header(OFFile0)
436     write_collapseDict_header(OFFile0)
437     write_general_OpenFoam_bottom_curly(OFFile0)
438     OFFile0.close()
439     print "collapseDict has been written. \n"
440     # execute createPatch
441     os.chdir(case_dir)
442     flag = os.system('collapseEdges -overwrite')
443     # move back to starting_directory
444     os.chdir(start_dir)
445     if flag == 0:
446         print ("Aligned edges have been collapsed")
447     else:
448         raise MyError("Problem during execution of collapseEdges.")
449 
450     return flag
451 
452 class MyError(Exception):
453     def __init__(self, value):
454         self.value = value
455     def __str__(self):
456         return repr(self.value)
457 
458 
459 def main(uoDict):
```

```
460     # create string to collect warning messages
461     warn_str = "\n"
462
463     # main file to be executed
464     jobName = uoDict.get("--job", "test")
465
466     # strip .py extension form jobName
467     jobName = jobName.split('.')
468     jobName = jobName[0]
469
470     # establish case, root, and start directory
471     root_dir, case_dir, start_dir, case_name  = get_folders()
472
473     # check that correct directory structure exists
474     dir_flag = check_case_structure(case_dir, root_dir)
475     if dir_flag == 1:
476         raise MyError('ERROR: Incorrect Directory Structure. e3preToFoam
                must be run inside an OpenFoam case with appropriate sub-
                directories. \nSee error message above and create missing
                folders or copy from existing case. \nOnce folders have been
                created, re-run.')
477
478     # change into e3prep directory
479     os.chdir((case_dir+'/e3prep'))
480
481     # get data from job.config
482     nblock, dimensions, axisymmetric_flag, other_block, other_face,
            patch_Label = get_job_config_data(jobName)
483
484     # check that combination of diemnsions and axi-symetric flag is
            appropriate
485     if not (((dimensions == 2 or dimensions == 3) and axisymmetric_flag ==
            0) or (dimensions == 2 and axisymmetric_flag == 1)):
486         raise MyError('ERROR: Combination of dimensions and
                axisymmetric_flag is not supported')
487     # run e3post to generate /foam folder containing meshes for respective
            block
488     os.system(("e3post.py --job=" + jobName + " --OpenFoam"))
489
490     print 'e3post has been executed and individual foam meshes have been
            generated for each block \n \n '
491
492     # merging individual blocks
493     print ('Working on Case = '+case_name)
494
495     ## move data currently in /polMesh
496     #sh.move('polyMesh','polyMesh_old')
497     sh.rmtree(case_dir + '/constant/polyMesh')
498
499     # create case file for slave_mesh
500     sh.copytree(case_dir,(root_dir+'/slave_mesh'))
501
502     # copy Master mesh data into required folder
```

```
503     sh.copytree((case_dir+'/e3prep/foam/b0000/'),case_dir+'/constant/
            polyMesh')
504
505     for block in range(nblock-1):
506         # copy correct slave_mesh into slabe_mesh case
507         sh.copytree((case_dir+'/e3prep/foam/b'+ '%04d' % (block+1) + '/'),
                root_dir+'/slave_mesh/constant/polyMesh')
508
509         # execute mergeMeshes command
510         os.chdir(root_dir)
511         flag = os.system('mergeMeshes -overwrite ' + case_name + '
                slave_mesh')
512         if flag == 0:
513             print ('Block ' + '%04d' % block + ' and ' + '%04d' % (block+1)
                    + ' have been merged.')
514         else:
515             sh.rmtree(root_dir+'/slave_mesh') # removing slave_mesh
                    directory before exiting
516             os.chdir(start_dir)
517             raise MyError('Error with mergeMeshes. \n Try running of230 to
                    load OpenFOAM module')
518
519         # remove polyMesh from slave_mesh
520         sh.rmtree(root_dir+'/slave_mesh/constant/polyMesh')
521
522     # remove slave_mesh
523     sh.rmtree(root_dir+'/slave_mesh')
524     # move back to starting_directory
525     os.chdir(start_dir)
526
527     print "Merging of meshes complete. \n \n "
528
529     # Remove faces with zero area, positioned along centreline
530     if axisymmetric_flag == 1:
531         print "Removing zero Area faces along centreline. \n"
532         flag = collapse_faces(case_dir,start_dir)
533
534     #identify number of block connections
535     interfaces = len(other_block[np.where(other_block != -1)]) # counts 2 x
            internal connections, as seen by other blocks
536     if interfaces > 0:
537
538         # move /0 directory
539         sh.move((case_dir + '/0'), case_dir + '/temp')
540
541         while True:
542             (block,face) = np.where(other_block != -1)
543             if len(block) == 0:
544                 break
545
546             # print (block,face)
547             o_block = other_block[block[0],face[0]]
548             o_face = other_face[block[0],face[0]]
```

```
549
550             current_facename = (face_index_to_string(face[0]) + '%04d' %
                    block[0])
551             other_facename = (face_index_to_string(o_face) + '%04d' %
                    o_block)
552
553             # print (current_facename, other_facename)
554
555             # overwrite matching face in other block
556             other_block[o_block, o_face] = -1
557             other_face[o_block, o_face] = -1
558             other_block[block[0], face[0]] = -1
559
560             # execute stitchMesh command
561             os.chdir(case_dir)
562             flag = os.system('stitchMesh -overwrite -perfect ' +
                    current_facename + ' ' + other_facename)
563             # move back to starting_directory
564             os.chdir(start_dir)
565             if flag == 0:
566                 print ('Face ' + current_facename + ' and ' +
                        other_facename + ' have been stitched.')
567             else:
568                 raise MyError('Error with stitchMesh.')
569
570         # move /0 directory back
571         sh.move((case_dir + '/temp'), case_dir + '/0')
572
573     print "Stitching of internal Faces complete. \n \n"
574
575     # Group all boundaries with Centreline label as corresponding patch
576     if axisymmetric_flag == 1:
577         name = "Centreline"
578         cent_str = ""
579         for block in range(nblock):
580             L_block = patch_Label[block]
581             #print L_block
582             ind = [n for n, s in enumerate(L_block) if name in s]
583
584             if ind != []:
585                 for n in ind:
586                     if n == 0:
587                         cent_str = (cent_str + ' n' +'%04d' % block)
588                     if n == 1:
589                         cent_str = (cent_str + ' e' +'%04d' % block)
590                     if n == 2:
591                         cent_str = (cent_str + ' s' +'%04d' % block)
592                     if n == 3:
593                         cent_str = (cent_str + ' w' +'%04d' % block)
594                     if n == 4:
595                         cent_str = (cent_str + ' t' +'%04d' % block)
596                     if n == 5:
597                         cent_str = (cent_str + ' b' +'%04d' % block)
```

```
598         print cent_str
599         if cent_str != "":
600             combine_faces(case_dir,start_dir,cent_str,name,'empty')
601 
602     # do automatic patch combination
603     # top and bottom faces
604     if dimensions == 2:
605         if axisymmetric_flag == 0:
606             # crete empty FrontBack patch
607             patch_str = ' '
608             for i in range(nblock):
609                 patch_str = (patch_str+' b'+ '%04d' % i + ' t' + '%04d' % i
                        )
610             patch_name = 'FrontBack'
611             patch_type = 'empty'
612             combine_faces(case_dir,start_dir,patch_str,patch_name,
                    patch_type)
613         elif axisymmetric_flag == 1:
614             # create pair of wedge patches
615             patch_str = ' '
616             for i in range(nblock):
617                 patch_str = (patch_str+' b'+ '%04d' % i)
618             patch_name = 'Back'
619             patch_type = 'wedge'
620             combine_faces(case_dir,start_dir,patch_str,patch_name,
                    patch_type)
621             patch_str = ' '
622             for i in range(nblock):
623                 patch_str = (patch_str+' t'+ '%04d' % i)
624             patch_name = 'Front'
625             patch_type = 'wedge'
626             combine_faces(case_dir,start_dir,patch_str,patch_name,
                    patch_type)
627 
628     # combine patches, based on block label.
629     # Following labels are supported:
630     # OF_inlet_00, OF_inlet_01, OF_inlet_02 (up to 09)
631     # OF_outlet_00, OF_outlet_01, OF_outlet_02 (up to 09)
632     # OF_wall_00, OF_wall_01, OF_wall_02 (up to 09)
633     # OF_symmetry_00, OF_symmetry_01, OF_symmetry_02 (up to 09)
634 
635     N_list_in = []
636     N_list_out = []
637     N_list_wall = []
638     N_list_sym = []
639 
640     for i in range(10):
641         in_n = ("OF_inlet_"+'%02d' % i)
642         out_n = ("OF_outlet_"+'%02d' % i)
643         wall_n = ("OF_wall_"+'%02d' % i)
644         sym_n = ("OF_symmetry_"+'%02d' % i)
645 
646         inlet_str = ""
```

```
647         outlet_str = ""
648         wall_str = ""
649         sym_str = ""
650         for block in range(nblock):
651             L_block = patch_Label[block]
652             #print L_block
653             i_ind = [n for n, s in enumerate(L_block) if in_n in s]
654             o_ind = [n for n, s in enumerate(L_block) if out_n in s]
655             w_ind = [n for n, s in enumerate(L_block) if wall_n in s]
656             s_ind = [n for n, s in enumerate(L_block) if sym_n in s]
657             #print i_ind != []
658             #print o_ind != []
659 
660             if i_ind != []:
661                 for n in i_ind:
662                     if n == 0:
663                         inlet_str = (inlet_str + ' n' +'%04d' % block)
664                     if n == 1:
665                         inlet_str = (inlet_str + ' e' +'%04d' % block)
666                     if n == 2:
667                         inlet_str = (inlet_str + ' s' +'%04d' % block)
668                     if n == 3:
669                         inlet_str = (inlet_str + ' w' +'%04d' % block)
670                     if n == 4:
671                         inlet_str = (inlet_str + ' t' +'%04d' % block)
672                     if n == 5:
673                         inlet_str = (inlet_str + ' b' +'%04d' % block)
674             if o_ind != []:
675                 for n in o_ind:
676                     if n == 0:
677                         outlet_str = (outlet_str + ' n' +'%04d' % block)
678                     if n == 1:
679                         outlet_str = (outlet_str + ' e' +'%04d' % block)
680                     if n == 2:
681                         outlet_str = (outlet_str + ' s' +'%04d' % block)
682                     if n == 3:
683                         outlet_str = (outlet_str + ' w' +'%04d' % block)
684                     if n == 4:
685                         outlet_str = (outlet_str + ' t' +'%04d' % block)
686                     if n == 5:
687                         outlet_str = (outlet_str + ' b' +'%04d' % block)
688             if w_ind != []:
689                 for n in w_ind:
690                     if n == 0:
691                         wall_str = (wall_str + ' n' +'%04d' % block)
692                     if n == 1:
693                         wall_str = (wall_str + ' e' +'%04d' % block)
694                     if n == 2:
695                         wall_str = (wall_str + ' s' +'%04d' % block)
696                     if n == 3:
697                         wall_str = (wall_str + ' w' +'%04d' % block)
698                     if n == 4:
699                         wall_str = (wall_str + ' t' +'%04d' % block)
```

```
700                     if n == 5:
701                         wall_str = (wall_str + ' b' +'%04d' % block)
702             if s_ind != []:
703                 for n in s_ind:
704                     if n == 0:
705                         sym_str = (sym_str + ' n' +'%04d' % block)
706                     if n == 1:
707                         sym_str = (sym_str + ' e' +'%04d' % block)
708                     if n == 2:
709                         sym_str = (sym_str + ' s' +'%04d' % block)
710                     if n == 3:
711                         sym_str = (sym_str + ' w' +'%04d' % block)
712                     if n == 4:
713                         sym_str = (sym_str + ' t' +'%04d' % block)
714                     if n == 5:
715                         sym_str = (sym_str + ' b' +'%04d' % block)
716 
717 
718         print inlet_str, outlet_str, wall_str, sym_str
719         if inlet_str != "":
720             combine_faces(case_dir,start_dir,inlet_str,in_n,'patch')
721             N_list_in.append(in_n)
722         if outlet_str != "":
723             combine_faces(case_dir,start_dir,outlet_str,out_n,'patch')
724             N_list_out.append(out_n)
725         if wall_str != "":
726             combine_faces(case_dir,start_dir,wall_str,wall_n,'wall')
727             N_list_wall.append(wall_n)
728         if sym_str != "":
729             combine_faces(case_dir,start_dir,sym_str,sym_n,'symmetry')
730             N_list_sym.append(sym_n)
731 
732     # check if there are patches remaining that havent been defined.
733     String1 = check_for_undefined_faces(case_dir,nblock)
734     String2 = check_for_undefined_labels(patch_Label)
735 
736     if not(String1 == []):
737         warn_str = warn_str + 'WARNING: Not all external boundaries were
                defined in e3prep \n' + 'Check these faces: ' + String1 + '\n'
738 
739     if not(String2 == []):
740         warn_str = warn_str + 'WARNING: labels used to define boundary
                faces do not follow standard OF_names \n' + 'Check these labels
                : ' + String2 + '\n'
741 
742     # Option to create template entries for /0.
743     if uoDict.has_key("--create_0"):
744 
745         # check if /0/p file exists
746         if os.path.isfile(case_dir+'/0/'+'p') == 1:
747             sh.copyfile(case_dir+'/0/'+'p', case_dir+'/0/'+'p.bak')
748             warn_str = warn_str + "WARNING: Existing copy of /0/p has been
                    copied to /0/p.bak \n"
```

```
749         # check if /0/U file exists
750         if os.path.isfile(case_dir+'/0/'+'U') == 1:
751             sh.copyfile(case_dir+'/0/'+'U', case_dir+'/0/'+'U.bak')
752             warn_str = warn_str + "WARNING: Existing copy of /0/U has been
                    copied to /0/U.bak \n"
753 
754         # U and p template are created. The others can be duplicated form
                these
755         file_name = "p"
756         file_name = os.path.join((case_dir+ '/0/'), file_name)
757         OFFile0 = open(file_name, "wb")
758 
759         write_general_OpenFoam_header(OFFile0)
760         write_p_header(OFFile0)
761 
762         for n in range(len(N_list_in)):
763             write_p_Boundary(OFFile0,N_list_in[n],'zeroGradient')
764         for n in range(len(N_list_out)):
765             write_p_Boundary(OFFile0,N_list_out[n],'zeroGradient')
766         for n in range(len(N_list_wall)):
767             write_p_Boundary(OFFile0,N_list_wall[n],'zeroGradient')
768         for n in range(len(N_list_sym)):
769             write_p_Boundary(OFFile0,N_list_sym[n],'symmetry')
770         if dimensions == 2:
771             if axisymmetric_flag == 0:
772                 write_p_Boundary(OFFile0,'FrontBack','empty')
773             else:
774                 write_p_Boundary(OFFile0,'Front','wedge')
775                 write_p_Boundary(OFFile0,'Back','wedge')
776                 write_p_Boundary(OFFile0,'Centreline','empty')
777 
778         write_general_OpenFoam_bottom_curly(OFFile0)
779         OFFile0.close()
780         print "/0/p has been written. \n"
781 
782         file_name = "U"
783         file_name = os.path.join((case_dir+ '/0/'), file_name)
784         OFFile0 = open(file_name, "wb")
785 
786         write_general_OpenFoam_header(OFFile0)
787         write_U_header(OFFile0)
788         for n in range(len(N_list_in)):
789             write_U_Boundary(OFFile0,N_list_in[n],'fixedValue')
790         for n in range(len(N_list_out)):
791             write_U_Boundary(OFFile0,N_list_out[n],'zeroGradient')
792         for n in range(len(N_list_wall)):
793             write_U_Boundary(OFFile0,N_list_wall[n],'zeroGradient')
794         for n in range(len(N_list_sym)):
795             write_U_Boundary(OFFile0,N_list_sym[n],'symmetry')
796         if dimensions == 2:
797             if axisymmetric_flag == 0:
798                 write_U_Boundary(OFFile0,'FrontBack','empty')
799             else:
```

```
800                 write_U_Boundary(OFFile0,'Front','wedge')
801                 write_U_Boundary(OFFile0,'Back','wedge')
802                 write_U_Boundary(OFFile0,'Centreline','empty')
803 
804         write_general_OpenFoam_bottom_curly(OFFile0)
805         OFFile0.close()
806         print "/0/U has been written. \n"
807 
808 
809     # Re-order numbering of faces/cells for numerical efficiency
810     # execute renumberMesh
811     os.chdir(case_dir)
812     flag = os.system('renumberMesh -overwrite')
813     # move back to starting_directory
814     os.chdir(start_dir)
815     if flag != 0:
816         raise MyError("Problem during execution of renumberMesh.")
817 
818     print warn_str
819 
820 if __name__ == "__main__":
821     userOptions = getopt(sys.argv[1:], shortOptions, longOptions)
822     uoDict = dict(userOptions[0])
823 
824     if len(userOptions[0]) == 0 or uoDict.has_key("--help"):
825         printUsage()
826         sys.exit(1)
827 
828     try:
829         main(uoDict)
830         print "\n \n"
831         print "SUCESS: The multi-block mesh created by e3prep.py has been
                converted into a single Polymesh for use with OpenFoam."
832         print "\n \n"
833     except MyError as e:
834         print "This run of e3prepToFoam.py has gone bad."
835         print e.value
836         sys.exit(1)
```