Python scripts for Automatic Mesh Generation using BlockMesh

SuperMarine Mixer Geometry Builder

Gabriel St-Pierre-Lemieux

Université de Sherbrooke

April 2018

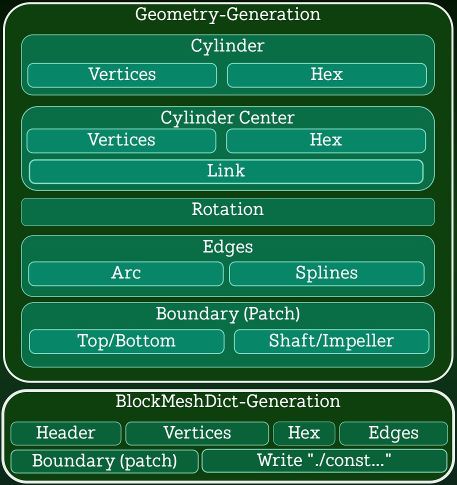
The big idea

The Concept

- Create cylinder with a variable number of separations.
- Cut the desired geometry by withdrawing section of the cylinder.
- Rotate the different level to bend the impeller.

The main difficulties

- Mesh the center of the cylinder.
- Create the arcs and the splines (in case of a rotation).



Geometry-Generation

Cylinder

Vertices | Hex

Cylinder Center

Vertices | Hex

Link

Rotation

Edges

Arc | Splines

Boundary (Patch)

Top/Bottom | Shaft/Impeller

BlockMeshDict-Generation

Header | Vertices | Hex | Edges

Boundary (patch) | Write "./const..."

Code Available:
https://github.com/Spationaute/SuperMarine

The big idea

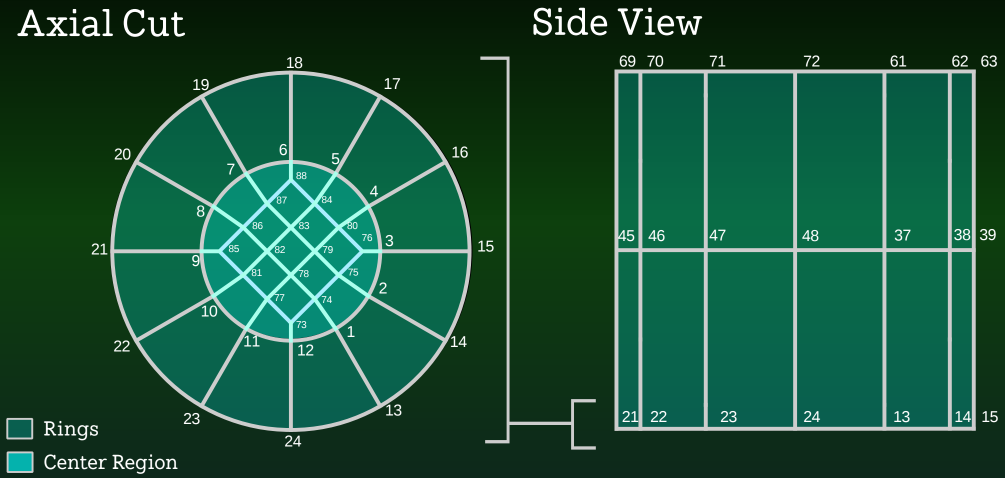


Figure: SuperMarine Schema

Regarding the script

The Good

- SuperMarine is a python scripts using wide spread library like numpy to create a blockMesh dictionary.
  - No exotic library or software
  - Simple code, easy to integrate in a work scheme
- The script generates a mixer geometry with simple shape, aiming toward a predictable meshing.
  - It is possible to compute the number of cells in a coarser or finer mesh.
  - Hexahedral Meshing.
- The code defines all the required information for the geometry, including the patch names.

The Bad

- Code still can be improved with more options.
- Good space perception is required to understand the geometry.
- Missing precision for industrial cases.

(Altered Art from DenisM79 on DeviantArt)

Regarding the script

DIVI Angular, Radial and Vertical divisions per block

RQUAD Radius of each QUADran This parameter must be a list of at least two elements, The first being the center hole/square section.

NSEC The Number of SECtors to create Must be a multiple of 4 (12,24 and 36 are useful multiple of 4!)

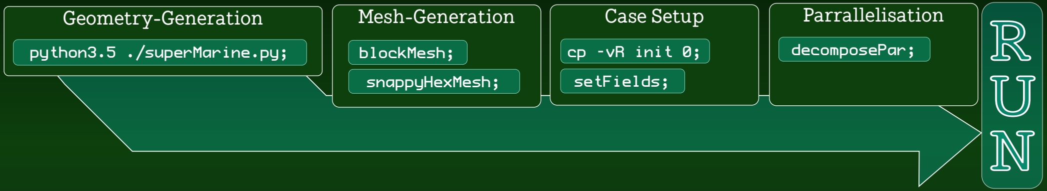
HLAY Height of each LAYers This parameter must be a list of at least one element

SHAFT Section on which the SHAFT exists This parameter must be a list which as the same number of elements of HLAY

IMPELLERCUT Where to CUT for the IMPELLER. This parameter must be a NSEC by NCAR by NHLAY 3d matrix. A 1 in a region means to cut that region for the impeller.

SQRRATIO The RATIO for the distance between the center SQuaRe region and the outer cylinder. Must be larger than 0 and smaller than 1.

Typical Case Preparation



Geometry-Generation

```
python3.5 ./superMarine.py;
```

Mesh-Generation

```
blockMesh;
snappyHexMesh;
```

Case Setup

```
cp -vR init 0;
setFields;
```

Parrallelisation

```
decomposePar;
```

superMarine is a python scripts using wide spread library like numpy to create a blockMesh dictionary. It is used before the meshing step and can be automatized to generate geometry on the fly.

Exemple: Marine Impeller

Configuration:

```
DIVI = [10, 10, 20]
RQUAD = [ 0.05, 0.1, 0.350, 0.615]
NSEC = 36
HLAY = [ 0.25, 0.60, 0.80,1.05,2.75]
SHAFT = [ 0, 1, 1, 1, 1]
LVLROT = [ 0, 0, 90, 90, 90, 90]
IMPELLERCUT =
          np.zeros((NSEC,len(RCAD),len(HLAY)))
IMPELLERCUT[::(NSEC//3),[0,1],2] = 1
IMPELLERCUT[0:NSEC,0,2] = 1
SQRRATIO = 0.62112
```

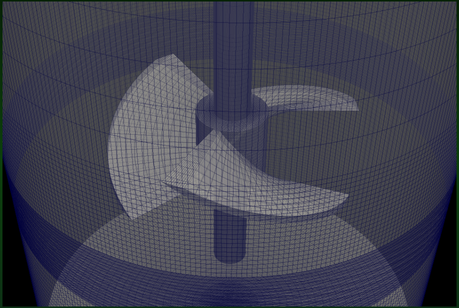


Figure: Marine Impeller Meshing

Exemple: Marine Impeller

Configuration:

```
DIVI = [5, 5, 10]
RQUAD = [ 0.05, 0.1, 0.350, 0.615]
NSEC = 72
HLAY = [ 0.25, 0.60, 0.80,1.05,2.75]
SHAFT = [ 0, 1, 1, 1, 1]
LVLROT = [ 0, 0, 70, 70, 70, 70]
IMPELLERCUT =
          np.zeros((NSEC,len(RCAD),len(HLAY)))
IMPELLERCUT[::(NSEC//8),[0,1],2] = 1
IMPELLERCUT[0:NSEC,0,2] = 1
SQRRATIO = 0.62112
```

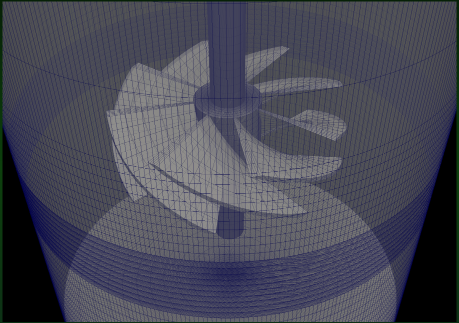


Figure: Marine Impeller Meshing 8 blades

Writing a BlockMesh Dictionary

Anatomy of a blockMesh Dictionary

1. **Header** : Information about the file, including the version number, the format and the targeted OpenFoam object.
2. **Vertices** : Contains all the points used for the geometry.
3. **Blocks** : Contains sets of vertices use by each block dividing the geometry.
4. **Edges** : Contains information about arcs/splines or other special cases.
5. **Boundary** : Contains sets of vertices which define the faces of a geometry and their type.

Writing a BlockMesh Dictionary: Vertices

blockMeshDict

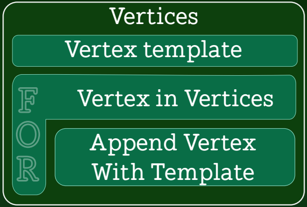
```
convertToMeter = 1;
vertices
(
  (0.0500000000 0.0000000000 0.0000000000)
  (0.0433012702 -0.0250000000 0.0000000000)
  (0.0250000000 -0.0433012702 0.0000000000)
  ...
);
```

superMarine.py

```
vtemp="({:20.10f} {:20.10f} {:20.10f})"
blockMesh+=["","vertices","("]
for v in vertex:
  blockMesh.append(vtemp.format(*v))
blockMesh+=[");"]
```

Writing the blockMeshDict

[Lines 352-443]


Vertices

Vertex template

FOR

Vertex in Vertices

Append Vertex With Template

Each subsequent section of the dictionary is built the same way.

Drawing a Cylinder

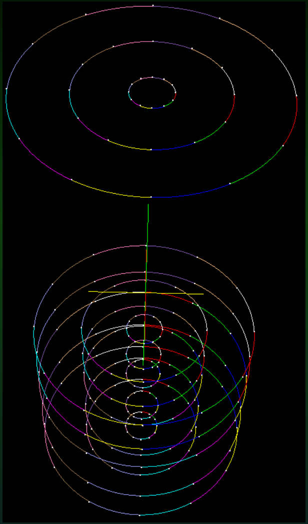
Cylinder Vertices Definition [Lines 92-109]

1. The vertex are created by applying a rotation matrix to the unit vector.

$$\text{rotz}(A, \theta) = A \cdot \begin{bmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

[Def. at lines 58-62]

2. The set is then appended by its product with each radius set by the user.
3. Then, the set is appended by its addition with each level defined by the user.

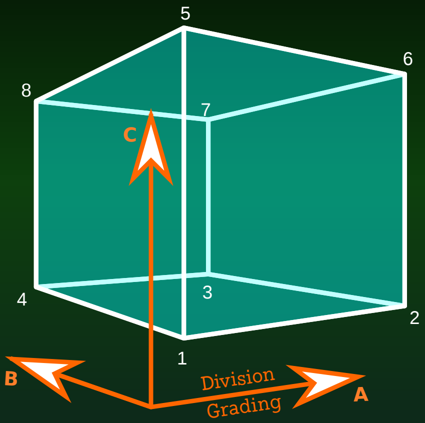


Writing a BlockMesh Dictionary: Hex

The Hex vertex must be defined in a specific order to be valid. First, the bottom, with the vertices following the **right-hand rules**. Then the top, with the same order.

blockMeshDict

```
blocks
(
  hex ( 0 1 13 12 48 49 61 60 )
     ( 10 10 20 ) simpleGrading ( 1 1 1 )
  hex ( 1 2 14 13 49 50 62 61 )
     ( 10 10 20 ) simpleGrading ( 1 1 1 )
  hex ( 2 3 15 14 50 51 63 62 )
     ( 10 10 20 ) simpleGrading ( 1 1 1 )
  ...
);
```



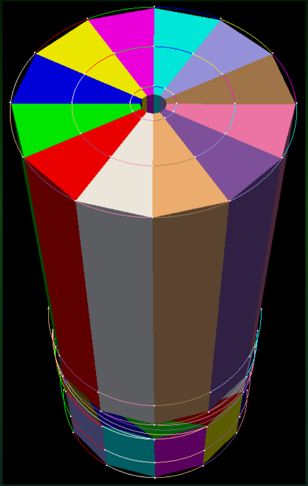
Building blocks

Cylinder Hex Definition `[Lines 114-134]`

1. The Hex can be formed by selecting the vertex in the right order, using a template.

```
[ 0, 1, 1+NSEC, NSEC, NSEC*nCad, 1+NSEC*nCad,
1+NSEC+nCad*NSEC, NSEC+nCad*NSEC ]
```

2. The template is applied for each quadrant in each sector and at each level, with the exception of selected cells that will compose the impeller.
3. The last Hex must use the first vertex instead of the next set, adding an exception in the script.



Filling the Hole

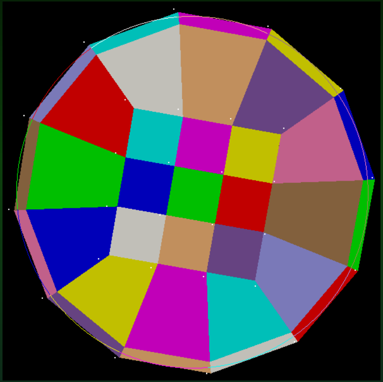
Center Vertices Definition [Lines 137-151]

1. For each level:
    1. Four equidistant points are chosen for the inner circle vertices.
    2. Between those points, an interpolation is used to generate a grid based on inner vertices.

$$ratio * (p_0 + X * \frac{p_1 - p_0}{NSEC//4}) \quad \forall X \in [0..NSEC//4]$$

Center Hex Definition [Lines 159-190]

1. For each level, the hex is set using a template on the grid.
2. For each level, a template is applied to join the inner cylinder with the hex of the grid.

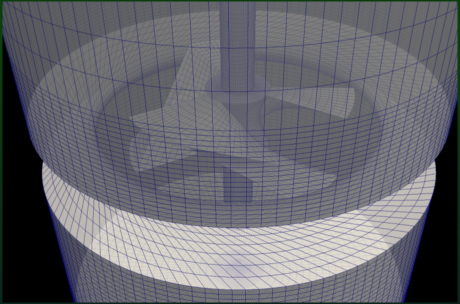


Explaining Splines

Why the addition of Arcs and Splines are necessary in SuperMarine

1. When the boundary of the cylinder is turned using straight line will result in a distorted geometry. The line must follow the cylinder edge.

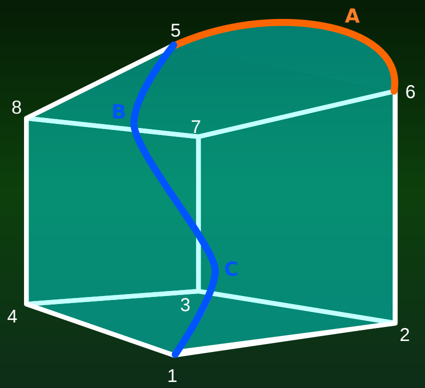
2. The outer edge of the bottom and the top of each cylinder hex must be curved to follow the edge of the vat.



Writing a BlockMesh Dictionary: Edges

blockMeshDict

```
edges
(
  arc 271 272
   ( 0.24748737341529 0.24748737341529176 2.75 )
  arc 272 273
   ( 0.338074039201173 0.09058666578588254 2.75 )
  arc 273 274
   ( 0.33807403920117 -0.09058666578588195 2.75 )
  spline 108 156 (
    ( 0.0996917334 -0.0078459096 0.6100000000)
    ( 0.0987688341 -0.0156434465 0.6200000000)
    ...
    ( 0.0156434465 -0.0987688341 0.7800000000)
    ( 0.0078459096 -0.0996917334 0.7900000000)
  )
  ...
);
```



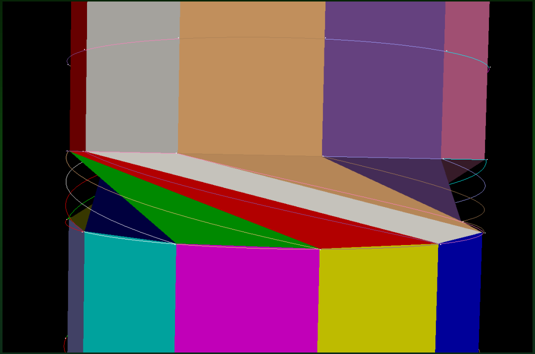
Following the curves

Arcs Definition[Lines 202-217]

1. An arc is created for each pair of vertices on the outer of the cylinder.
2. The last point must join with the first, adding an exception to the script.

Splines Definition[Lines 222-240]

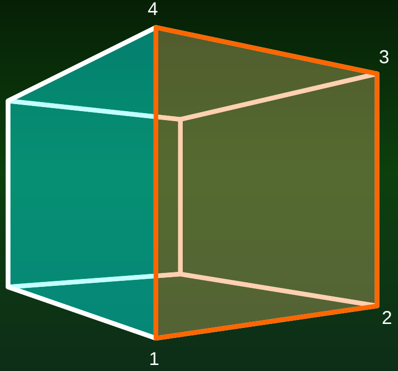
1. For each quadrant in each sector and at each level, a spline is created IF the vertices aren’t axially aligned.
2. The spline is generated with a linear interpolation of the two vertex for the Axial position, and the edge of the cylinder for the other axis.



Writing a BlockMesh Dictionary: Patches

blockMeshDict

```
boundary
(
walls
{
  type wall;
  faces
  (
    (36 37 85 84)
    (37 38 86 85)
    (38 39 87 86)
    ...
  );
}
...;
);
```



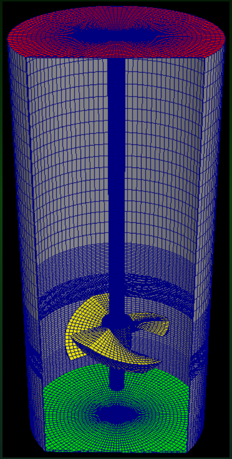
Stitching Patches

Patch Definition[Lines 244-348]

1. A set of template is applied on each sector in each level to create the wall patch.
2. For the impeller and the shaft, another set of template is applied on each filtered cells.
3. The same is done for the bottom and the top of the impeller, and the cylinder.

Note: Fitting two intersecting face

It's possible to join two hex at another point than a sheared vertex. This is rather difficult for an automatized geometry since the generated meshing cells must match.



Conclusion

1. Python give powerful tool to conceive complex blockMesh dictionary
2. superMarine give the base for generating your own mixer geometry
3. The code is fully independent and can be used with all the OpenFoam toolkits

Foam Breaker

1. Use modified superMarine script to generate numerous Conic Foambreaker.
2. Used in conjunction with a refinement zone.

(Not Yet Published)

Electrolitical Cells

1. Use the script to generate a single pillar.

Askari E., Proulx P., Passalacqua A., *Modeling of Bubbly Flow Using CFD-PBM Solver in OpenFOAM: Study of Local Population Balance Models and Extended Quadrature Method of Moments Applications*, Chemengineering, MDPI, 8 Jan 2018.