設計/開発プロセスへのOpenFOAM展開
～CADモデルからの計算フロー構築の試み

2010.8.21　第3回勉強会

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1．やりたいこと(環境構築)

・現状：商用ソフト，Star-CD,-CCM+ による設計,開発支援

⇒ 商用であるがための制約(ライセンス数・形態、機能、ベンダポリシー ・・・)

⇒ やるべきことがやるべき時にできない

開発プロセスがソフト(ベンダ)に依存する

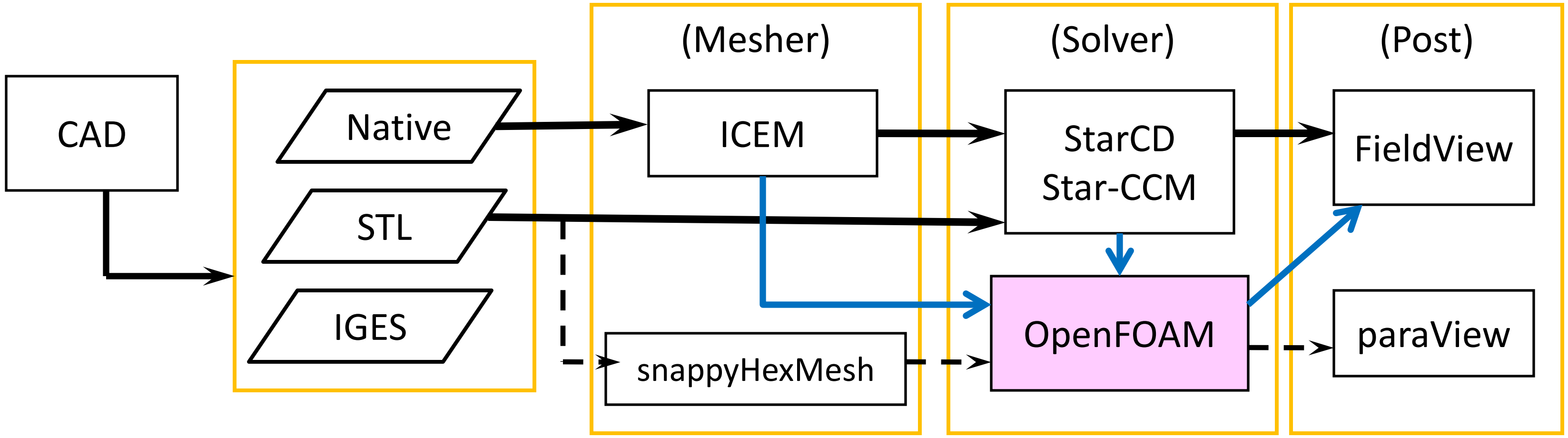
・設計/開発プロセスへのOpenFOAM展開

⇒ だれでも・いつでもCFD(CAE)にアクセスできる環境

やるべきことがやるべき時にできる環境

・CADデータ活用

・格子生成/ポスト処理は汎用Mesher活用？



２．やりたいこと（対象と課題）

評価項目：

・圧力損失，風量配分，温度分布

要検討項目：

・複雑形状（CADﾃﾞｰﾀ活用）

・熱交換器：Porous,

熱エネルギソース付与方法

３．やったこと

■OpenFOAMのDown Load，Install (2009.11 ~)

DEXCS, OpenFOAM 1.6

■Tutorial : icoFoam，simpleFoam，・・・・

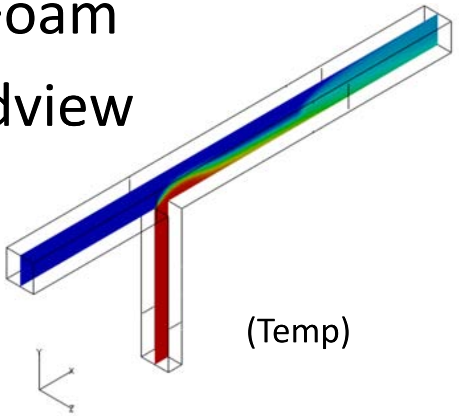
■**Trial on Practical Configurations**

・ STL -> snappyHexMesh -> simpleFoam -> paraView

・ ICEM -> proStar -> (starToFOAM) -> simpleFoam -> (foamToFieldview9) -> Fieldview

■**Temperature Calculation**

・ proStar -> (starToFOAM) -> buoyantBoussinesqFoam -> (foamToFieldview9) -> Fieldview



(Temp)

4. 本日の紹介内容

事例1：CADデータから格子生成し、FOAMで計算し評価するには

どうすればよいか？

・CAD⇒STL⇒blockMesh⇒snappyHexMesh⇒FOAM⇒Fieldview

・CAD⇒(Star-CD)⇒ICEM⇒FOAM⇒Fieldview

・結果のStar-CDとの比較

・困りごと

事例2：温度の計算はどうすればできるか？

・ buoyantBoussinesqSimpleFoam

・困りごと

事例3：Porousを含む流れ場の計算はどうすればできるか？

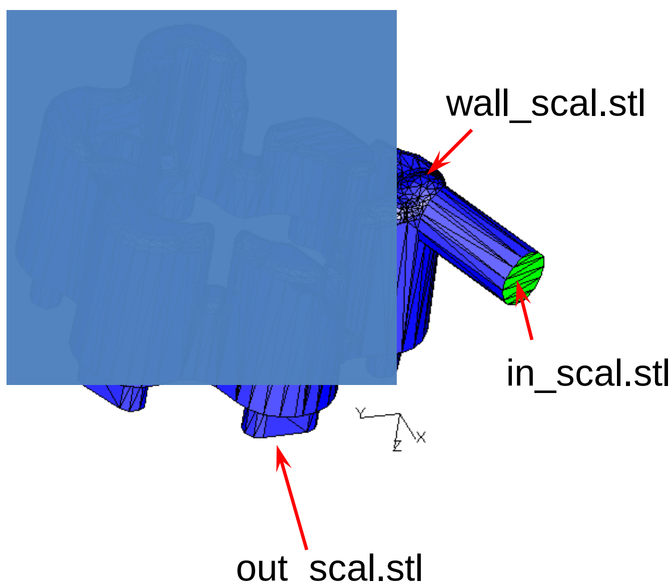
・ rhoPorousSimpleFoam

・困りごと

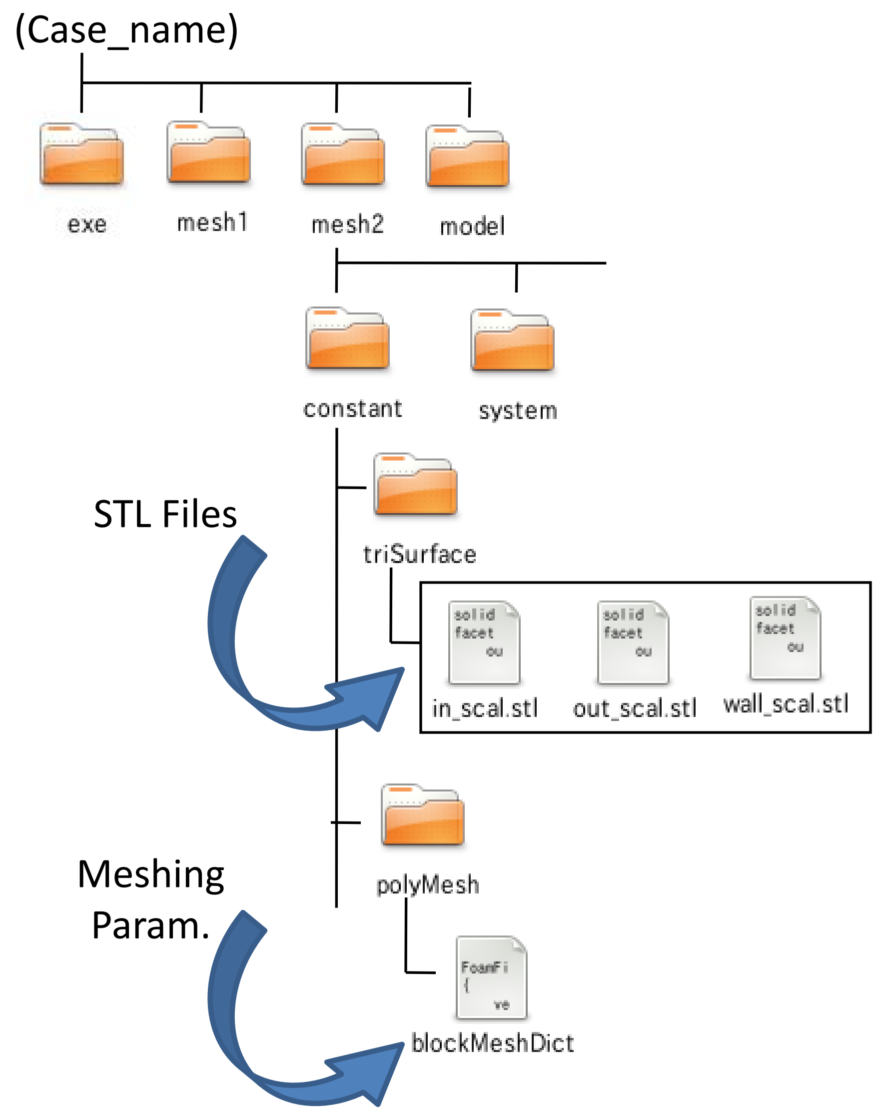
事例1: (1)CAD⇒STL⇒blockMesh ⇒ snappyHexMesh

- DEXCS利用

CAD⇒(Prostar)⇒STL
・境界条件付与面毎に別Data(File)として作成

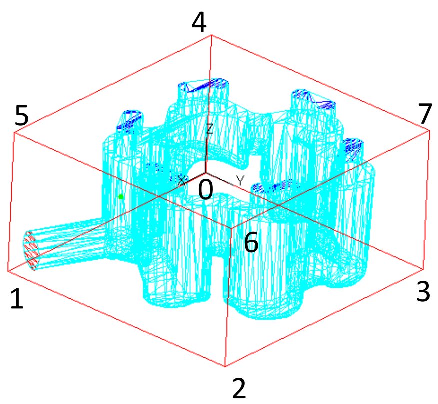


(Model detail masked. Sorry!)



事例1: (1)CAD⇒STL⇒blockMesh ⇒ snappyHexMesh

blockMeshDict



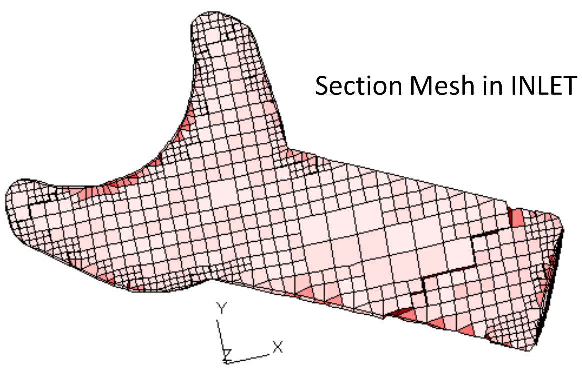

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    object      blockMeshDict;
}

convertToMeters 1;

vertices
(
     ( -0.050    -0.057          -0.044 ) // 0
     (  0.057    -0.057          -0.044 ) // 1
     (  0.057     0.046          -0.044 ) // 2
     ( -0.050     0.046          -0.044 ) // 3
     ( -0.050    -0.057           0.011 ) // 4
     (  0.057    -0.057           0.011 ) // 5
     (  0.057     0.046           0.011 ) // 6
     ( -0.050     0.046           0.011 ) // 7
);

blocks
(
    hex (0 1  2  3  4  5  6  7 ) (20 20 10) simpleGrading (1 1 1)
);

edges ();
patches ();
mergePatchPairs ();
```

⇒ blockMesh, snappyHexMesh

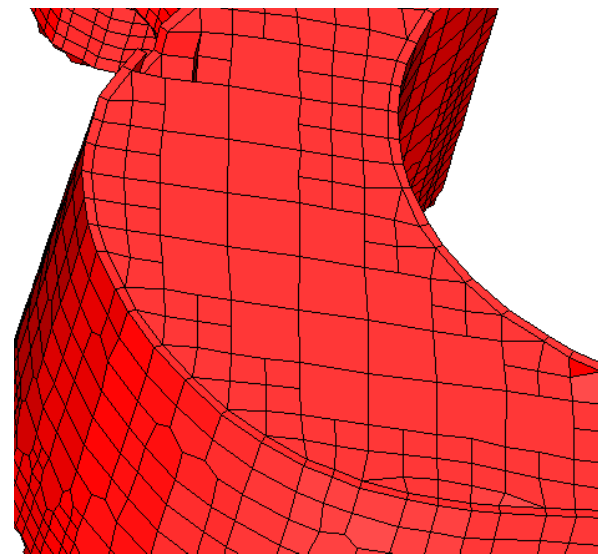
事例1: (1)CAD⇒STL⇒blockMesh ⇒ snappyHexMesh

Mesh by snappyHexMesh

(Partial Zoomed Mesh)

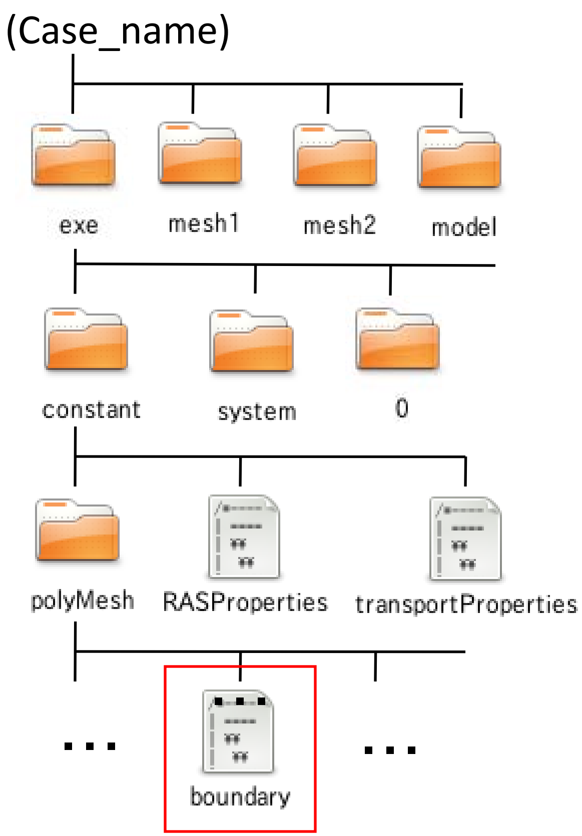


Section Mesh in INLET Pipe



事例1: (1)CAD⇒STL⇒blockMesh ⇒ snappyHexMesh

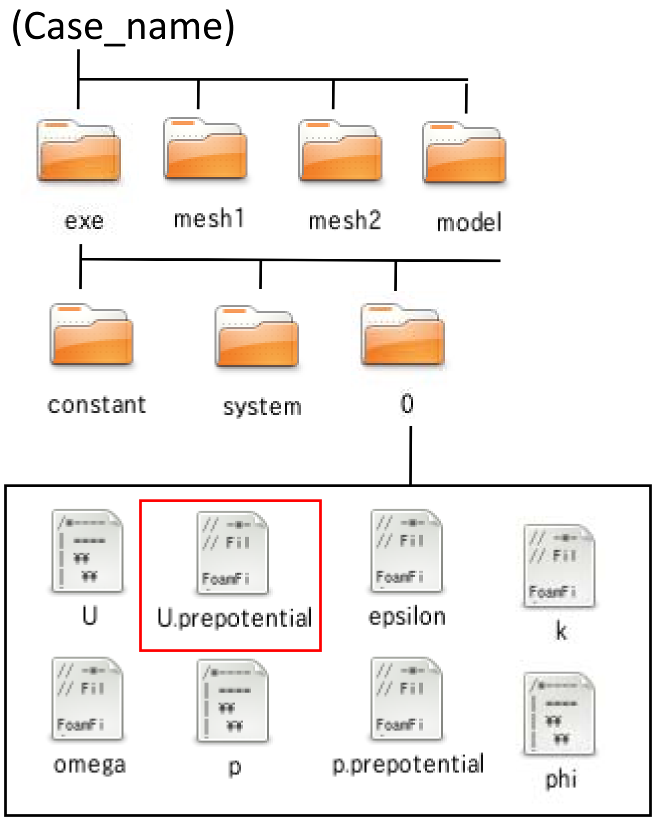
Boundary - Position




```
defaultFaces
  {
     type          empty;
     nFaces           0;
     startFace     364536;
  }
  out_scal_ascii
  {
     type          patch;
     nFaces        1553;
     startFace     364536;
  }
  in_scal_ascii
  {
     type          patch;
     nFaces        245;
     startFace     366089;
  }
  wall_scal_ascii
  {
     type          wall;
     nFaces        34901;
     startFace     366334;
  }
```

事例1: (1)CAD⇒STL⇒blockMesh ⇒ snappyHexMesh

Boundary - Value



(U.prepotential)

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

internalField uniform (0 0 0);

boundaryField
{
  in_scal_ascii
  {
    type fixedValue;
    value uniform ( -0.910  0.4147  0.0 );
  }
  defaultFaces
  {
    type empty;
  }
  out_scal_ascii
  {
    type zeroGradient;
  }
  wall_scal_ascii
  {
    type fixedValue;
    value uniform ( 0. 0. 0. ) ;
  }
}
```

事例1: (2)Calculation Results - simpleFoam

On Fieldview (data conversion : foamToFieldview9)

Surf. Press.

Data are not shown . Sorry!!

Sect. Velocity Vect.

Data are not shown . Sorry!!

事例1: (2) Calculation Results - Comparison with Star-CD Results

- Mesh by snappyhexMesh
- Foam to Star Mesh Data Conversion : foamToStarMesh (only to Star V4)

Surf. Press.

simpleFoam (non-dimensional Press)

Star-CD (Pa at dens=1.205kg/m3, MARS*)

Star-CD (Pa at dens=1.205kg/m3, UD)

Data are not shown . Sorry!!

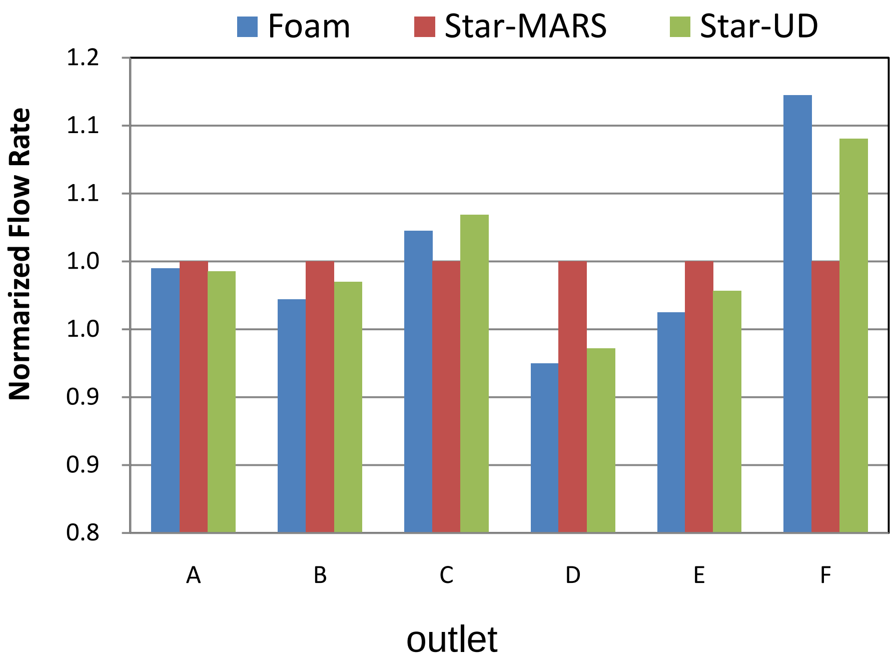
•: Monotone Advection and Reconstruction Scheme,
gradient-based second order accurate differencing scheme

事例1: (2) Calculation Results - Comparison with Star-CD Results

Flow Rate per Outlet

The model have 1-inlet and 6-outlets.

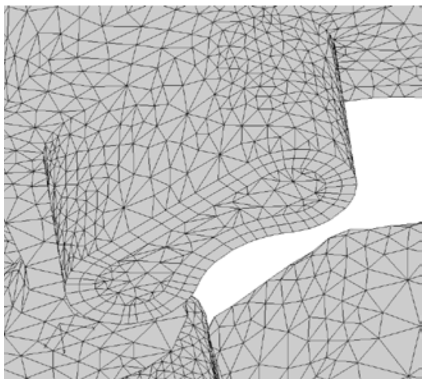
The detail of the model are not shown. Sorry!!

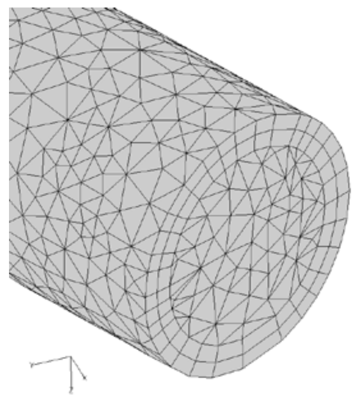


事例1: (3) CAD⇒ICEM⇒FOAM

ICEM Mesh : Tetra w/ Layer

(Partial Zoomed Mesh)

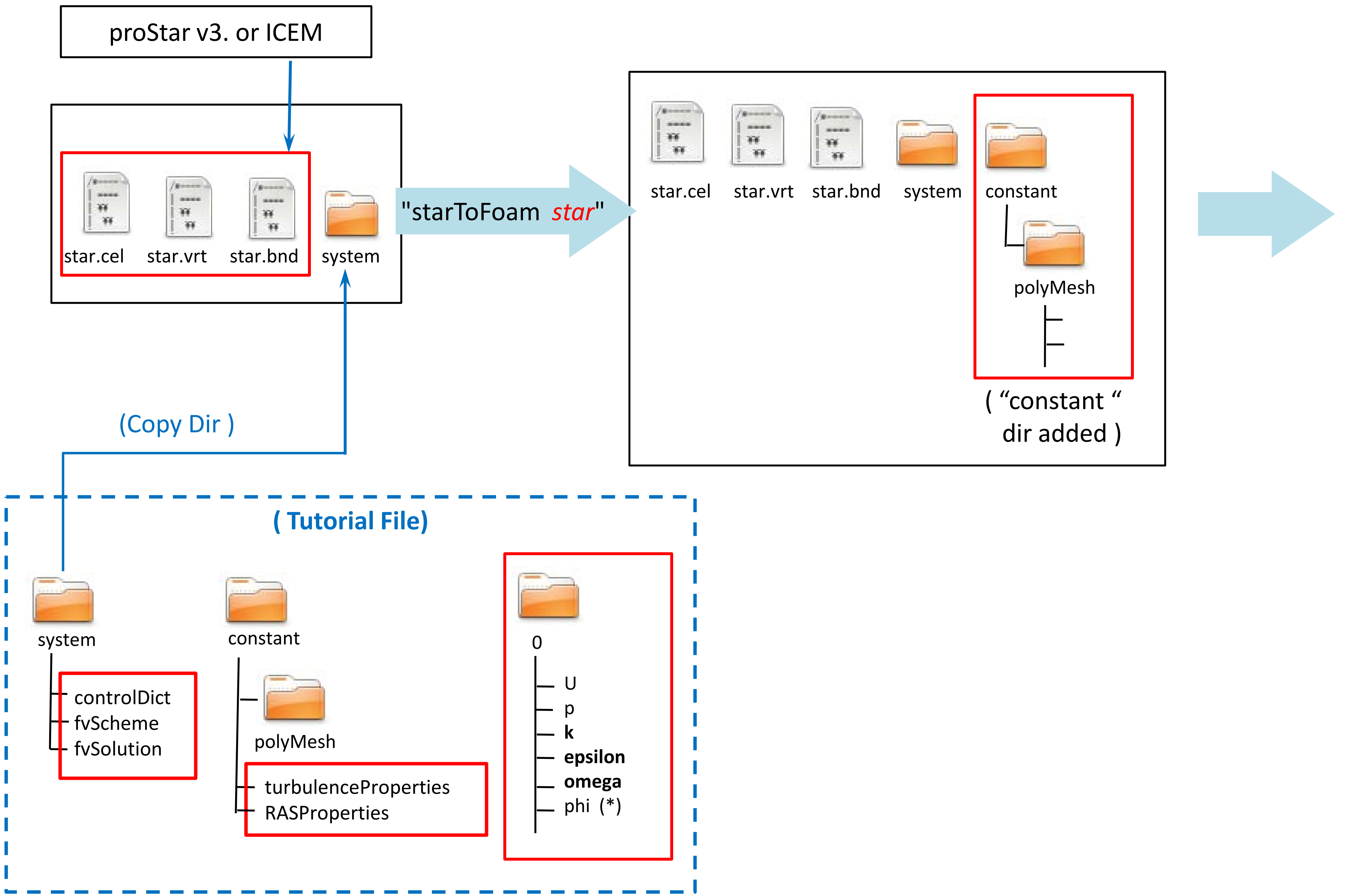




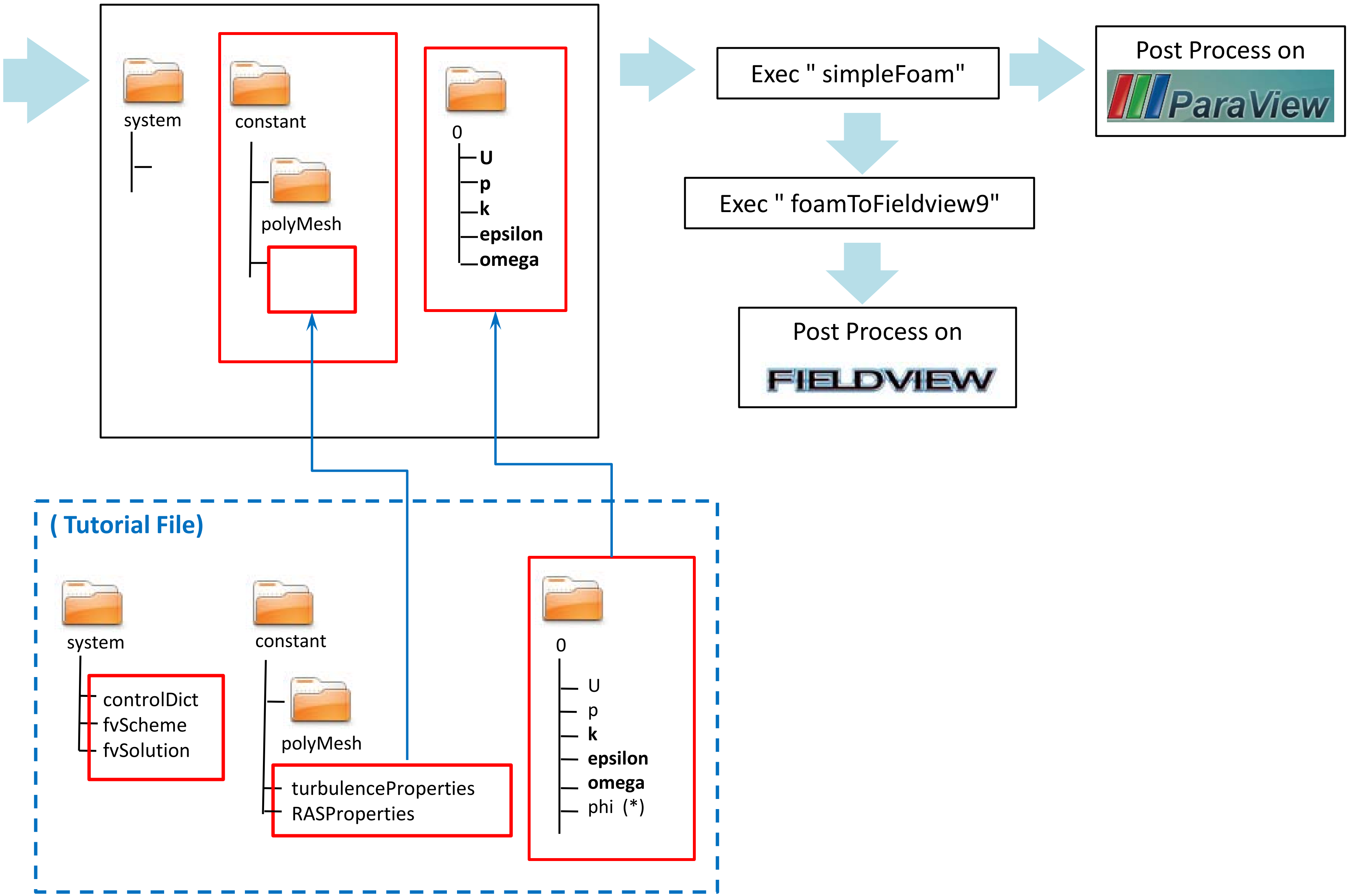
Prostar (V3)で読込み
・Boundary 設定
・star形式で吐出し
（.cel,.vrt,.bnd (.cpl))

Data Conversion
：starToFoam (file_root)

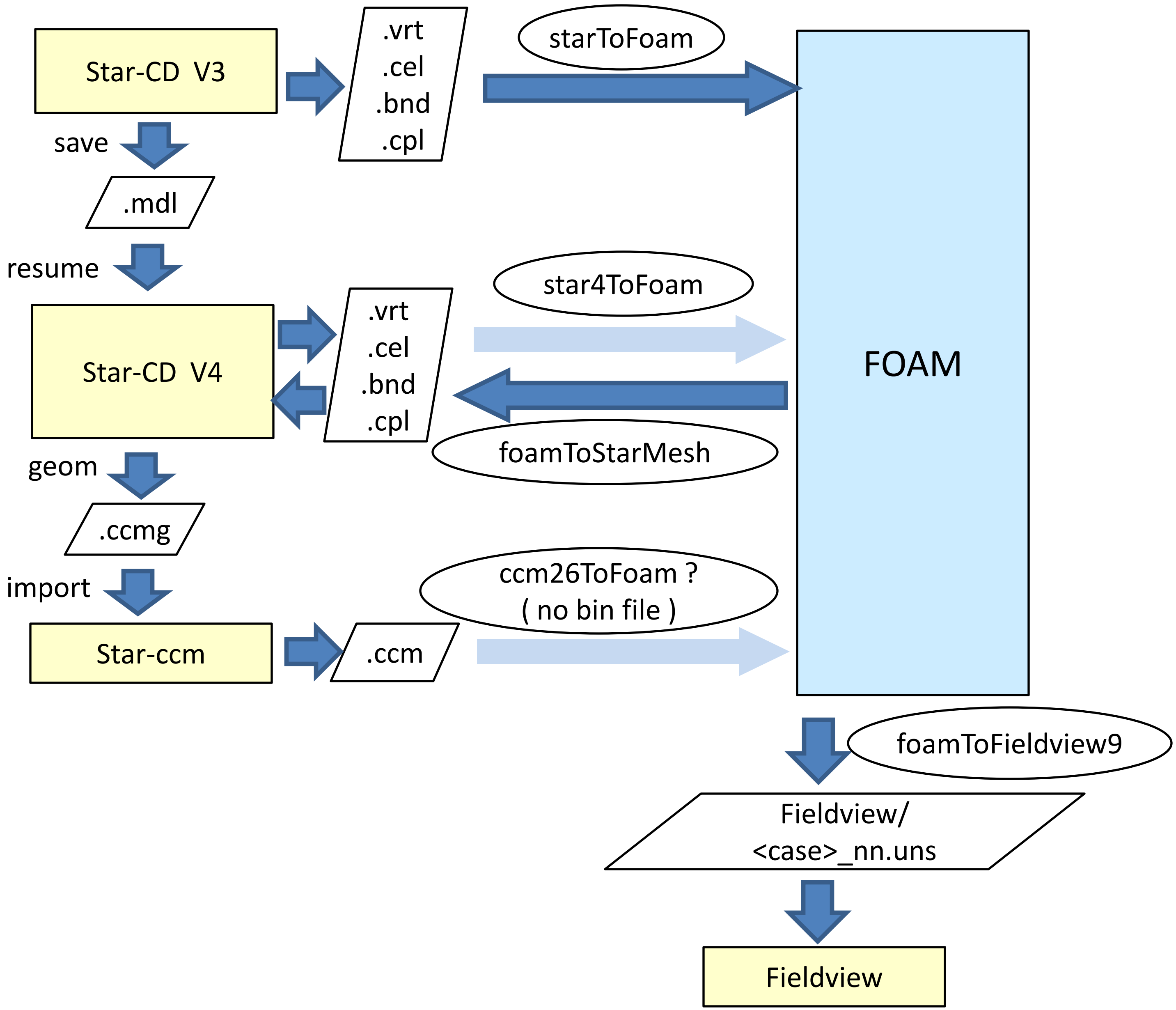
事例1: (3) CAD⇒ICEM⇒FOAM ⇒Fieldview　Diagram (1)



事例1: (3) CAD⇒ICEM⇒FOAM ⇒Fieldview　Diagram (2)

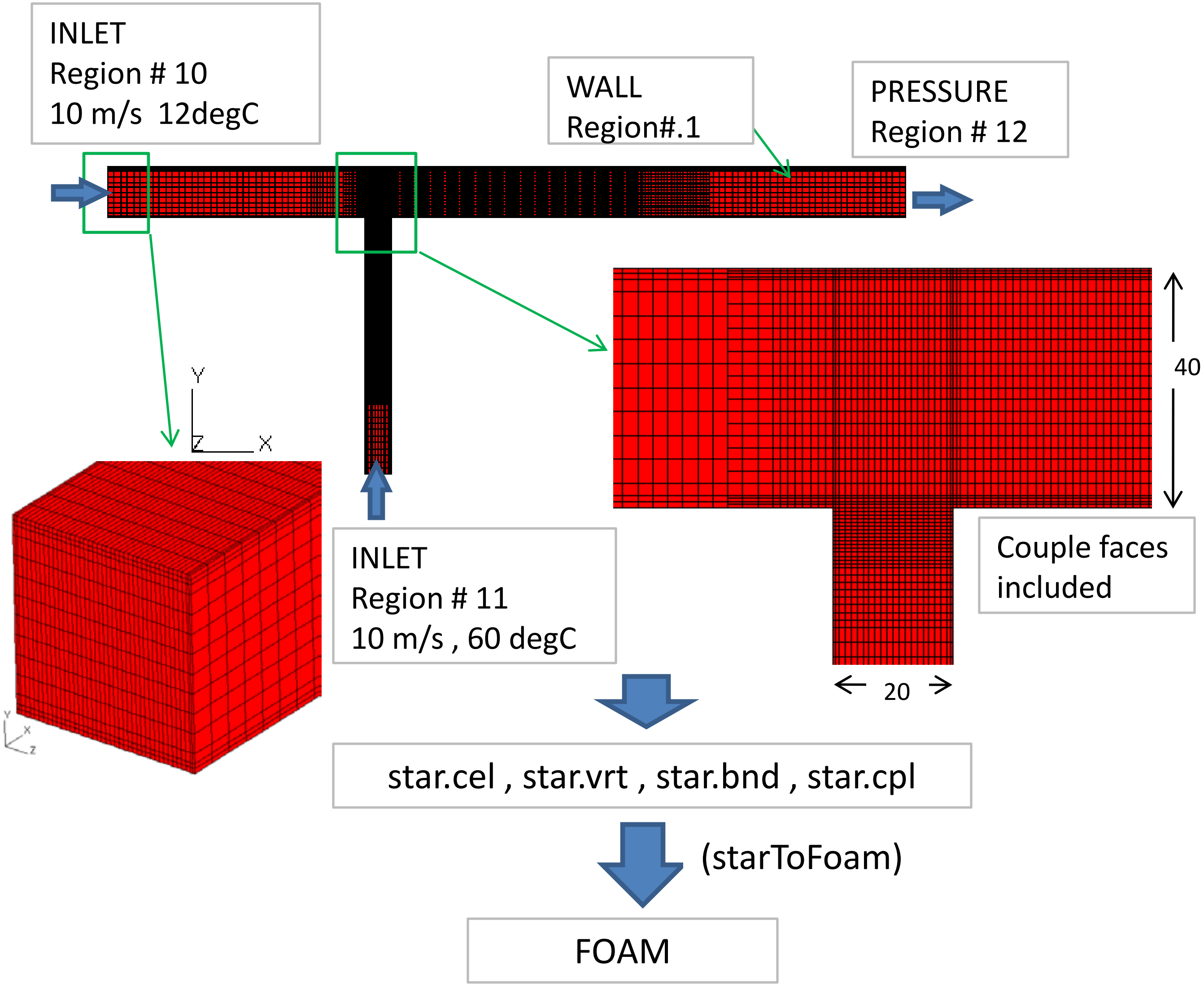


事例1: (まとめ) Star to Foam Mesh data conversion



事例2：Thermal (buoyantBoussinesqSimpleFoam)

Mesh and Boundary*　(Mesh generation on prostar V3)



*:浅野（Denso）ら，自動車用HVACにおける高・低温空気流の乱流混合に関する研究　(T字形合流管における熱流動特性)，機論Ｂ， 71-715 （2005-12)

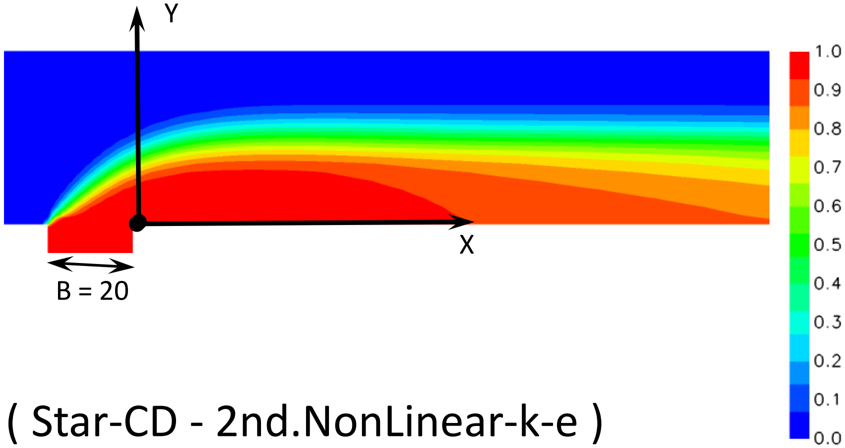
事例2：Thermal (buoyantBoussinesqSimpleFoam)

Relative Temp. Contour at Z = 0

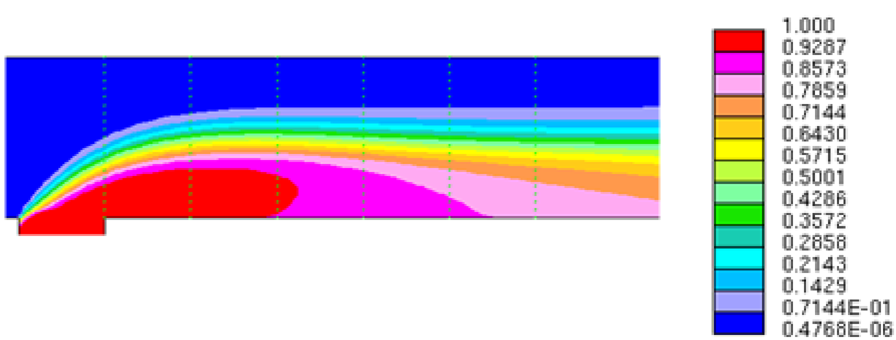
Relative Velo Contour at Z = 0

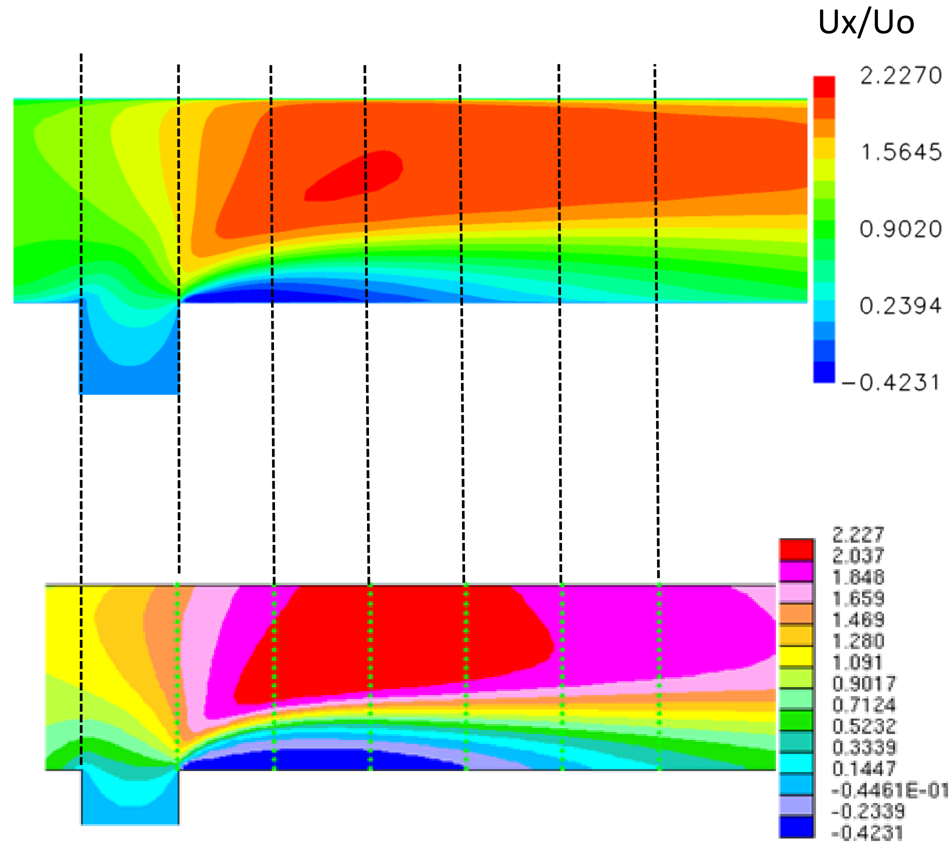
(FOAM - std.k-e)

(T-Tc)/(Th-Tc)



(Star-CD - 2nd.NonLinear-k-e)

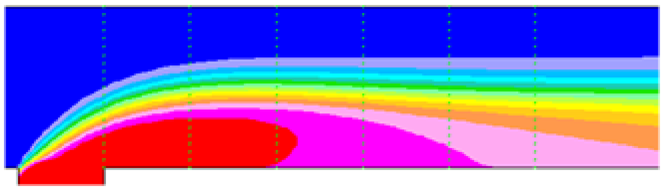




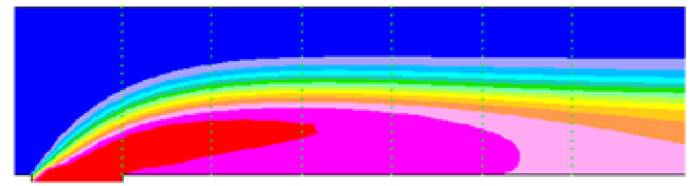
- 温度計算を行え、同一乱流モデルによればStar同等結果が得られたが、安定性悪い。
- 乱流モデル評価／選定

事例2：Thermal (buoyantBoussinesqSimpleFoam)

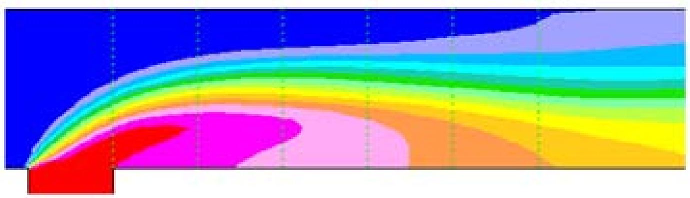
【参考】 Star-CD Results per Turb.Model (Relative Temp. Contour at Z = 0)



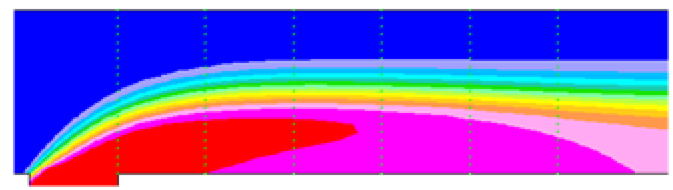
(std.−ke)



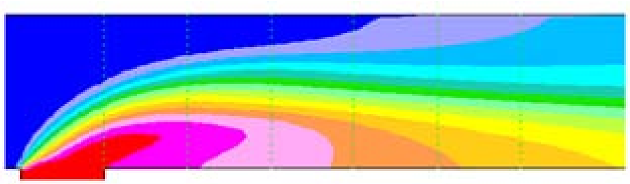
(kω−SST)



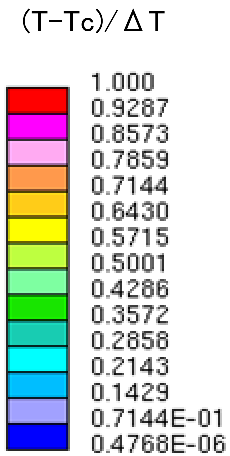
(NonLinear−ke−Quad)



(V2F)



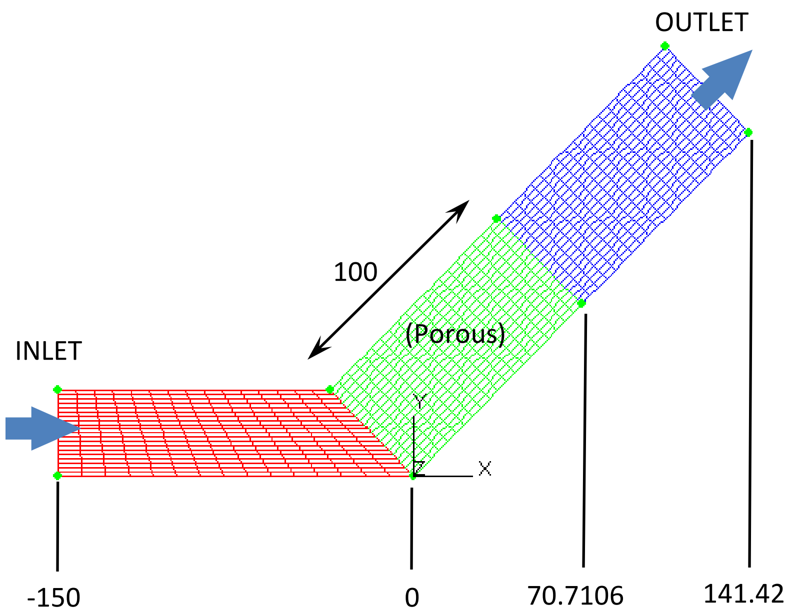
(NonLinear−ke−Cubic)

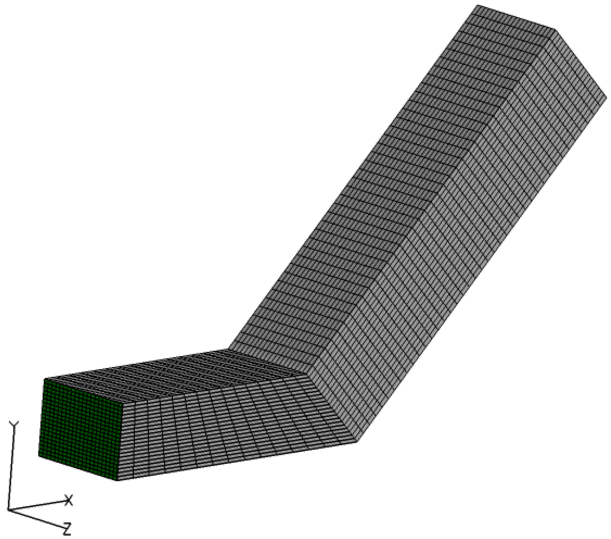


事例3：Porous (rhoPorousSimpleFoam -1.5.x　)

../tutorials/rhoPorousSimpleFoam/angleDuctImplicit

Mesh





事例3：Porous (rhoPorousSimpleFoam -1.5.x　)

Properties

	FOAM*	Star-CD
	Compressible	InCompressible
Fluid	Air	Air
分子量	28.9	28.96
比熱	1007	1006
融解熱	0	
粘性係数	Sutherland, **1.4792e-06，116**	1.81E-05
密度	Perfect Gas	1.205
TurbModel	std.k-e	Quad.k-e

B/C

		FOAM	Star-CD
INLET	Velocity	10 m/s	10 m/s
	Temp	293 K	--------
	MixLength	0.001	0.001
	Intensity	0.1	0.1
Wall		Non-Slip	Non-Slip
OUTLET	Pressure	1.0E5 Pa	0

Scheme

	FOAM	Star-CD
Momentum	Gauss Upwind	MARS
k,e	Gauss Upwind	UD

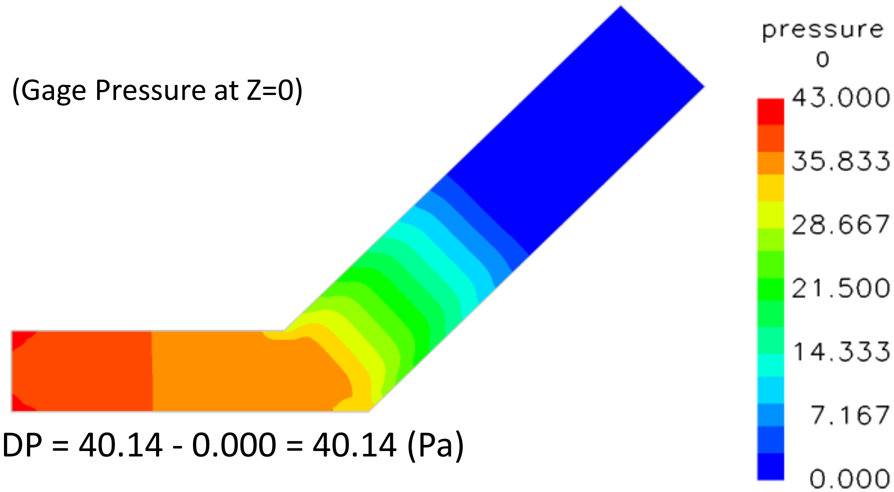
Porous

FOAM	Star-CD
DP=150 Pa at 15 m/s , L = 100 mm	
Darcy,	dP=aU^2+bU (Pa/m)
d = 0 , f = 11.07	a = 6.6667 , b = 0

事例3 : Porous (rhoPorousSimpleFoam -1.5.x)

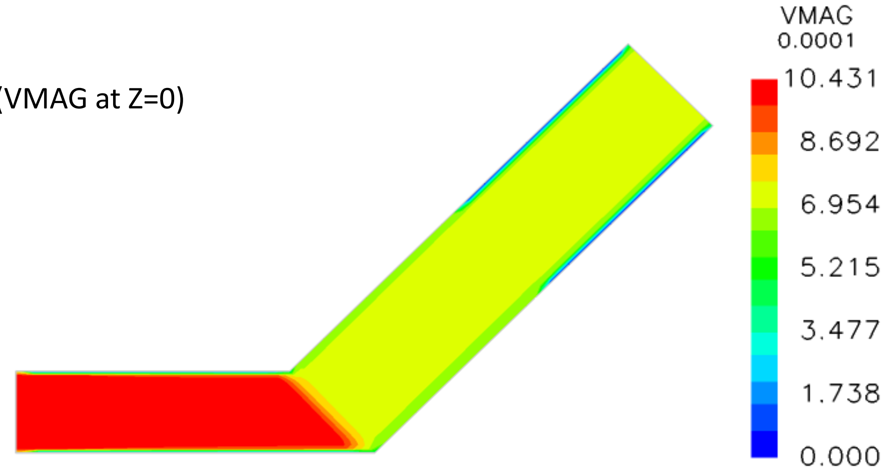
FOAM (rhoPorousSimpleFOAM)

(Gage Pressure at Z=0)



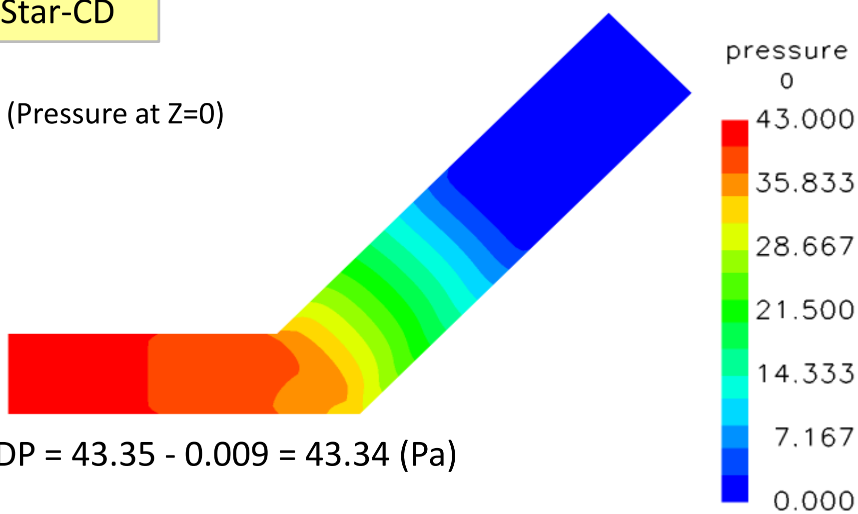
DP = 40.14 - 0.000 = 40.14 (Pa)

(VMAG at Z=0)



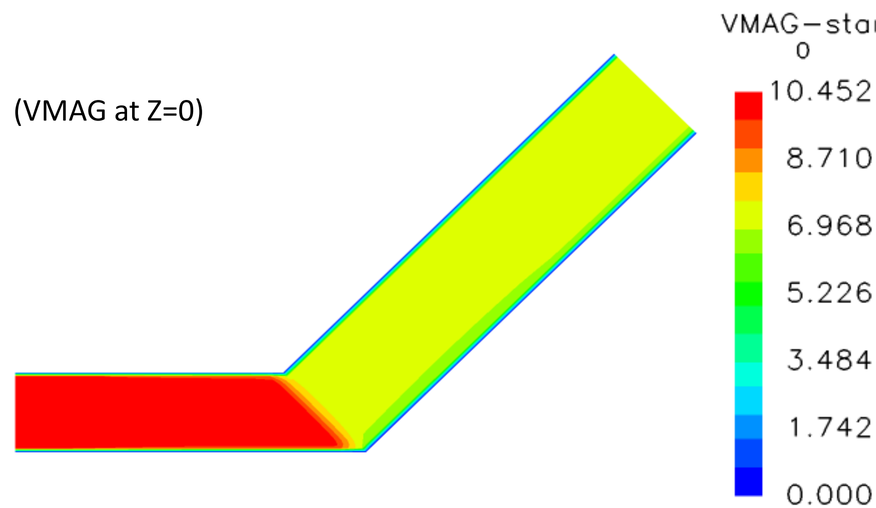
Star-CD

(Pressure at Z=0)



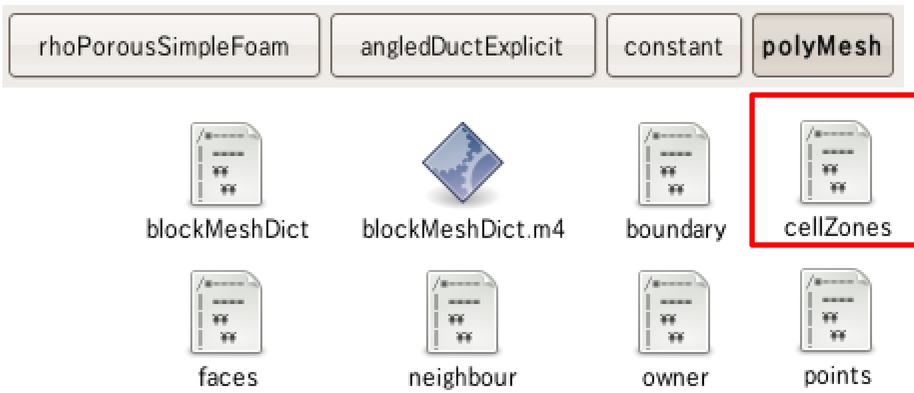
DP = 43.35 - 0.009 = 43.34 (Pa)

(VMAG at Z=0)

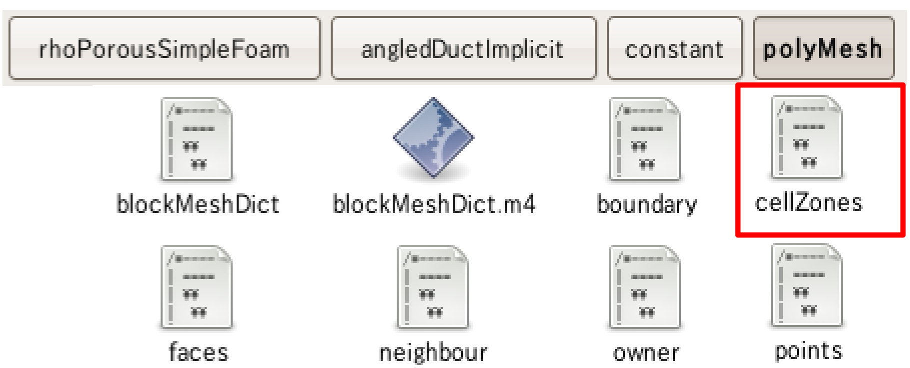


事例3：Porous (rhoPorousSimpleFoam -1.5.x　)

- Porousを含む内部流計算を行え、Star同等結果が得られたが、圧縮性ソルバのため設定煩雑。
  非圧縮ソルバはないか？（-1.7の/incompressible/porousSimpleFoam/angledDuctExplicit？）
- Porous部位指定方法？cellZone？



ascii



binary

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       regIOobject;
    location    "constant/polyMesh";
    object      cellZones;
}
// * * * * * * * * * * * * * * * * * * *

3
(
inlet
{
    type cellZone;
cellLabels      List<label>
6000
(
0
1
2
3

porosity
{
    type cellZone;
cellLabels      List<label>
8000
(
6000
6001
6002
6003

outlet
{
    type cellZone;
cellLabels      List<label>
8000
(
14000
14001
14002
```

- Heat-Source(Sink)の指定方法？

できるようになったこと/これからやっていくこと

- **CAD データを使用し、simpleFoam で単相流シミュレーションはできる目途が立った。**

    ⇒ より信頼性,将来性のあるMesh/Boundary data Converter の確保
- **単相流で温度計算を行う 目途も立った。**

    ⇒ 乱流モデル評価と確定
- **Porousを含む流れシミュレーションのTutorialとその大まかな流れはわかった。**

    ⇒ Porous位置指定方法の掌握

    外部Mesher作成Mesh data からの位置指定方法確保

    熱エネルギーSource/Sink との組み合わせ方法

そのほか,

Solid-Fluid 共役熱移動シミュレーション

回転場（MRF/Sliding），自由表面/2相流 ，FSI ・・・

GUI