Auxiliary Processing – swak4Foam and PyFoam

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Introduction (1/4)

swak4Foam

- **SW**iss **A**rmy **K**nife **for F**oam.
- It’s primary feature is the power of mathematical expressions, no C++ required, e.g.:
  - 10*(1+0.5*sin(500*time()))
  - 15*pow(x,2)+20*pow(y,2)
- Pre-processing utilities
- Boundary conditions
- Function Objects (co-processing)
- openfoamwiki.net/index.php/Contrib/swak4Foam

Introduction (2/4)

Why was **swak4Foam** created:

- OpenFOAM is a CFD toolbox
- It’s coded in C++
- Whenever a feature is missing, it’s expected the user to code it in C++

swak4Foam aims to bypass the requirement to code in C++, by empowering the user with capabilities that don’t exist yet in OpenFOAM, without the need to rely on coding in C++.

Introduction (3/4)

PyFoam

- Helps unleash the power of Python, applied to controlling and manipulating OpenFOAM cases
- Features:
  - Case running utilities
  - Utilities for log files
  - Networking utilities
  - Utilities for manipulating case data
  - Scripted manipulation of dictionaries
  - ParaView related utilities (requires Python in ParaView)
  - GUI-Tools (e.g. **pyFoamDisplayBlockMesh**)

- openfoamwiki.net/index.php/Contrib/PyFoam

Introduction (4/4)

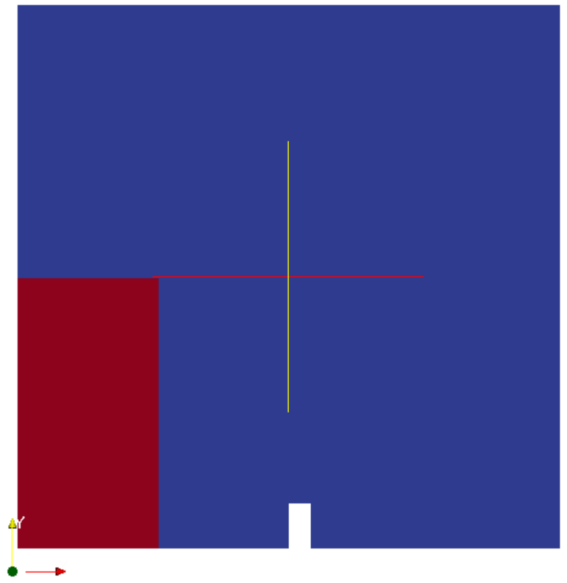
Why was **PyFoam** created:

- OpenFOAM relies on:
  - conventional shell scripting (usually **bash**) for handling cases;
  - the user to either post-process results manually or with one's own scripts.
- PyFoam aims to provide:
  - a common library infrastructure, built on top of Python, for manipulating and processing cases;
  - a common scripting toolkit for managing the cases.

funkySetFields (1/11)

Original tutorial case:

- “multiphase/interFoam/ras/damBreak”
- Static column of water
- Width of column: 0.1461 m
- Height of column: 0.292 m
- Non-moving obstacle at
  X= 0.292 m, width= 0.024 m
- Domain size:
  - width=0.584 m
  - height= 0.584 m



funkySetFields (2/11)

Our example case:

- Case folder: “funkySetFieldsDamBreak”
- Objective is to define the initial internal field:
  - 2D circle of water of 0.05m
  - Centred at x=0.14, y=0.2m
  - Added pressure +100*y (in Pascal)
  - Traveling upward at 1.5 m/s

funkySetFields (3/11)

Dictionary file: “system/funkySetFieldsDict”

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    location    "system";
    object      funkySetFieldsDict;
}

expressions
(
//…
);
```

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funkySetFields (4/11)

Basic parameters for each *expression*:

- ***field*** – to specify the name of the field to change.
- ***expression*** – to specify the expression to use for the new field values.
- ***condition*** – to define where the expression is applicable.
- ***keepPatches*** – define *true* or *false*, where *false* will discard the existing boundary conditions.

funkySetFields (5/11)

Expressions to initialize phase and velocity:

```
initFieldAlpha
{
  field alpha.water;
  expression "0";
  keepPatches true;
}

initFieldU
{
  field U;
  expression "vector(0.0,0.0,0.0)";
  keepPatches true;
}
```

funkySetFields (6/11)

Expression to initialize “pressure - rho*g*h”:

```
pressureAir
{
  field p_rgh;
  expression "0";
  keepPatches true;
}
```

funkySetFields (7/11)

Expression to initialize the phase for the water circle:

```
floatingCircle
{
  field alpha.water;
  expression "1";
  condition
    "sqrt(pow((pos().x-0.14),2)+pow((pos().y-0.2),2))<0.05";
  keepPatches true;
}
```

funkySetFields (8/11)

Expression to initialize the added pressure for the water circle:

```
pressureCircle
{
  field p_rgh;
  expression "100.0*pos().y";
  condition
    "sqrt(pow((pos().x-0.14),2)+pow((pos().y-0.2),2))<0.05";
  keepPatches true;
}
```

funkySetFields (9/11)

Expression to initialize the initial velocity for the water circle:

```
risingCircle
{
  field U;
  expression "vector(0.0,1.5,0.0)";
  condition
    "sqrt(pow((pos().x-0.14),2)+pow((pos().y-0.2),2))<0.05";
  keepPatches true;
}
```

funkySetFields (10/11)

To run the case, simply run:

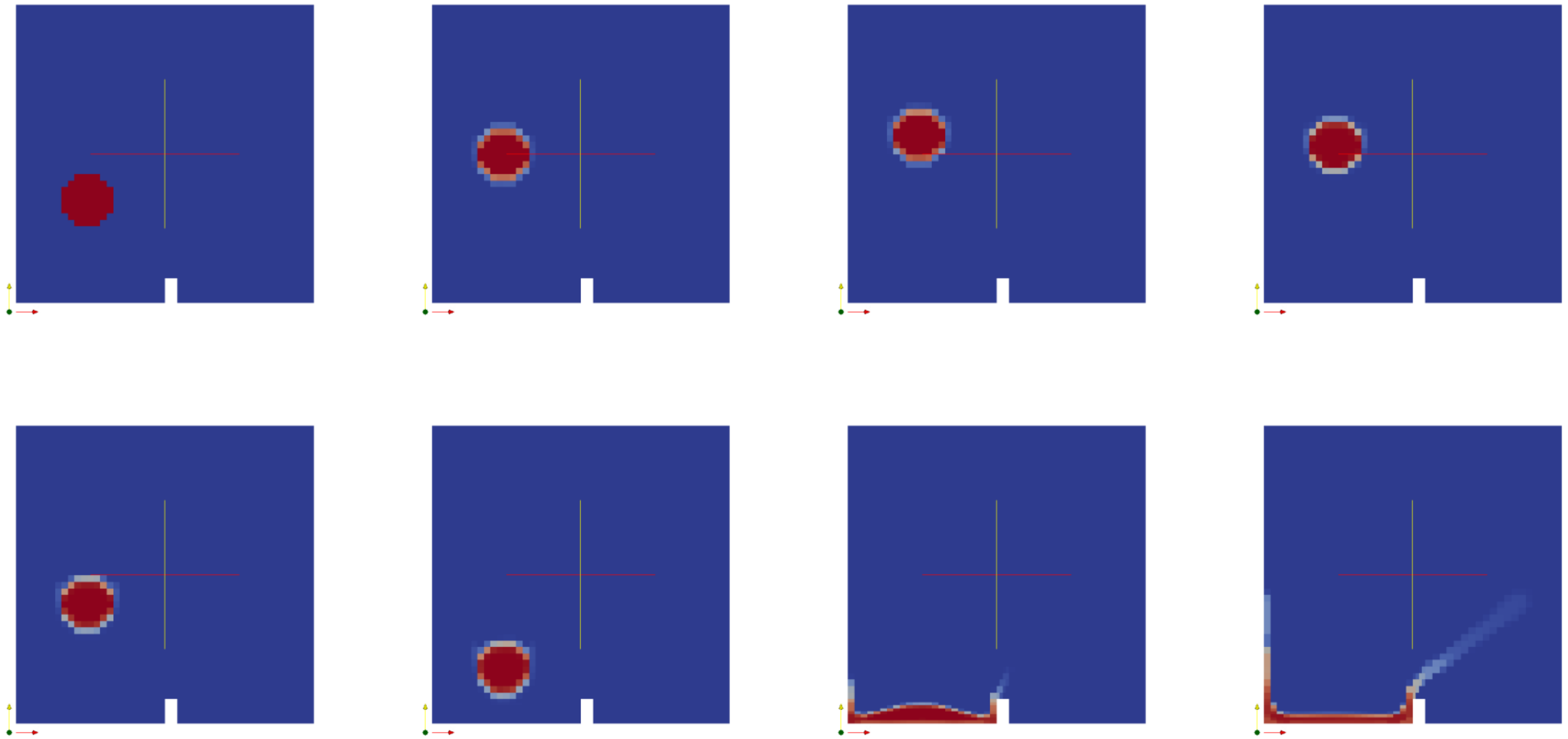
```
./Allrun
```

Or run manually each step:

```
cp 0/alpha.water.org 0/alpha.water
blockMesh
funkySetFields -time 0
interFoam
```

Then open it in ParaView!

funkySetFields (11/11)



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funkySetBoundaryField (1/4)

It’s essentially **funkySetFields**, for manipulating only the boundary fields on the surface mesh.

Specifically, it can operate on dictionary entries like this one:

```
     value                uniform (0 0 0);
```

We will also use the previous case and add a new dictionary file…

funkySetBoundaryField (2/4)

… “system/funkySetBoundaryDict”:

```
blowerLeftWall
{
    field U;
    expressions
    (
        {
            target value;
            patchName leftWall;
            variables "maxY=max(pts().y);thres=0.5*maxY;";
            expression
"(pos().y<thres)?vector(3,3,0)*(maxY-pos().y):vector(0,0,0)";
        }
    );
}
```

funkySetBoundaryField (3/4)

To run the case, simply run:

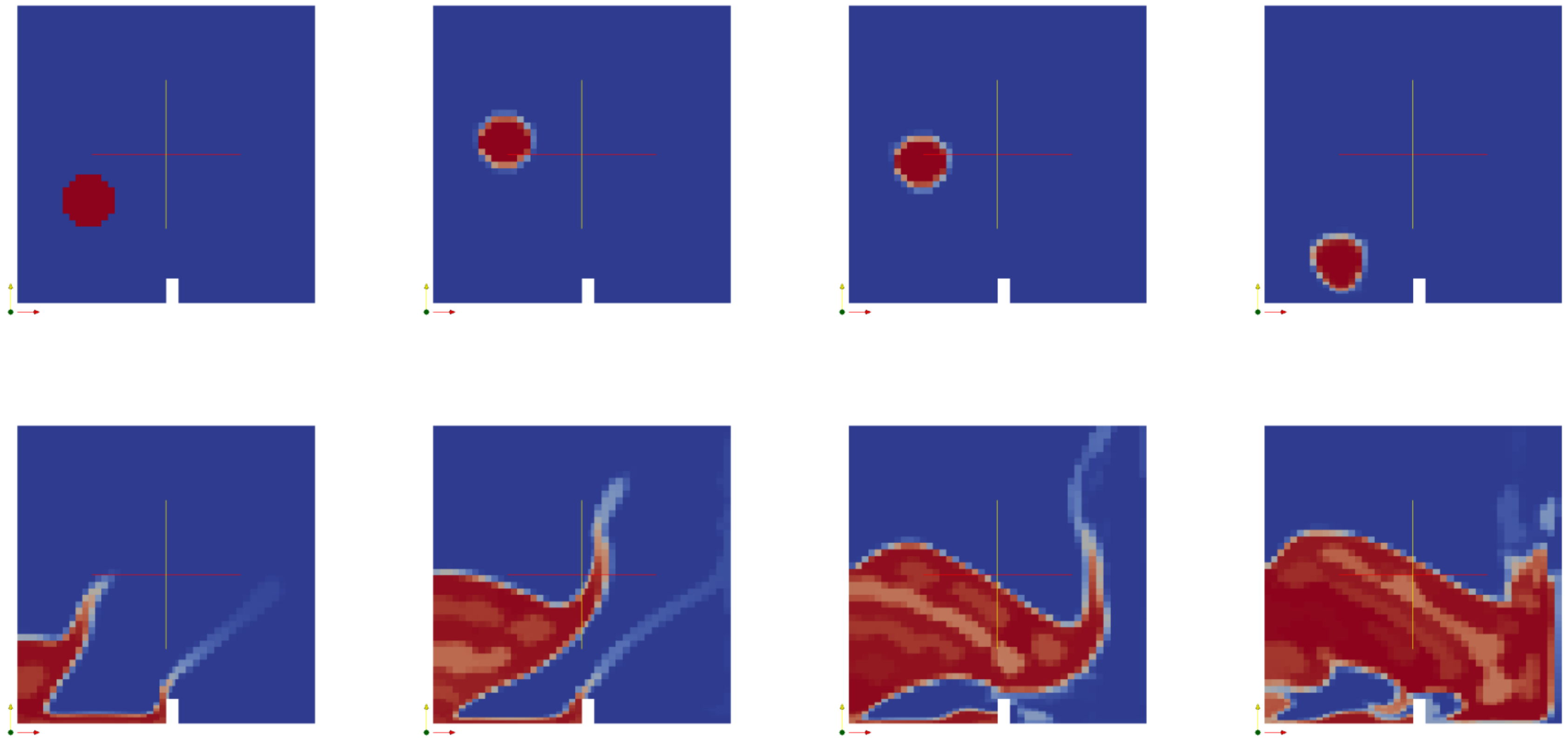
```
./Allrun
```

Or run manually each step:

```
cp 0/alpha.water.org 0/alpha.water
blockMesh
funkySetFields –time 0
funkySetBoundaryField -time 0
interFoam
```

Then open it in ParaView!

funkySetBoundaryField (4/4)



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groovyBC (1/7)

funkySetBoundaryField can initialize fields, but what if we need them to be time/iteration dependant? This is where *groovyBC* comes in!

Objective:

1. We use the case from the **funkySetFields** slides.
2. Use groovy BC for applying an air jet at 20 m/s.
3. Air jet works within the 0.1 and 0.2 second range.
4. Location is in the lower wall, with X within 0.12 and 0.16 metre.

groovyBC (2/7)

Edit the file “0/U”, scroll down to the end of the file and find “lowerWall”. Replace it with this:

```
lowerWall
{
    type            groovyBC;
    value           uniform (0 0 0);
    variables
    (
      "vel=20.0;"
      "minX=0.12;"
      "maxX=0.16;"
    );
    valueExpression
"(0.1<=time()&&time()<=0.2)&&(minX<=pos().x)&&(pos().x<=maxX)
?vector(0,vel,0):vector(0,0,0)";
}
```

groovyBC (3/7)

Edit the file “system/controlDict”, scroll down to the end of the file and add this line:

```
libs ( "libgroovyBC.so" );
```

Notes:

- Make sure you only have 1 entry named “libs”.
- For loading more than one library, list them, e.g.:

```
libs ( "libgroovyBC.so" "libOpenFOAM.so" );
```

groovyBC (4/7)

To run the case, simply run:

```
./Allrun
```

Or run manually each step:

```
cp 0/alpha.water.org 0/alpha.water
blockMesh
funkySetFields -time 0
interFoam
```

Then open it in ParaView!

groovyBC (5/7)

In ParaView (1/2):

1. Select “groovyBCDamBreak” (Pipeline Browser).
2. Change representation to the “alpha.water” field.
3. Menu: Filters → Common → Stream Tracer
4. Turn on the advanced options for “StreamTracer1” (it’s the button with the little gear symbol).
5. Click on the “X Axis” button.
6. “Seed Type” → “High Resolution Line Source”
7. “Resolution” → 50
8. Click on the “Apply” button.

groovyBC (6/7)

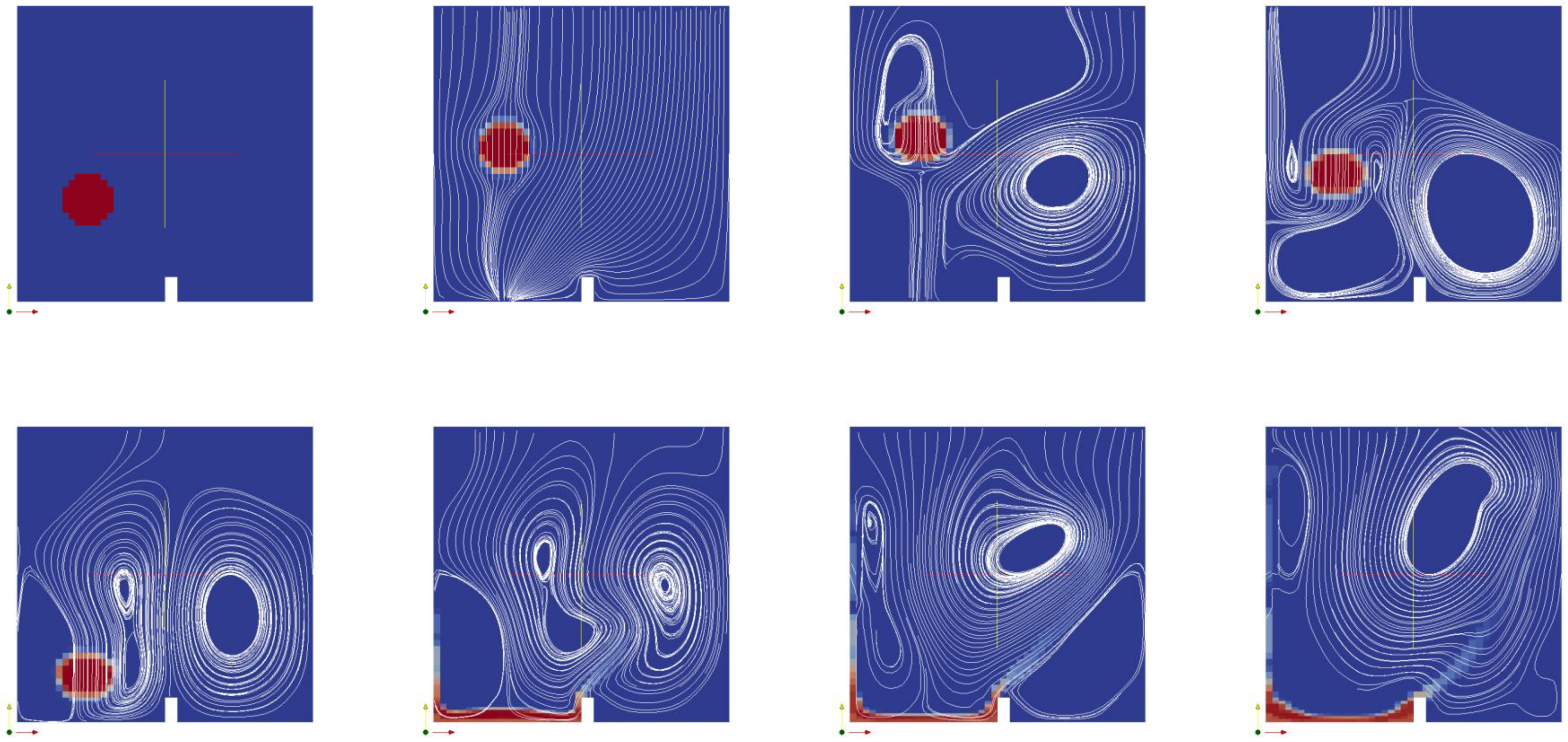
In ParaView (2/2):

9. Menu: Filters → Alphabetical → Transform

10. "Translation": 0 0 0.1

11. Click on the "Apply" button.
12. Go to the next or last time step, to check if the stream lines appear.

groovyBC (7/7)



patchExpression (1/11)

Need to calculate the mass flow rate going through a patch?

- OpenFOAM 2.3 already has that feature.

Need to calculate the mass flow rate going through a patch, in pound per hour (lb/h)?

- *patchExpression* can do that and a lot more!

patchExpression (2/11)

Example case:

- Original: “incompressible/simpleFoam/pitzDaily”
- Case folder: “patchExpressionPitzDaily”
- Objective:
  - Calculate the volumetric flow in m^3/s.
  - Calculate the mass flow in kg/s.
  - Calculate the mass flow in lb/h.
  - Get the maximum, minimum and average volumetric/mass flow values on the faces of the “inlet” and “outlet” patches.

patchExpression (3/11)

Create a copy of the tutorial:

```
cp -r $FOAM_TUTORIALS/incompressible/simpleFoam/pitzDaily \
    patchExpressionPitzDaily
```

Edit the file “system/controlDict”, scroll down to the end of the file and add these lines:

```
    libs (
      "libsimpleSwakFunctionObjects.so"
      "libswakFunctionObjects.so"
    );
```

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patchExpression (4/11)

Still in the file “system/controlDict”, find this block:

```
functions
{
    streamLines
    {
        //…
    }
}
```

We will add the next blocks inside the block “functions”, after the end of the block “streamLines”.

patchExpression (5/11)

The first block (accurate volumetric flow rate):

```
volumetricFlowSurfaceField
{
    type patchExpression;
    outputControlMode   outputTime;
    verbose true;
    accumulations (
        sum max min average
    );
    patches (
        inlet
        outlet
    );
    expression "phi";
}
```

patchExpression (6/11)

The second block (less accurate):

```
volumetricFlowVolumeField
{
    type patchExpression;
    outputControlMode   outputTime;
    verbose true;
    accumulations (
        sum max min average
    );
    patches (
        inlet
        outlet
    );
    expression "U&Sf()";
}
```

patchExpression (7/11)

The third block (mass flow rate kg/s):

```
massFlowSurfaceField
{
    $volumetricFlowSurfaceField;
    patches (
        inlet
        outlet
    );
    variables (
        "rhoAir=1.2041;"
    );
    expression "phi * rhoAir";
}
```

patchExpression (8/11)

The fourth block (mass flow rate lb/s):

```
massFlowSurfaceFieldInPoundPerHour
{
    $volumetricFlowSurfaceField;
    patches (
        inlet
        outlet
    );
    variables (
        "rhoAir=1204.1;"
        "poundPerHour=2.20462*3600.0;"
    );
    expression "U&Sf() * rhoAir * poundPerHour";
}
```

patchExpression (9/11)

For running the case:

```
foamRunTutorials
```

Location of the results (formatted with fixed width):

```
 ls -l postProcessing/patchExpression_*/*
```

For later clean up the case:

```
foamCleanTutorials
```

patchExpression (10/11)

The results are also available in the file “log.simpleFoam”. Example:

```
Expression volumetricFlowSurfaceField on outlet:
sum=0.000254001 max=6.97636e-006 min=7.27091e-007
average=4.45616e-006
Expression volumetricFlowSurfaceField on inlet:
sum=-0.000254 max=-3.13389e-006 min=-1.78262e-005
average=-8.46667e-006

Expression volumetricFlowVolumeField on outlet:
sum=0.00025273 max=6.9322e-006 min=7.08664e-007
average=4.43386e-006
Expression volumetricFlowVolumeField on inlet:
sum=-0.000254 max=-3.13389e-006 min=-1.78262e-005
average=-8.46667e-006
```

patchExpression (11/11)

What else can it do? A lot more! One last example:

```
deltaP
{
    type patchExpression;
    accumulations (
        min max average
    );
    patches (
        inlet
    );
    variables "pOut{outlet}=average(p);";
    expression "p-pOut";
    verbose true;
}
```

Source: “swak4Foam/Examples/groovyBC/pulsedPitzDaily”

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swakExpression (1/4)

The function object *patchExpression* is essentially derived from *swakExpression*, which is able to operate on following types of mesh domains:

```
cellSet
cellZone
faceSet
faceZone
internalField
patch
set
surface
```

swakExpression (2/4)

Copy the previous folder and replace all other function objects with just this one:

```
absolutePressureStats
{
    type swakExpression;
    valueType internalField;
    variables (
        "rhoAir=1.2041;"
        "refP=101325;"
    );
    expression "p*rhoAir + refP";
    verbose true;

    outputControlMode   outputTime;
}
```

```
accumulations (
 average
 weightedAverage
 median
 weightedMedian
 quantile0.50
 weightedQuantile0.50
 quantile0.75
 weightedQuantile0.75
);
```

swakExpression (3/4)

Notes:

- Quantile 50% is the median
- The weighted variants are based on the volumes of each cell
- The number next to the name of an *accumulation* is the argument for it:
  - quantile0.75 → quantile 75%
- Running the case is done the same way as the previous example, i.e.: **foamRunTutorials**

swakExpression (4/4)

The tabulated results are in this file:

postProcessing/swakExpression_absolutePressureStats/0/absolutePressureStats

The file “log.simpleFoam” also has these values, e.g.:

```
Expression absolutePressureStats :
average=101324 weightedAverage=101328
median=101319 weightedMedian=101328
quantile0.5=101319 weightedQuantile0.5=101328
quantile0.75=101332 weightedQuantile0.75=101337
```

expressionField

If you ever need to quickly create a new field for sampling or for common use with other function objects, this function object can do it for you. Example:

```
velocityMagSquared
{
    type expressionField;
    outputControl timeStep;
    outputInterval 1;
    fieldName UMag2;
    expression "U&U";
    autowrite true;
}
```

pyFoamPlotRunner (1/2)

Next, it’s time for PyFoam to shine.

- Feel the need to easily keep track of the residuals while the solver is running?
- What about keeping track of the residuals and launch the solver in a single command?

Then on the latest case, try the following commands:

```
foamCleanTutorials
blockMesh
pyFoamPlotRunner.py simpleFoam
```

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pyFoamPlotRunner (1/2)

What else can it do? Try running:

```
pyFoamPlotRunner.py –help
```

e.g., remove time steps + run 200 iterations only + 0.2s refresh plotting:

```
pyFoamPlotRunner.py --clear-case --run-until=200 \
--frequency=0.2 --persist simpleFoam
```

pyFoamPlotWatcher

pyFoamPlotRunner is nice, but what it the simulation is already finished? Then use **pyFoamPlotWatcher**!

Examples:

```
pyFoamPlotWatcher PyFoamRunner.simpleFoam.logfile
pyFoamPlotWatcher log.simpleFoam
```

Best of all? You can use this script while the solver is running!

Further Information

This presentation was only a fraction of the tip of the iceberg. Several presentations are available in the wiki pages of each respective project:

- openfoamwiki.net/index.php/Contrib/swak4Foam:
  - 7.2 Further information
- openfoamwiki.net/index.php/Contrib/PyFoam:
  - 1.3 Other material

Questions?

Thank you for your attention!

Any questions?