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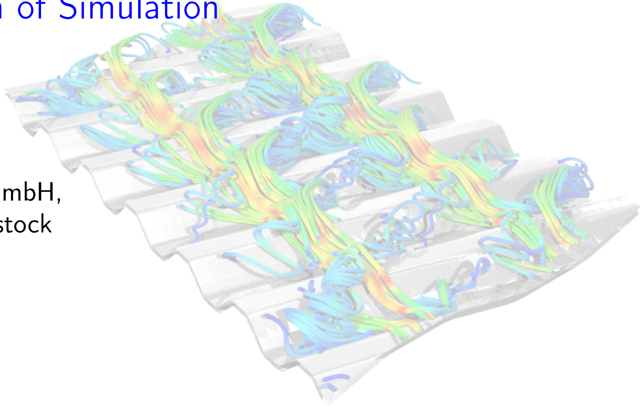
Automation of Simulation Workflows



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Contents

- Using FEA software *efficiently*
  - simple and quick setup of analysis

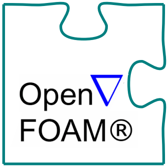
  - avoid errors in setup

  - quick repetition of analysis after geometry or BC change
    $\Rightarrow$prerequisite for optimization
    also:

  - quick and reliable documentation of results
- including heat transfer, but not limited to it

Which tools do we use?

⇒open-source CAE tools



Finite-Volume-Method for CFD: OpenFOAM

- Most used CFD code
- Convective and conductive heat transport
- Radiation
- much more features
- GPL: no license fees, full source code available
- no GUI, configuration through text files

Finite-Element-Method: Elmer

- general purpose Finite-Element code
- heat transport
- electric and magnetic field analysis, induction heating
- GPL: no license fees, full source code available
- configuration through text files, GUI available

Building bricks

Visualization: Paraview

- visualization of grid-based data
- reads many mesh-based formats
- extensively used by open source and commercial projects
- GPL: no license fees, full source code available
- configuration through text files, GUI available

There is even more available:

- Geometry: FreeCAD / Blender / MeshLAB ...
- Meshing: cfMesh / Netgen / GMSH
- Solving: OpenFOAM / Code Aster / Code Saturn
- PostProcessing: Paraview / Ensight / python

What might disable efficiency

- lack of documentation $\Rightarrow$steep learning curve
- freedom to make invalid settings / feature combinations
- complicated interfaces between analysis building bricks
- uncomfortable user interfaces

How to gain efficiency

How to gain efficiency? ⇒through automation and integration

An integration software layer is needed ⇒InsightCAE

InsightCAE is an **open source** project (GPL)
Source Code: `https://sourceforge.net/p/insightcae`

Install packages available. Install on current Ubuntu LTS:

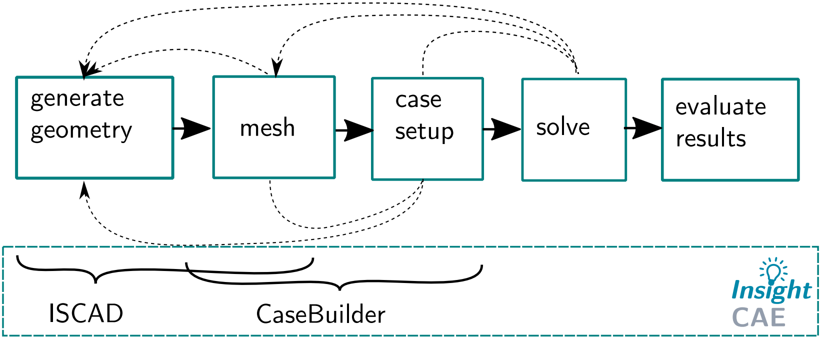
```
$ sudo add-apt-repository http://downloads.silentdynamics.de/ubuntu
$ sudo apt-key adv --recv-key --keyserver keys.gnupg.net 79F5CBA4
$ sudo apt-get update
$ sudo apt-get install insightcae-base
```

Build from sources:

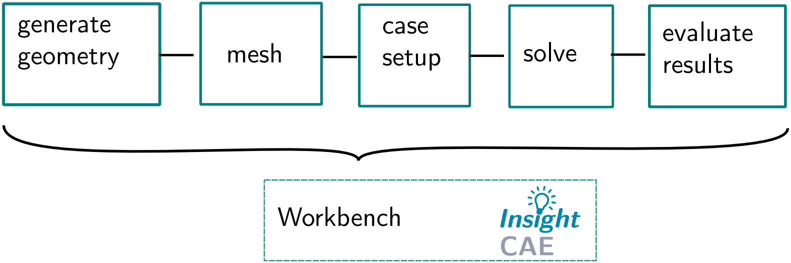
```
$ git clone git://git.code.sf.net/p/insightcae/code insight-src
$ mkdir insight && cd insight
$ ccmake ../insight-src
$ make
```

Add to your `~/.bashrc`: `source /path/to/insight/bin/insight_setenv.sh`

First step: develop a working analysis procedure:



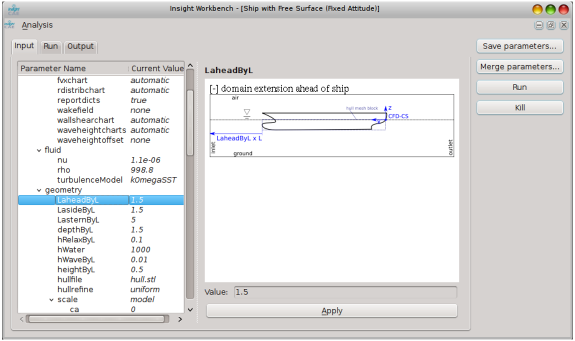
Next step: collect developed workflow steps into an analysis module



InsightCAE provides:

- modular handling of input parameters and result sets
- GUI for parameter editing
  $\Rightarrow$helpful for unexperienced users

GUI for editing parameters / run analyses / view results (“workbench”)



Parameters Documentation / Help

Alternative: Command line tool to perform analyses (“analyze”)

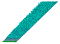
```
$> analyze --double LaheadByL:2.3 inputfile.ist
```

Realized Analysis Modules

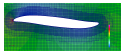
simple generic analyses for validation

- channel flow

- flat plate



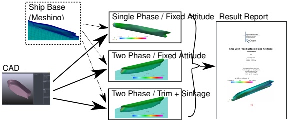
- 2D airfoil



- ...

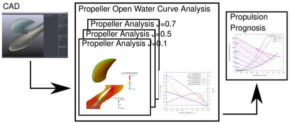
CFD of ship resistance

- single phase
- two phase fixed
- two phase with trim and sinkage



propeller and turbomachinery analyses

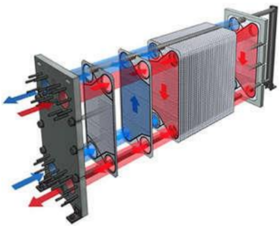
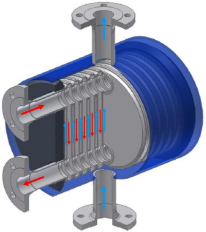
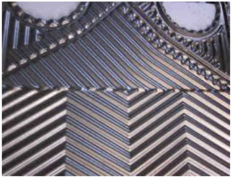
- free propeller
- ducted propeller
- axial pump
- optimal diameter, optimal rpm, propulsion prognosis



Object of investigation

- Analysis of complex heat exchangers in circular shape in high pressure environment
- Determination of pressure drop and heat transfer rates of complex geometries

⇒Automated workflow for optimization

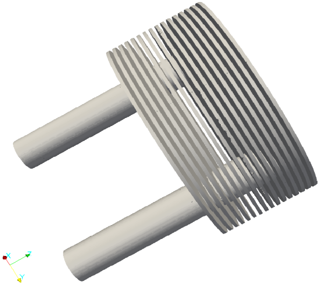
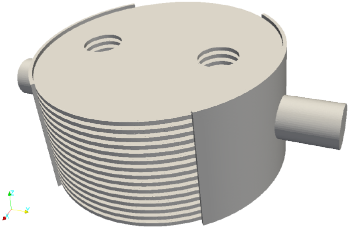




Simulation challenge

- heat exchangers consist of 100 plates or more
- each PHE is especially designed
- integration into workflow for "non" CFD experts
- easy and fast parameter variation

- Key points
  - Fast performance evaluation
  - Complete automated workflow
  - Robust and trustful analysis

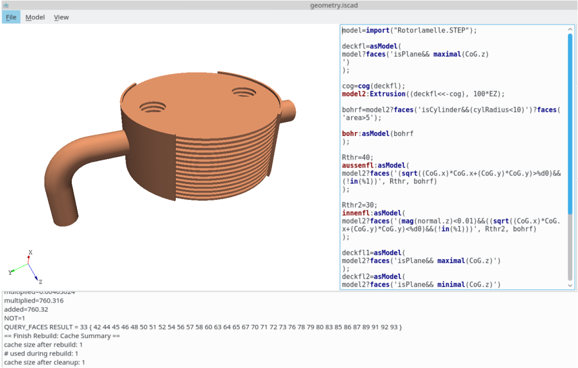
- Detailed CHT Simulation of many plates not possible
- Simplification of PHE using porous media

- Parametric geometry build up possible

Create geometry

- Task: Generate a combined geometry for the cold fluid side
  ⇒generate STL surfaces for snappyHexMesh
- Use `ISCAD` from InsightCAE to build up the model



Geometry handling

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Script-based CAD, some examples

- Parametric sketches through FreeCAD:

```
xsec_plates=
 Sketch(YZ, "sketch_plates.fcstd", 'xsec_plates',
  D=340);
xsec_inlet=
 Sketch(YZ, "sketch_inlet.fcstd", 'xsec_inlet',
  D=100, L=50);
```

- create solids

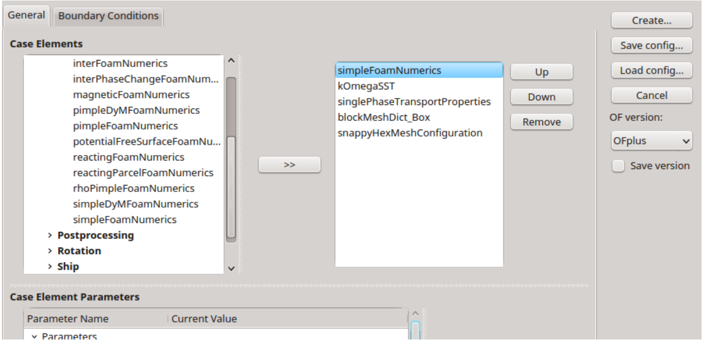
```
geometry:
 Extrusion(xsec_plates, 5*EZ)
 |
 Revolution(xsec_inlet, 0, 360*deg*EX);
```

- export STL file:

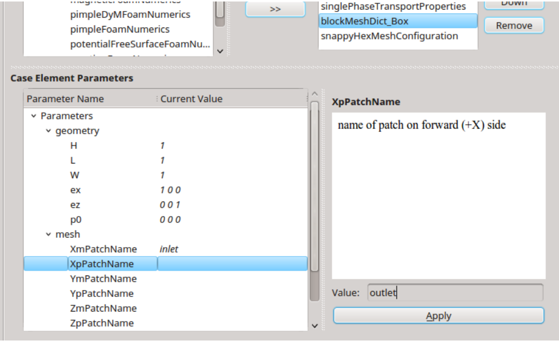
```
exportSTL("geometry.stlb", 1e-2) << geometry;
```

Create OpenFOAM case configuration

- Supported features of OpenFOAM are stored in "case elements" They can be combined together into an OpenFOAM case.
- frontend: `isofCaseBuilder`:

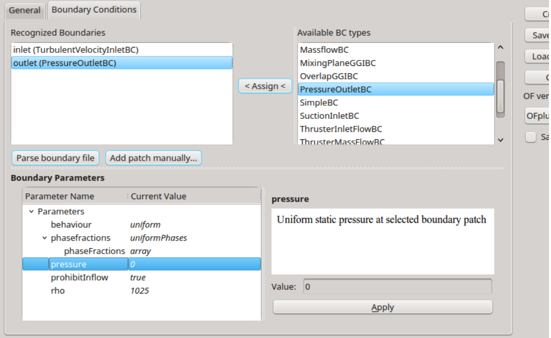


- The case elements usually need parameters
- Reasonable defaults are provided which need to be customized:



- Give me the state file for the case setup
- Save as `case.iscb`

- Last step: configure boundary conditions
- BC case elements set the appropriate BCs for all fields on the patch



- Finished: save configuration ⇒`case.iscb`

Running the case

- Our simple example could be run by this script (`run.sh`):

```
#!/bin/bash
iscad -b geom.iscad
isofCaseBuilder -sb case.iscb # no mesh yet: skip BCs
blockMesh
snappyHexMesh -overwrite
isofCaseBuilder -b case.iscb
simpleFoam
```

Workflow so far

1. Parameterize geometry
2. Run the `run.sh` file
3. Analyze results, e.g. through `paraview`

- Prepare repetition of postprocessing
- Start `paraview` → generate multiple layouts → save the state file
- Run the postProcessing script by:
  `isPV.py -b state.pvsm`
- Gives us the pictures as png file for every paraview layout!

The next level: add a GUI

Complete automation by adding GUI and report creation

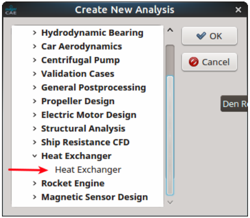
- GUI for parameter editing and analysis execution: "workbench"
- InsightCAE supports Python analysis modules
  go into `$HOME/.insight/share/python_modules`
- create script to `$HOME/.insight/share/python_modules/Heat\ Exchanger.py`

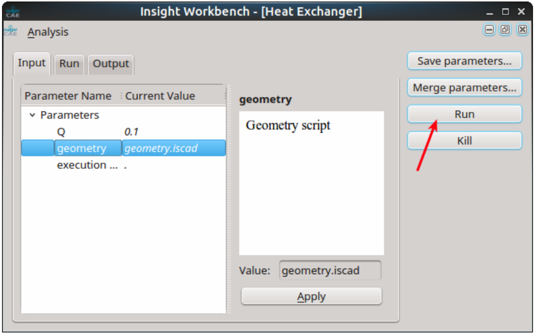
The scripts looks like this:

```
#!/usr/bin/env python
from Insight.toolkit import *

def category():
    return "Heat Exchanger"

def defaultParameters():
    p=ParameterSet([
        ("Q", DoubleParameter(0.1, "[m^3/s] Volume flux")),
        ("geometry", PathParameter("geometry.iscad", "
            Geometry script"))
        ])
    return p
```

Python Analysis Module

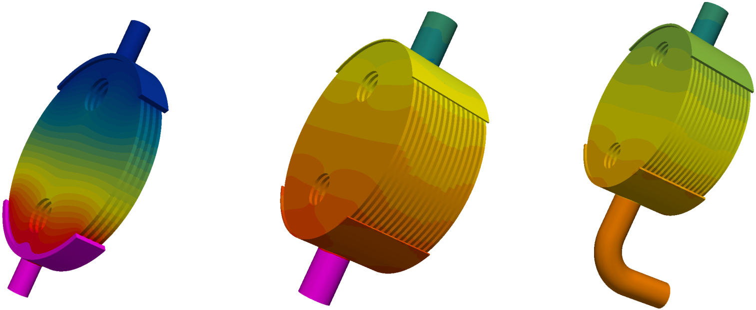
```python
def executeAnalysis(p, workdir):
    Q=ps.getDouble("Q")

    # execute analysis and evaluation

    res=ResultSet(ps, "Heat␣Exchanger", "Result␣Report")
    res.insert("deltap",
       ScalarResult(deltap, "Pressure␣loss", "", "Pa"))
    res.insert( "deltapConvergence",
       Chart( "iter", "Q",
            [PlotCurve(p_vs_t[:,0], p_vs_t[:,9], "deltap",
             "w␣l␣t␣'$\\Delta_p$'")], "", "", "" ) )
    return res
```


Create New Analysis
Hydrodynamic Bearing
Car Aerodynamics
Centrifugal Pump
Validation Cases
General Postprocessing
Propeller Design
Electric Motor Design
Structural Analysis
Ship Resistance CFD
Heat Exchanger
Heat Exchanger
Rocket Engine
Magnetic Sensor Design
OK
Cancel


Insight Workbench - [Heat Exchanger]
Analysis
Input
Run
Output
Parameter Name
Current Value
Parameters
Q
0.1
geometry
geometry.iscad
execution ...
geometry
Geometry script
Value:
geometry.iscad
Apply
Save parameters...
Merge parameters...
Run
Kill

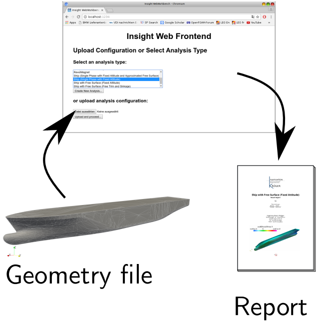
Automated workflow

- Version 1,2,3 ...



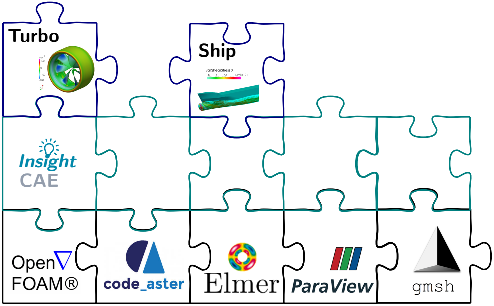
Change the Geometry → Run → Get the report

- WiP: Web-Frontend (“web-workbench”) for usage e.g. in on-premise clouds



Summary

- Efficient and automated computations using insightCAE
- InsightCAE connects different OSS using predefined interfaces
- Standardized simulations / reducing of time consuming user mistakes
- Quality is ensured
- Fast workflow!



Thank you very much!

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silentdynamics GmbH
http://silentdynamics.de

```
$ sudo add-apt-repository http://downloads.silentdynamics.de/ubuntu
$ sudo apt-key adv -recv-key -keyserver keys.gnupg.net 79F5CBA4
$ sudo apt-get update
$ sudo apt-get install insightcae-base
```