Profiling of Modelica Real-Time Models

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Overview

1. Introduction
2. Profiling of Modelica Models
3. Implementation
4. Case Study
5. Conclusion

Introduction

- Usages of RT simulation:
  - Rapid Control Prototyping (RCP)
  - Hardware-in-the-Loop (HiL)
  - Model Predictive Control (MPC)
- Hard real-time (execution time per global solver step <= output step size)
- Overruns due to events and algebraic loops
- Model has to be improved manually
- Profiling helps to trace back the cause of an overrun
- There is no applicable profiling tool
- We want to profile on the RT-Target:
  - Calls to external functions (libraries)
  - Algebraic loops
- We want minimize the overhead caused by profiling

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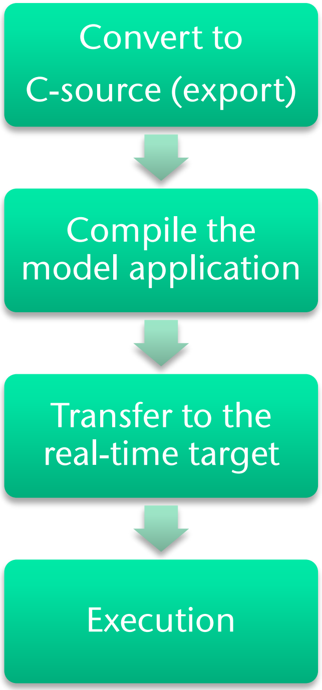
Simulation on Real-Time Targets

- To execute a model on a Real-Time target one has to:


Convert to C-source (export)
Compile the model application
Transfer to the real-time target
Execution

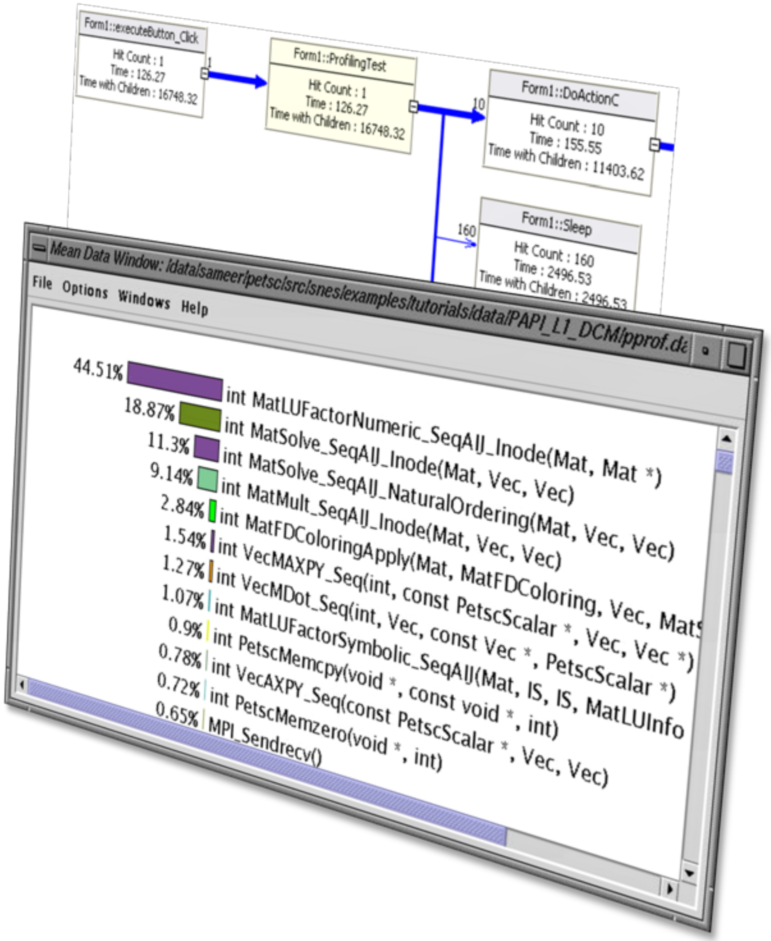
Profiling

- Tracing vs. Profiling
  - Call-Graph
  - Flat-Profile

- Instrumentation must be added but causes additional work load

- We are profiling by measurement (just like Tau) but are not logging the callee or point in time

- One can draw this information from the general structure of those models


Mean Data Window: /data/sameer/petsc/src/snes/examples/tutorials/data/PAPI_L1_DCM/pprof.da
File
Options
Windows
Help
1
10
160

```
Form1::executeButton_Click
Hit Count : 1
Time : 126.27
Time with Children : 16748.32

Form1::ProfilingTest
Hit Count : 1
Time : 126.27
Time with Children : 16748.32

Form1::DoActionC
Hit Count : 10
Time : 155.55
Time with Children : 11403.62

Form1::Sleep
Hit Count : 160
Time : 2496.53
Time with Children : 2496.53
```

```
44.51% int MatLUFactorNumeric_SeqAIJ_Inode(Mat, Mat *)
18.87% int MatSolve_SeqAIJ_Inode(Mat, Vec, Vec)
 11.3% int MatSolve_SeqAIJ_NaturalOrdering(Mat, Vec, Vec)
 9.14% int MatMult_SeqAIJ_Inode(Mat, Vec, Vec)
 2.84% int MatFDColoringApply(Mat, MatFDColoring, Vec, Mat
 1.54% int VecMAXPY_Seq(int, const PetscScalar *, Vec, Vec *)
 1.27% int VecMDot_Seq(int, Vec, const Vec *, PetscScalar *)
 1.07% int MatLUFactorSymbolic_SeqAIJ(Mat, IS, IS, MatLUInfo
  0.9% int PetscMemcpy(void *, const void *, int)
 0.78% int VecAXPY_Seq(const PetscScalar *, Vec, Vec)
 0.72% int PetscMemzero(void *, int)
 0.65% MPI_Sendrecv()
```

Source code of Modelica models

- Separated into Initialization and Simulation
- Solver step:
  - n_I integration steps
    - e_I external function calls
    - c_I additional calculations
    - a_I (non-)linear blocks
      - e_{aI} external function calls
      - c_{aI} additional calculations
  - 1 output of variables
    - e_O external function calls
    - a_O additional calculations
- flat profiling for each section
- profiling is done separately for each solver step

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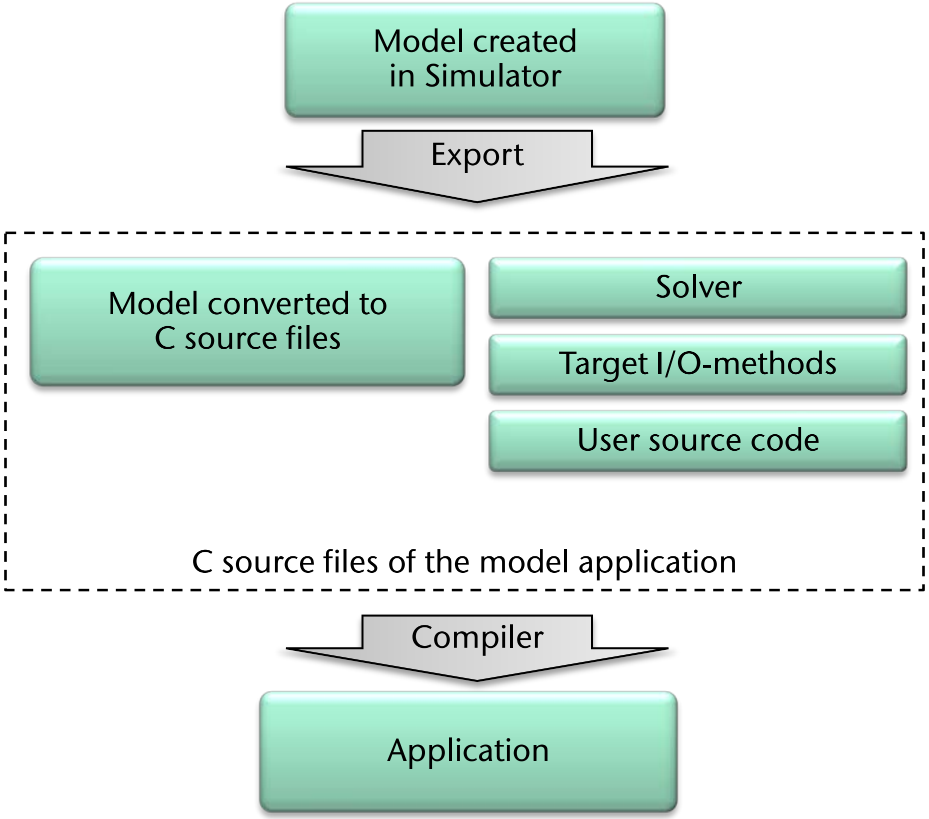
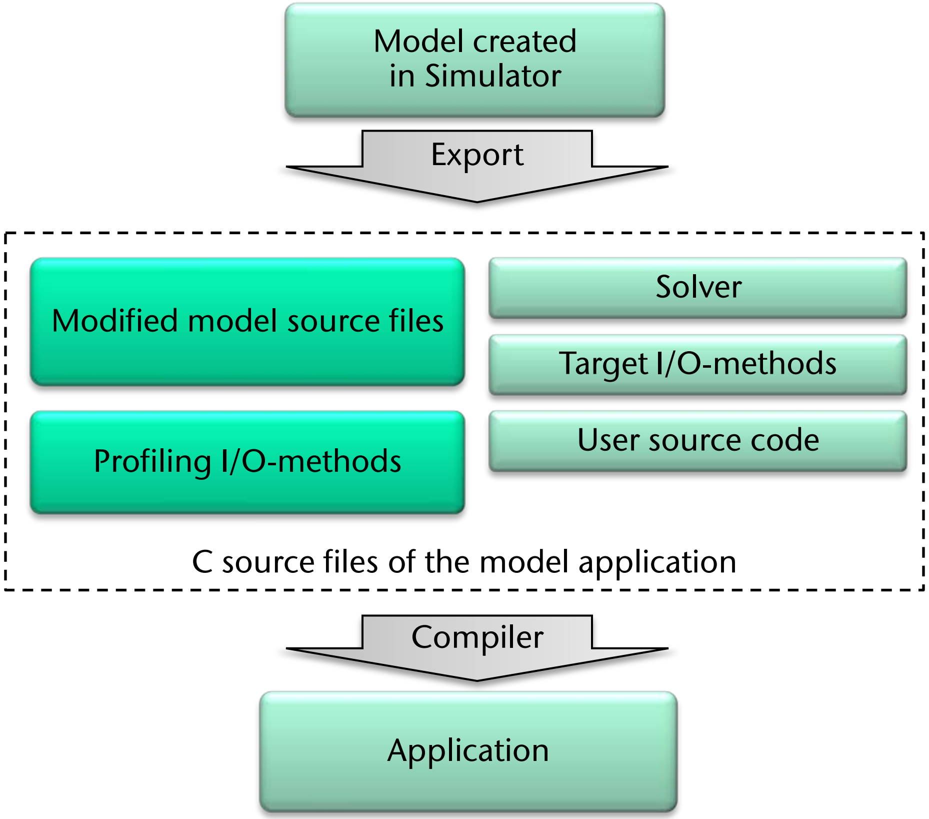
Export of models


Model created in Simulator
Export
Model converted to C source files
Solver
Target I/O-methods
User source code
C source files of the model application
Compiler
Application

Modified Export of models



Modified Source Code

- Major impact on the overhead:
  - Saving profiling data (access to HDD)

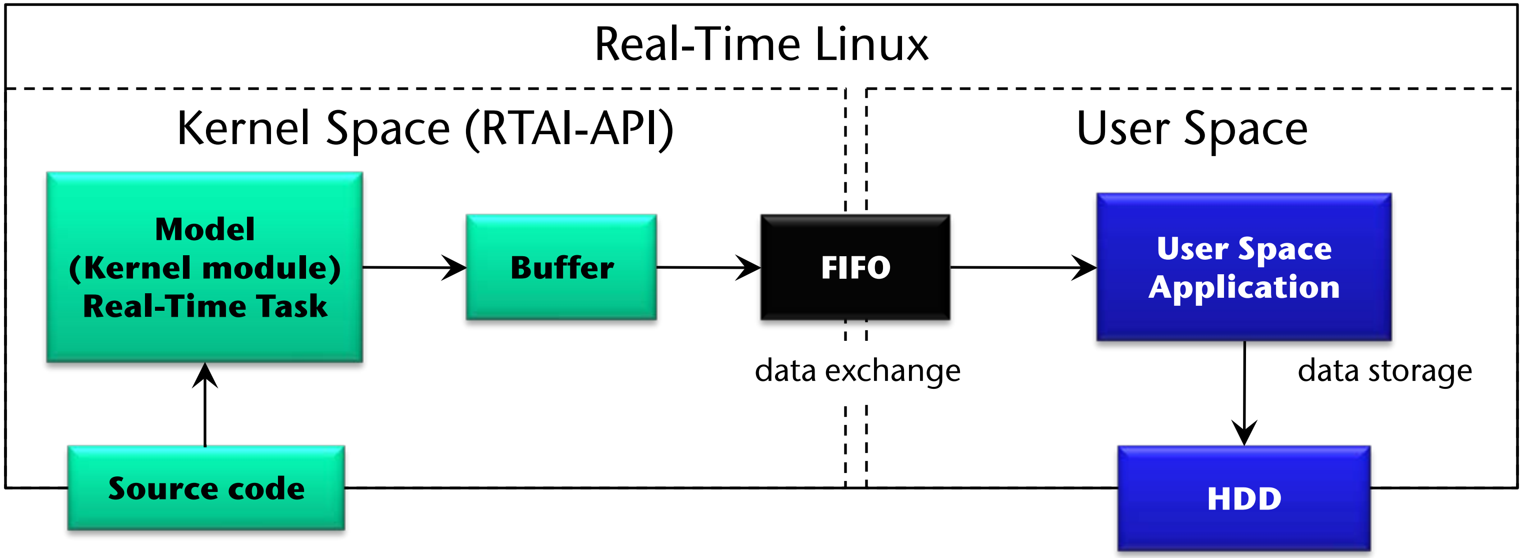
- Access to HDD is outsourced to secondary application

- Model application is a Real-Time Kernel Task(SCALE-RT)
  - Prioritized execution

- Model runtime increases at maximum by 4%

Implementation

- Communication between user task and model task



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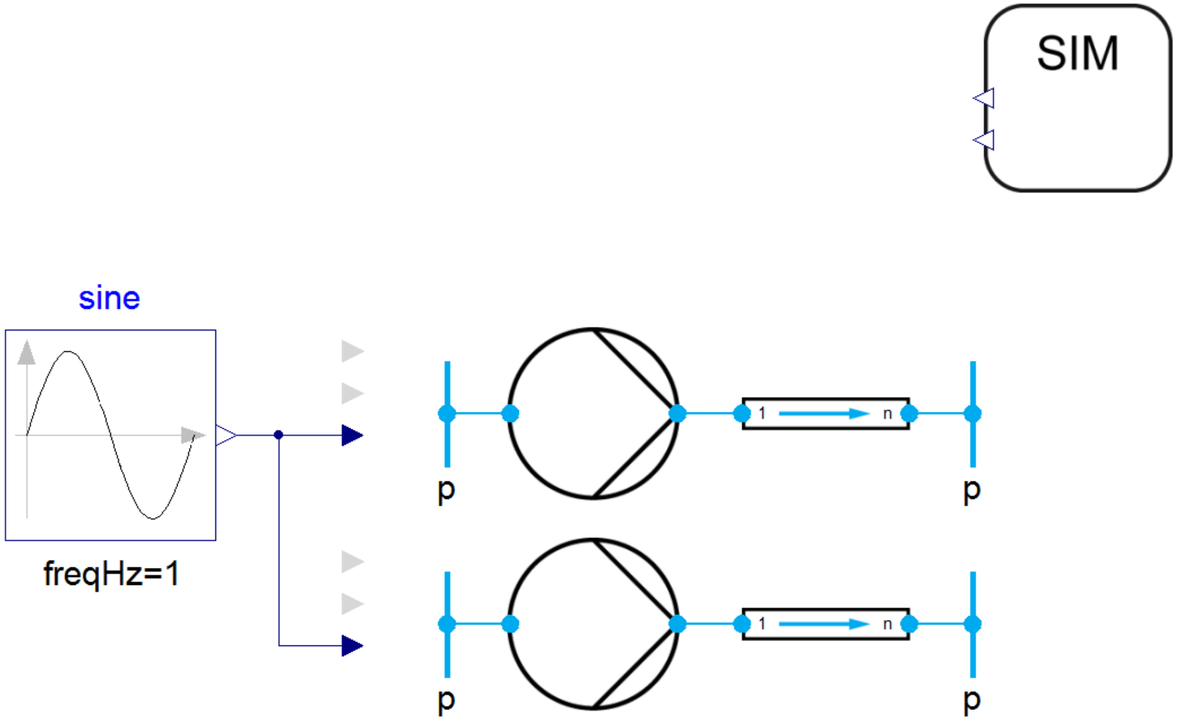
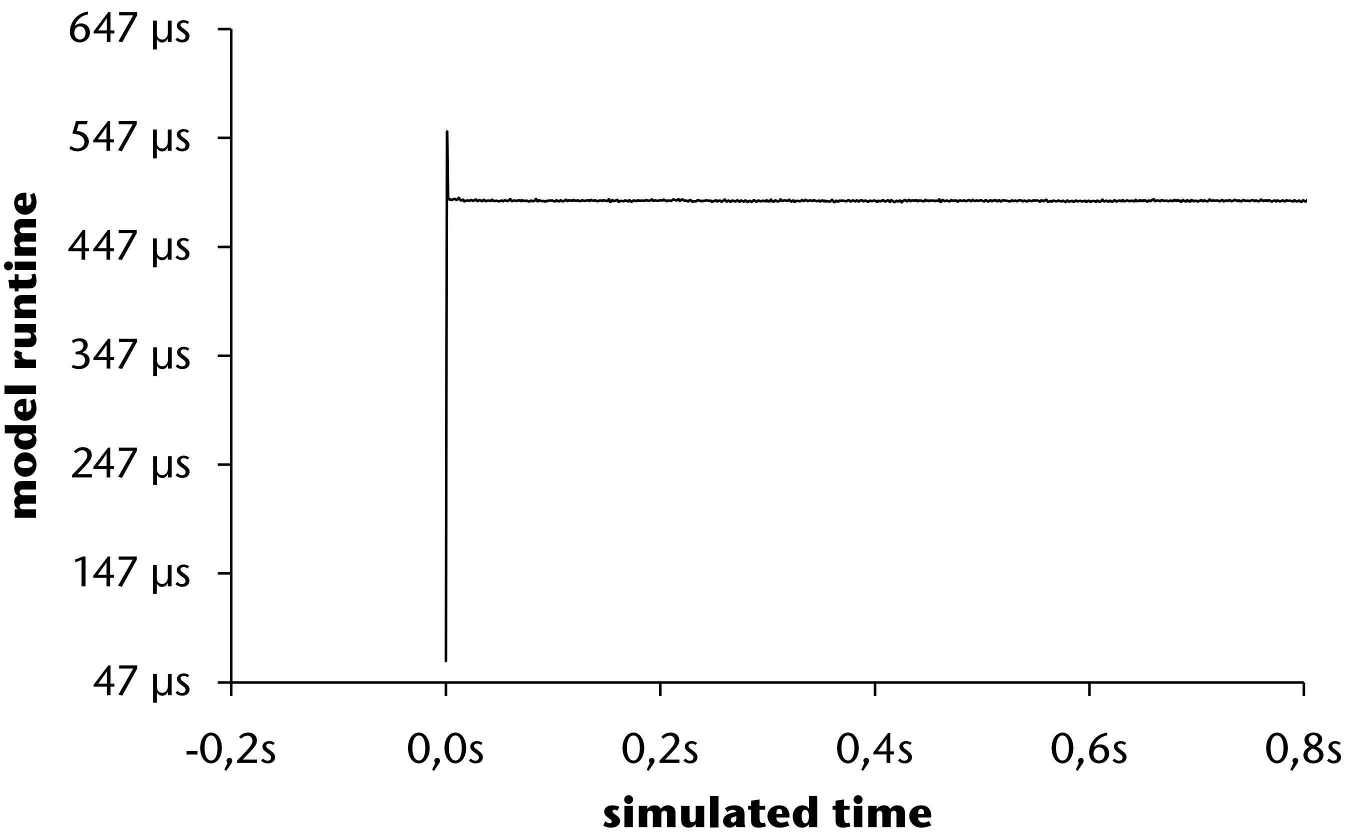
Case Study

- Steady State Continuity Equation

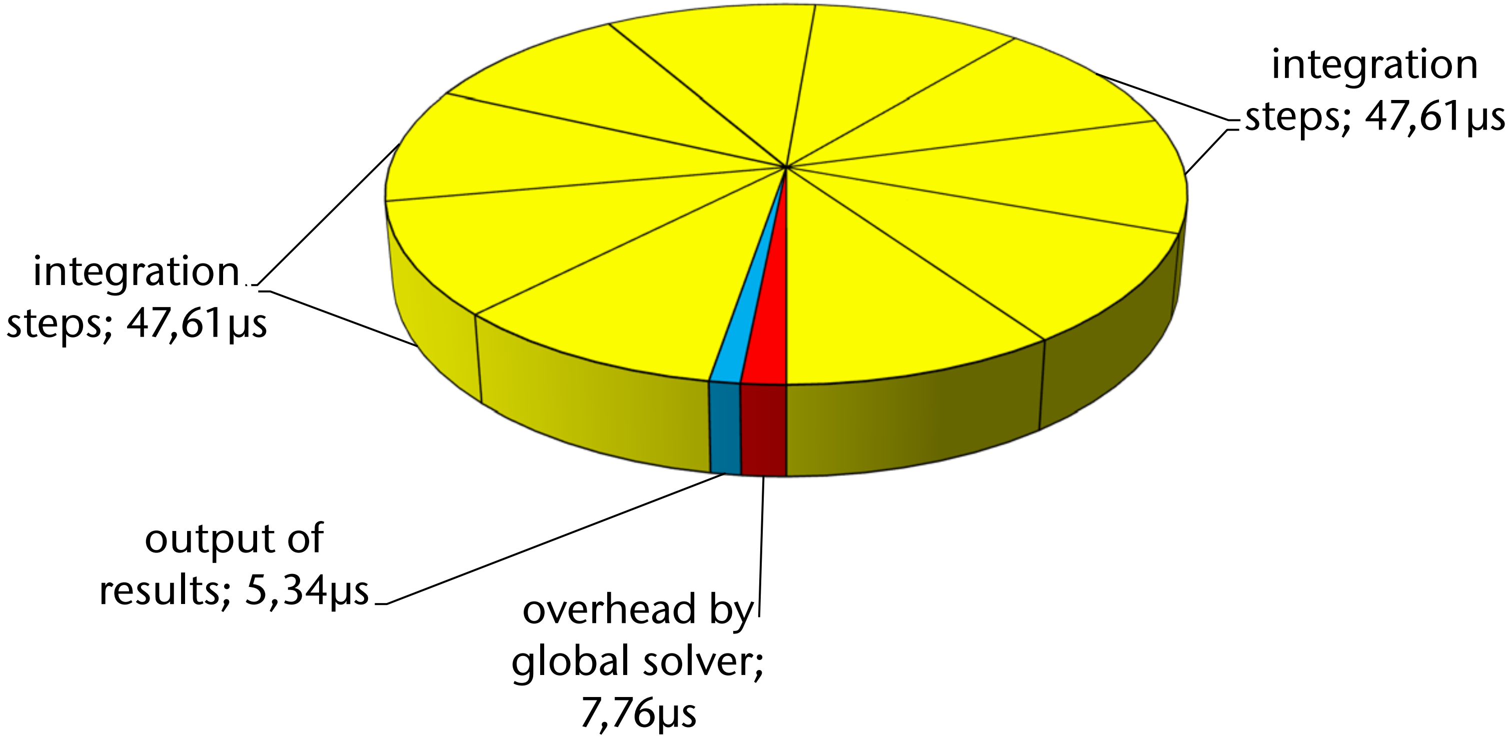


Model runtime over simulated time



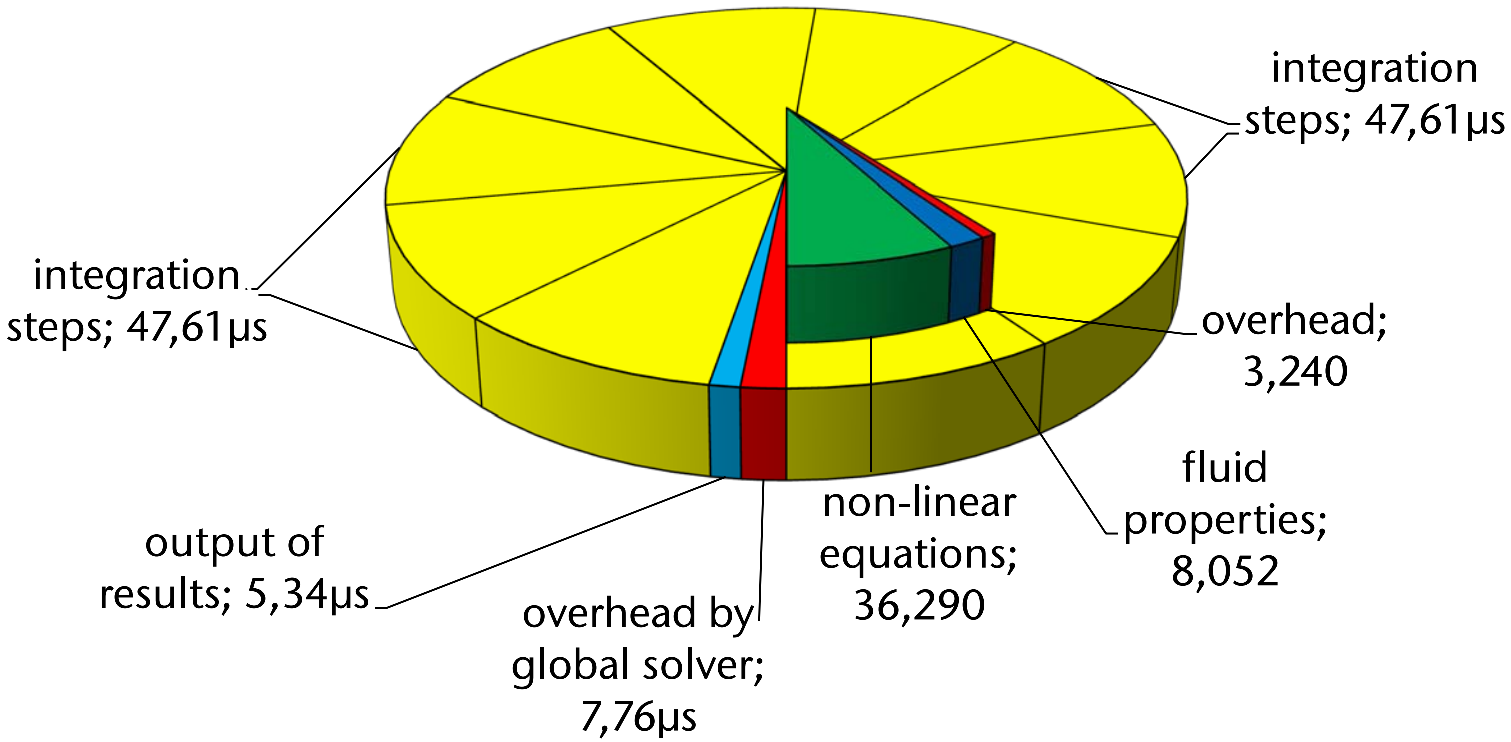
Results of Profiling

- Global solver step separated into integration steps and output of results



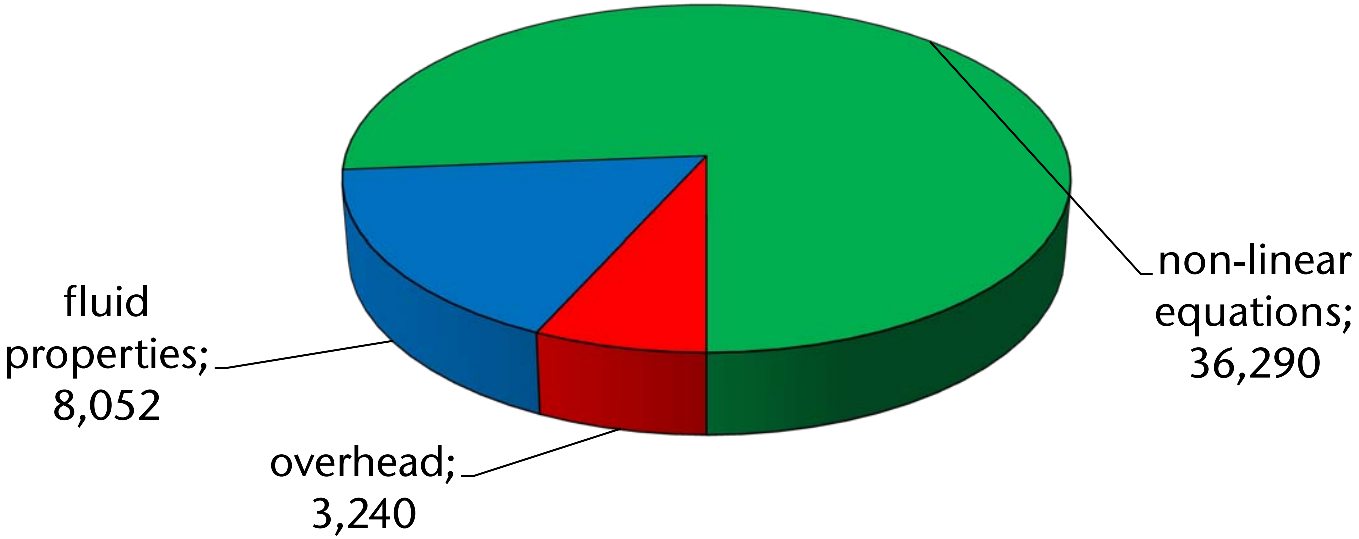
Results of Profiling

- Integration steps separated into external fluid property calculations, non-linear equations and overhead



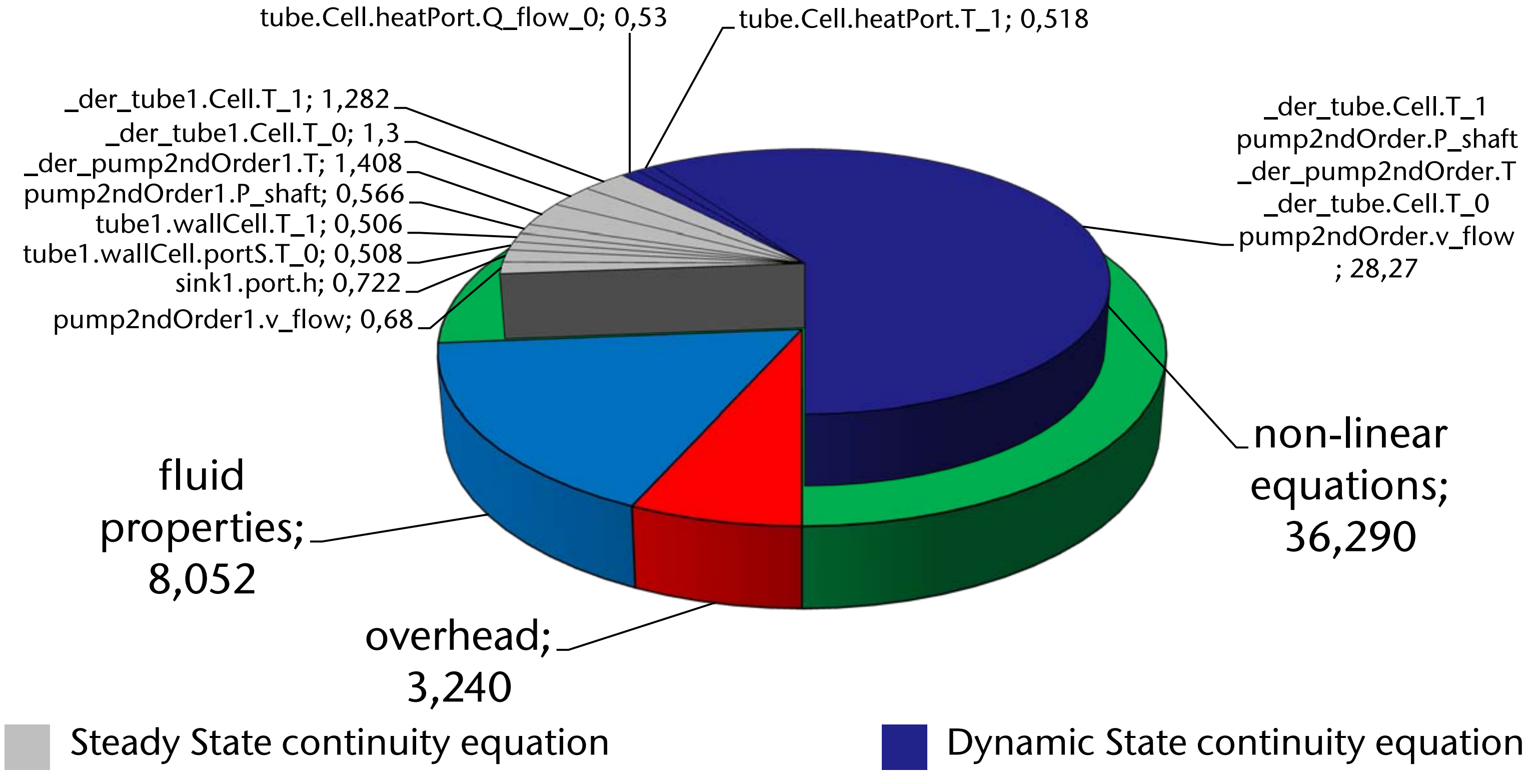
Algebraic loops

- Closer look on integration steps



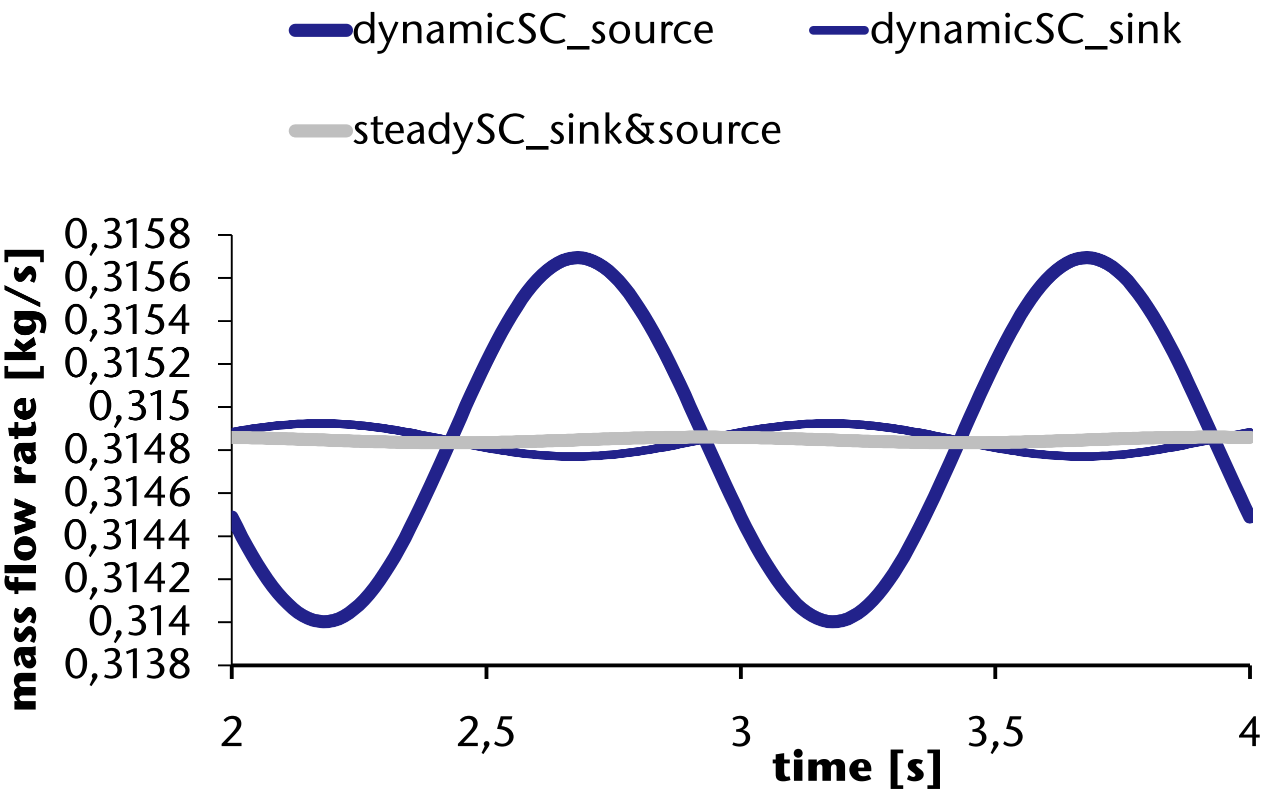
Algebraic loops

- Non-linear equations assinged to submodels



Mass flow of inlet and outlet

- Error due to thermal expansion of liquid



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Conclusion

- Saving results to HDD should be outsourced to a secondary non-Real-Time application
- Flat profiling by measurement for each step gives more than enough information
- Profiling helps identifying the work load contributions and aids the user optimizing the model

Thank you for your attention!