Toward Fast Heterogeneous Virtual Prototypes: Increasing the Solver Efficiency in SystemC AMS

Alexandra Küster, Bosch Sensortec GmbH

SystemC Evolution Fika, 23.04.2026

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HYPRSENSE

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MEMS sensing solutions
The enablers for CE and IoT applications

Smartphones

Hearables

Wearables

Laptops & Tablets

Robots & Drones

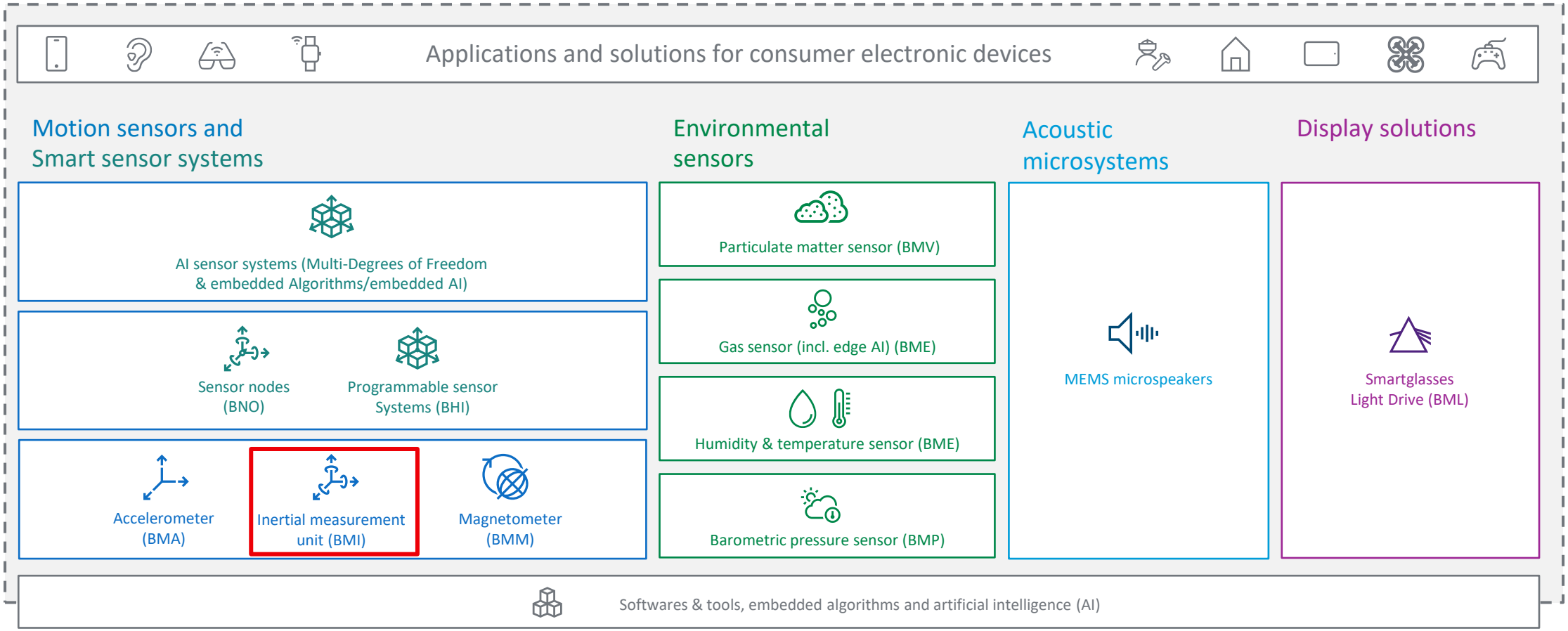
Gaming & TV

Air quality

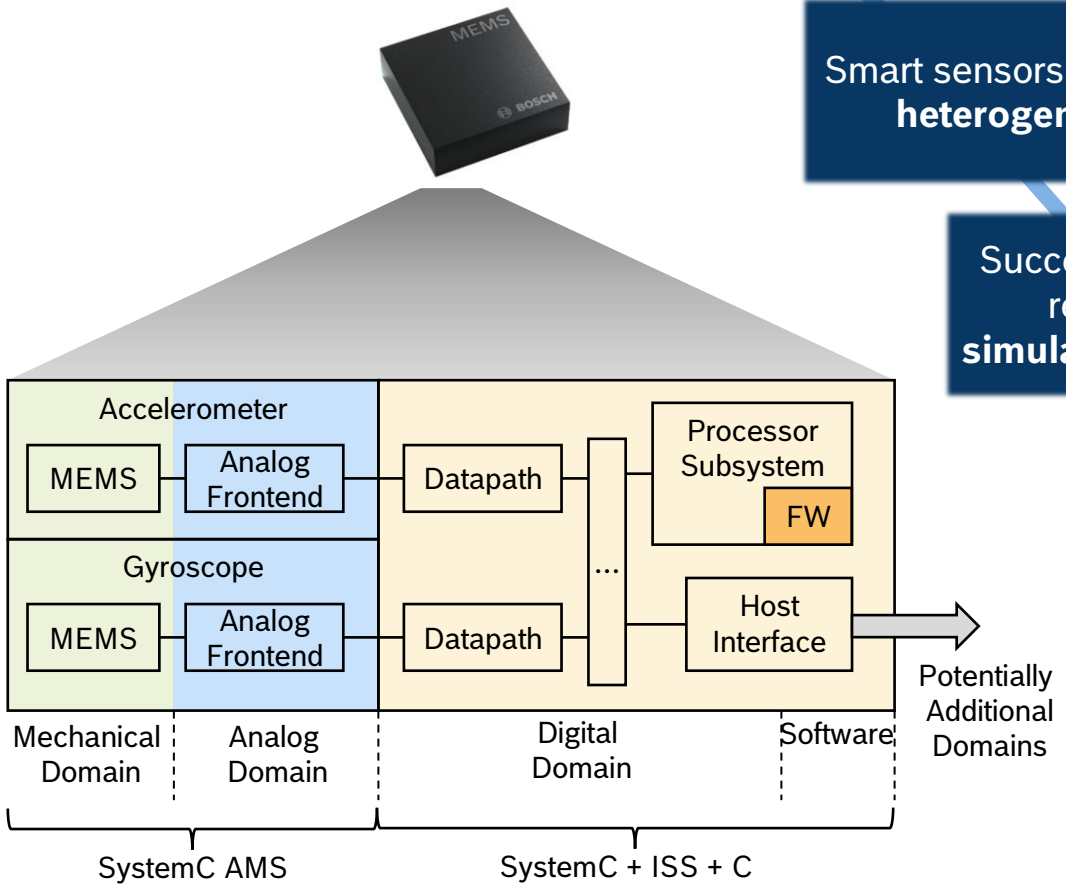
IoT, Whitegoods, Smart Home

AR/VR Glasses & Headsets

MEMS sensing solutions
Our portfolio



Motivation and Idea
The Need for Heterogeneous Virtual Prototypes

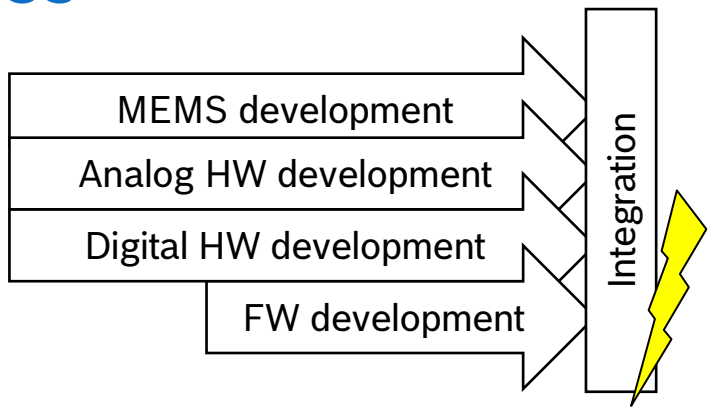


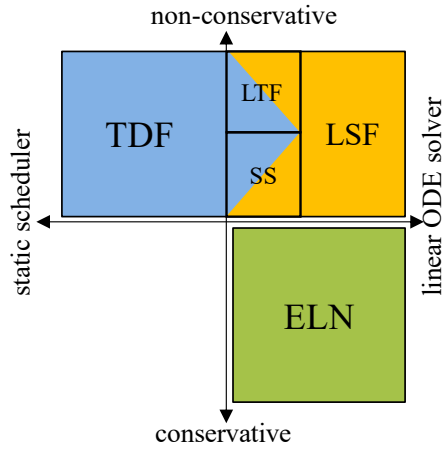
Smart sensors are highly **heterogeneous**

Successful integration requires early **simulation capabilities**

DE simulations are fast, but we also need **fast AMS simulation**

Approach: **SystemC AMS** with **adaptive solvers**





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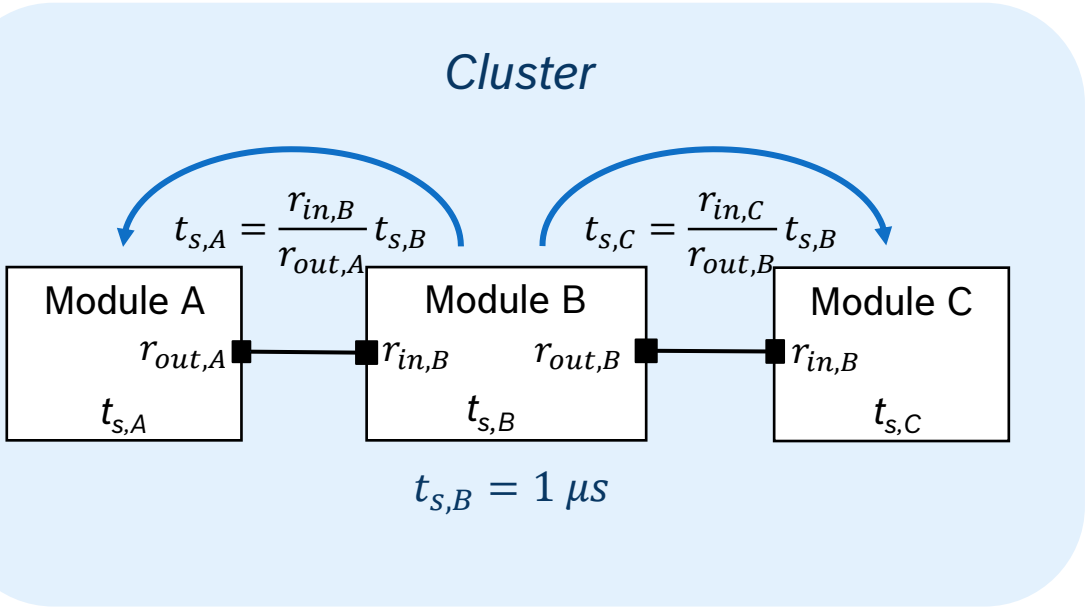
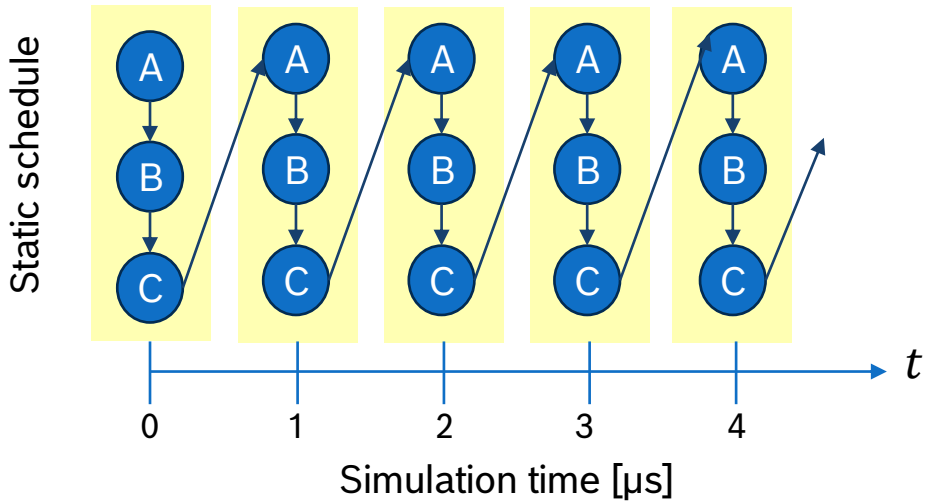
Adaptive Step Size Control in SystemC AMS

Starting Point





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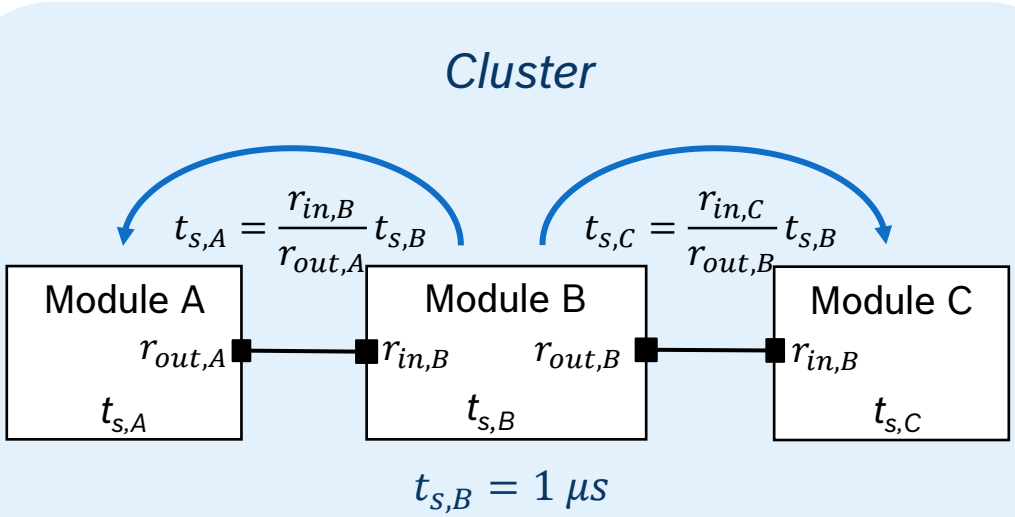

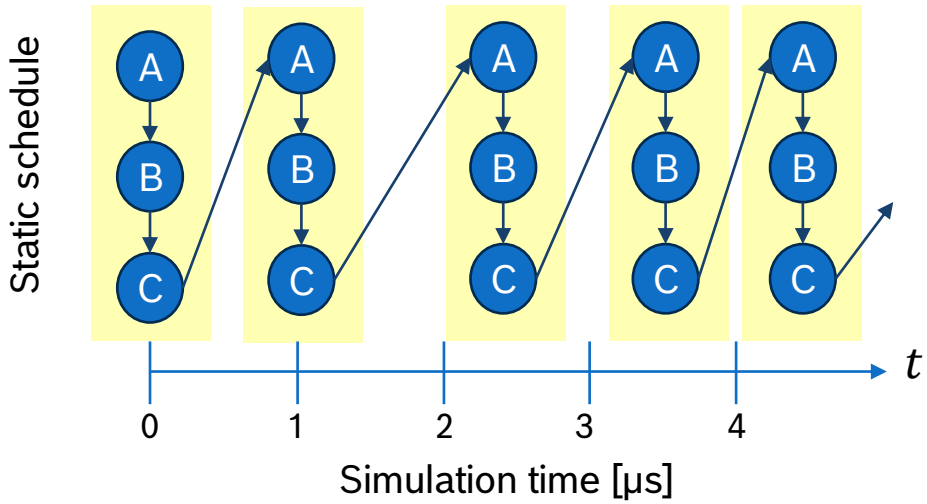

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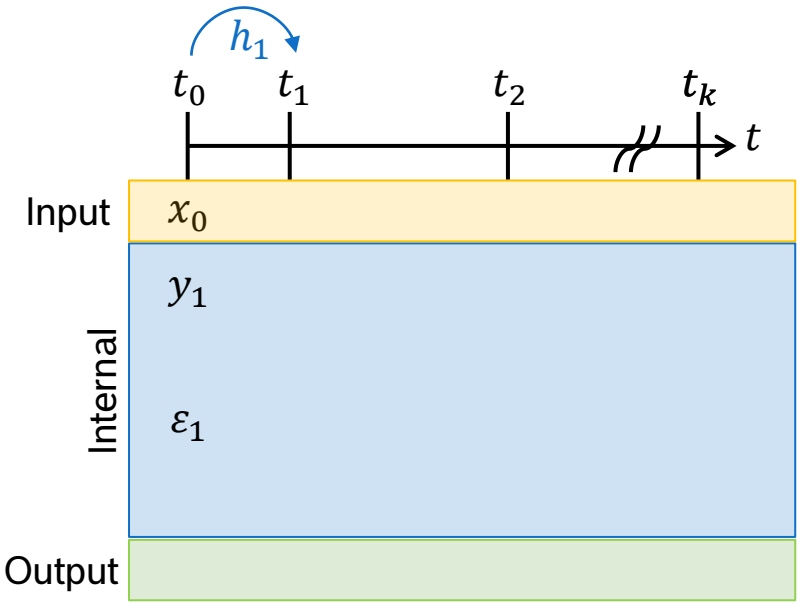
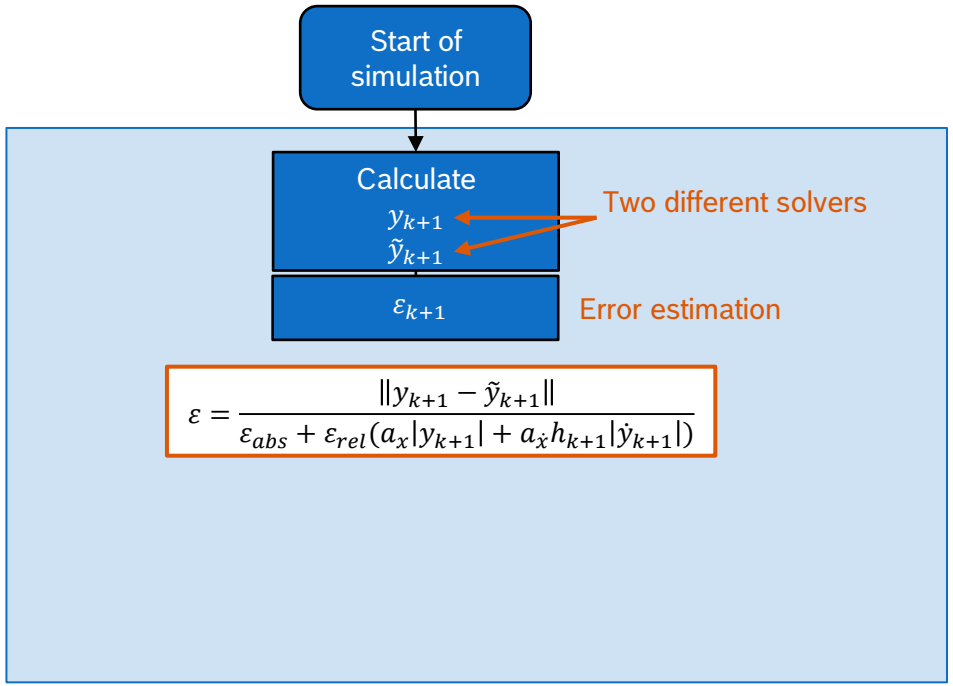
Method 1: PRECALC

Mechanism: Pre-calculation





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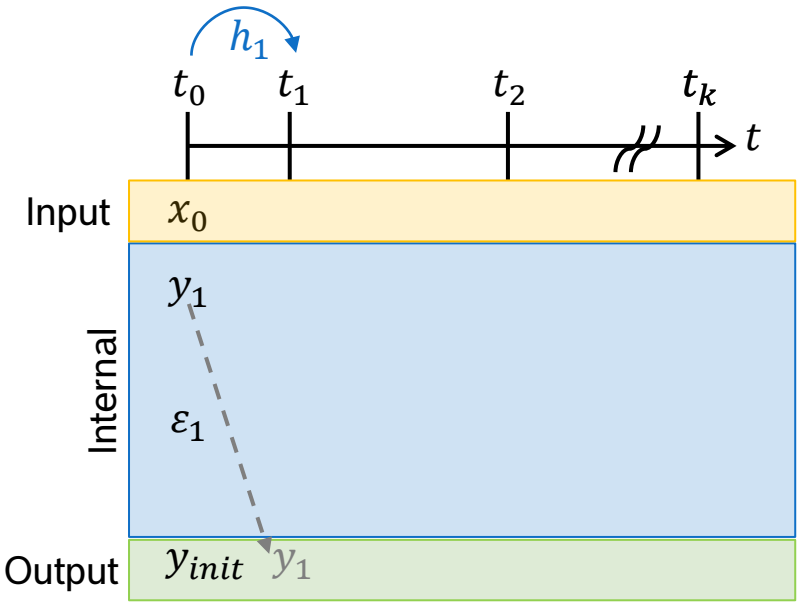

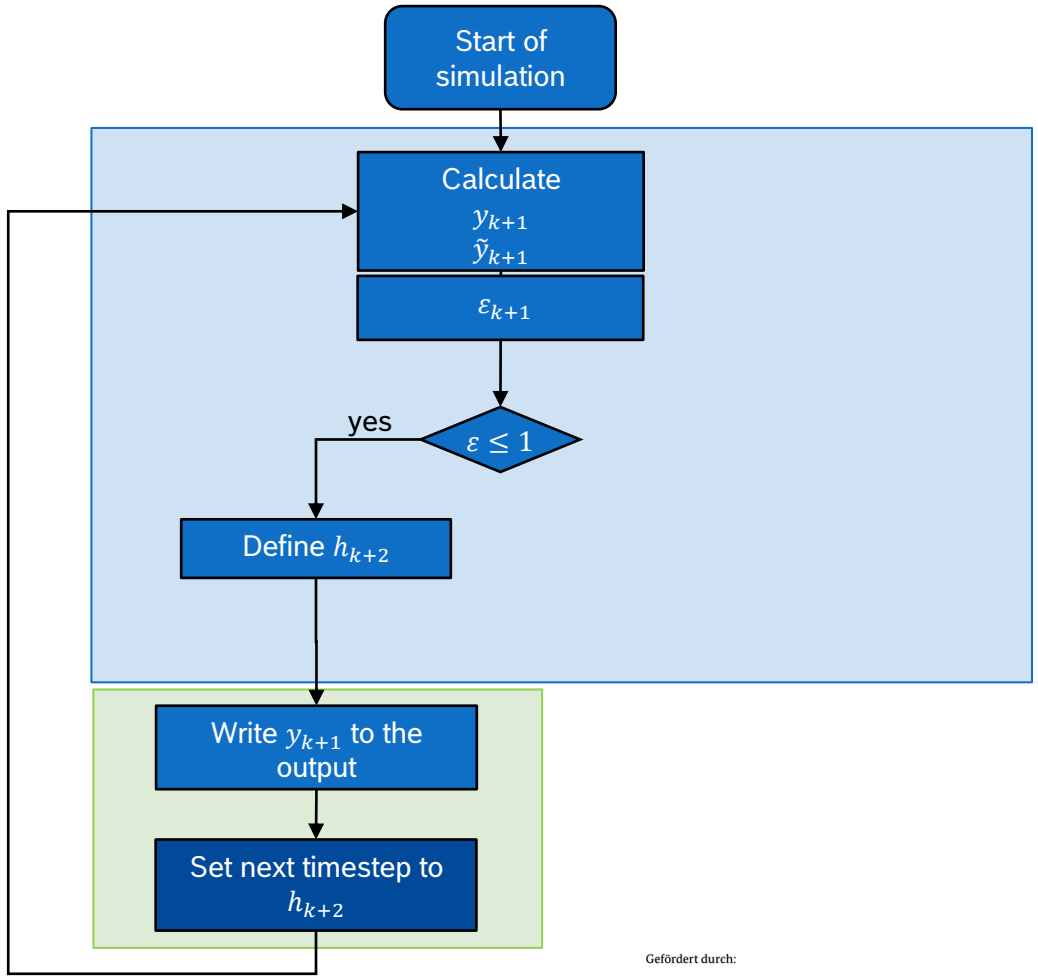

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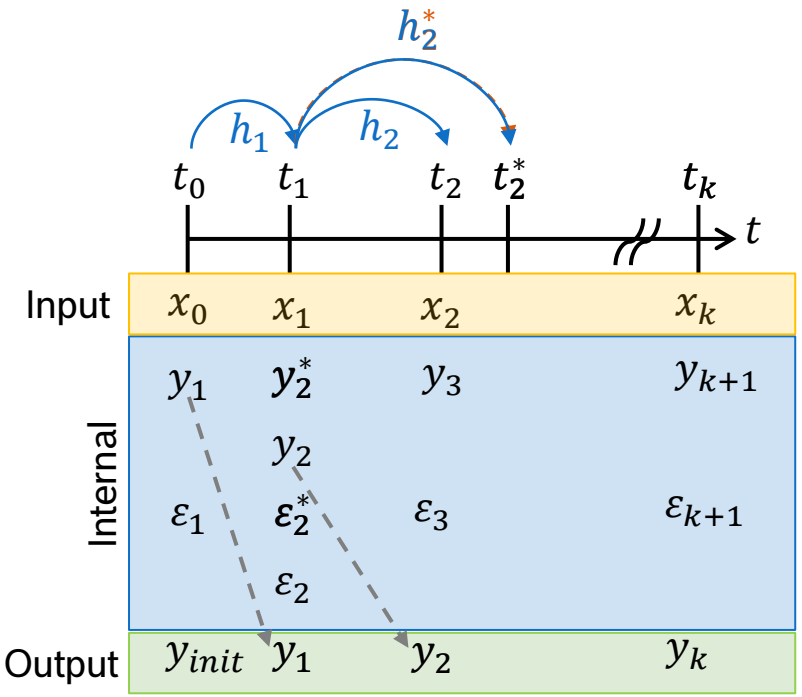

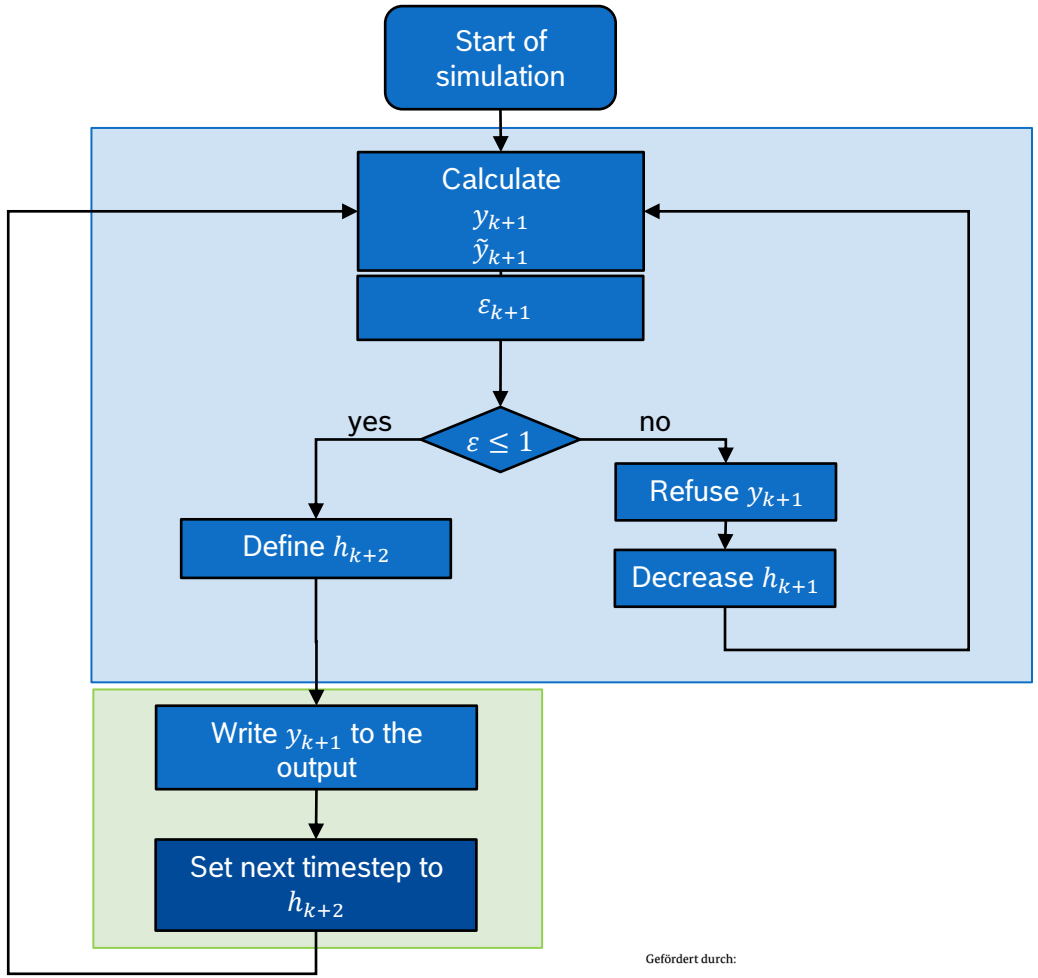

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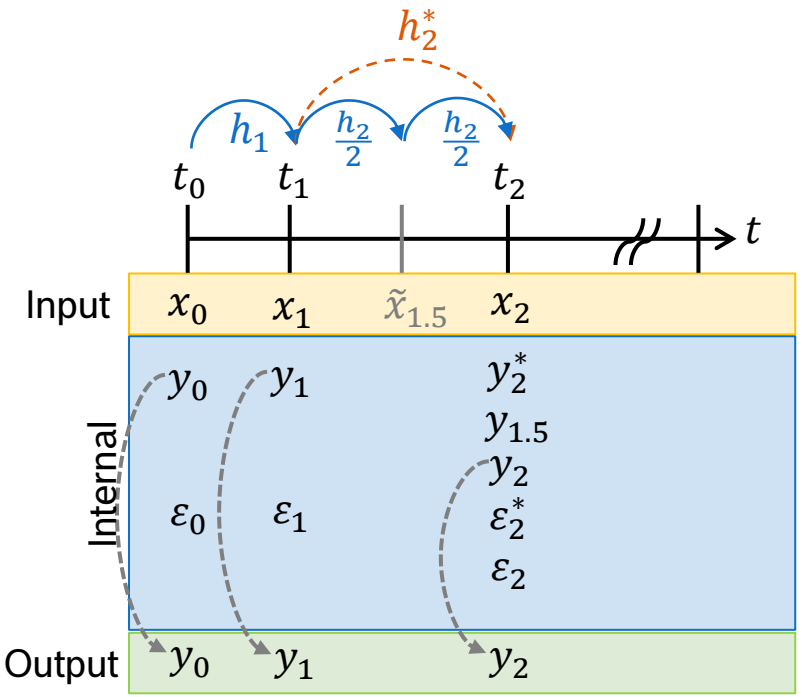
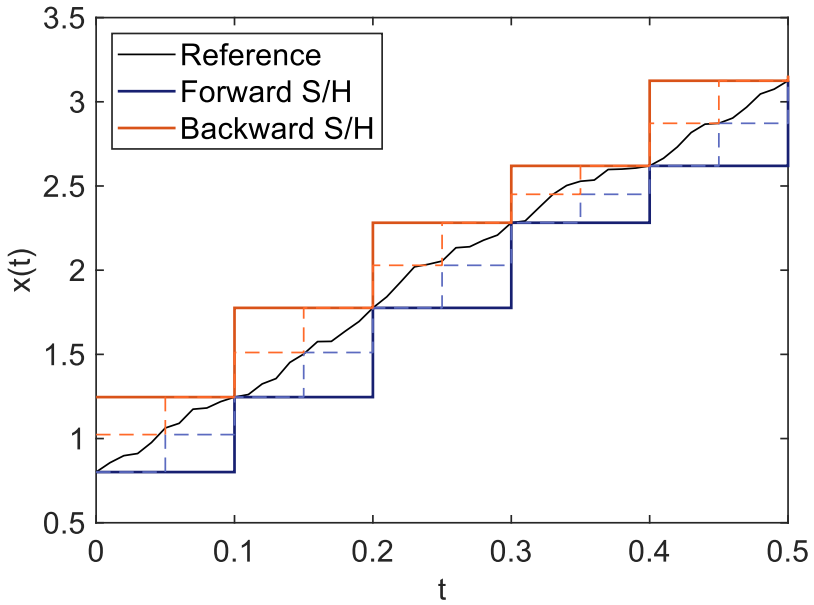
Method 2: SEGMENT

Mechanism: Segmentation





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Summary of Methodologies

PRECALC: Pre-calculation using a delay at the output

SEGMENT: Internal refinement using segmentation and interpolation

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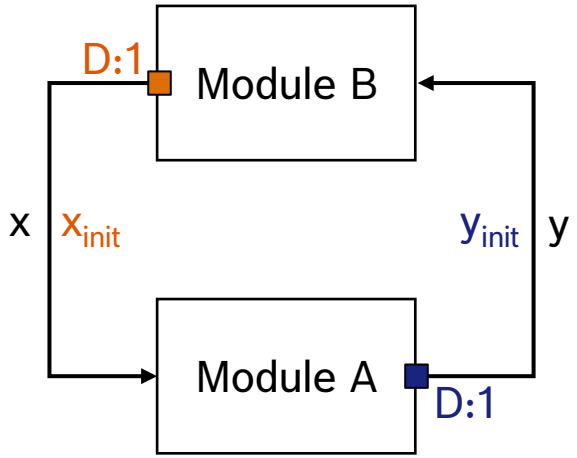
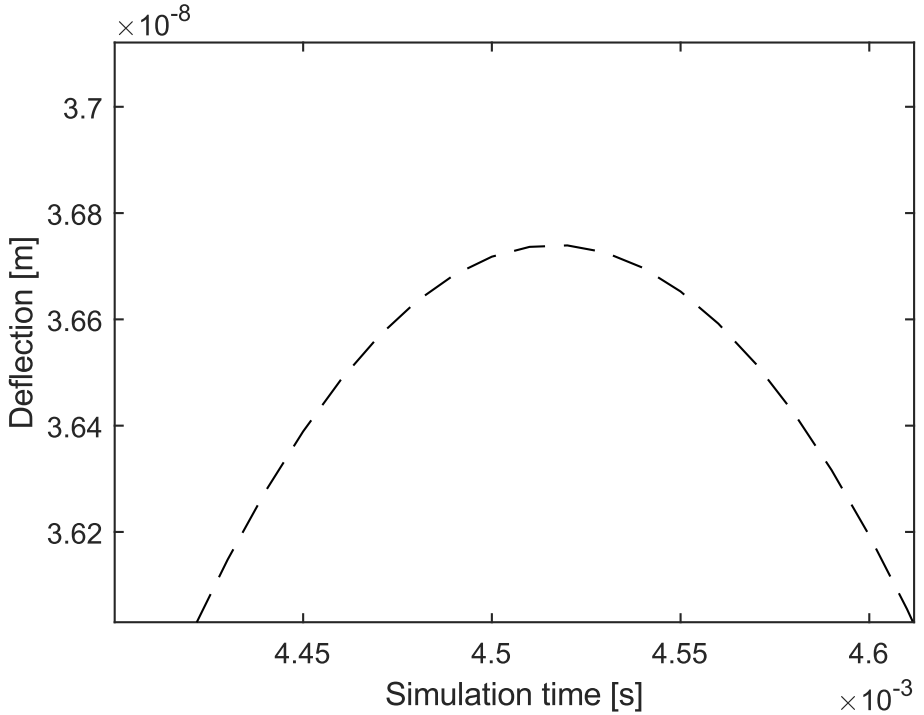
Analysis of Methodologies
Feedback Loops



Schedule:
{A, B}
{B, A}



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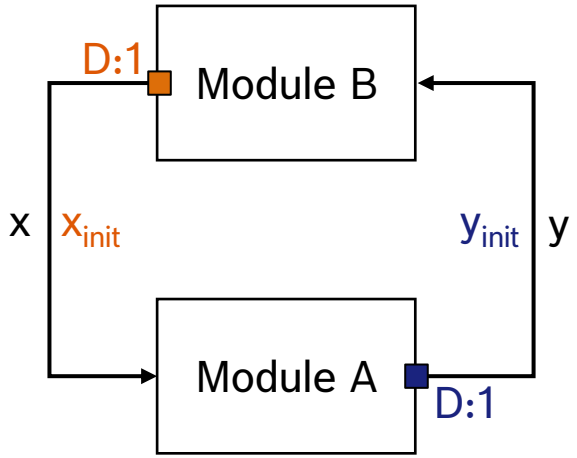

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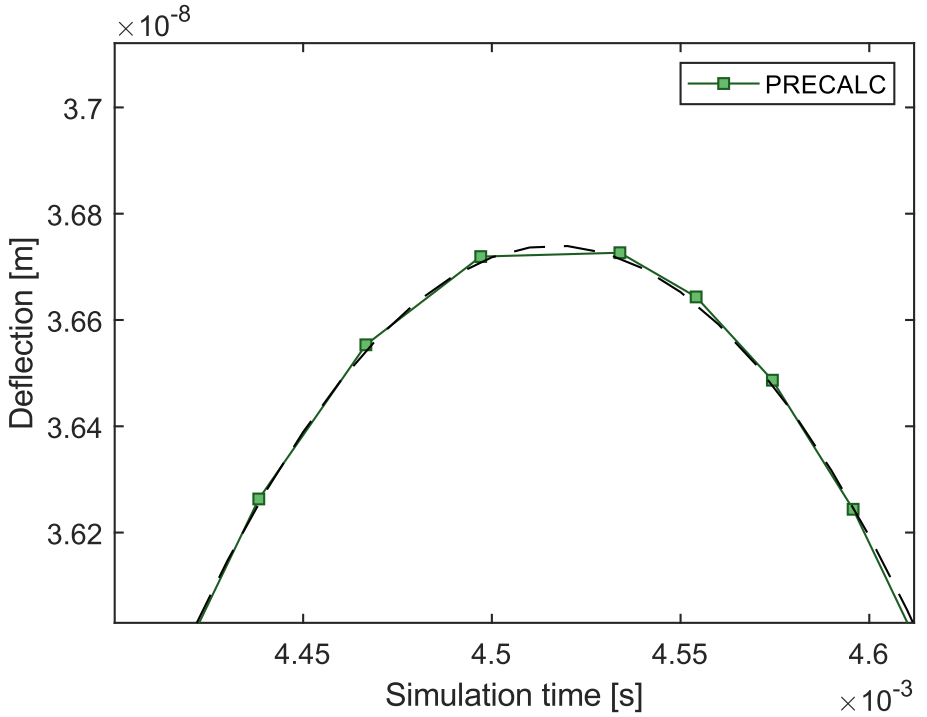

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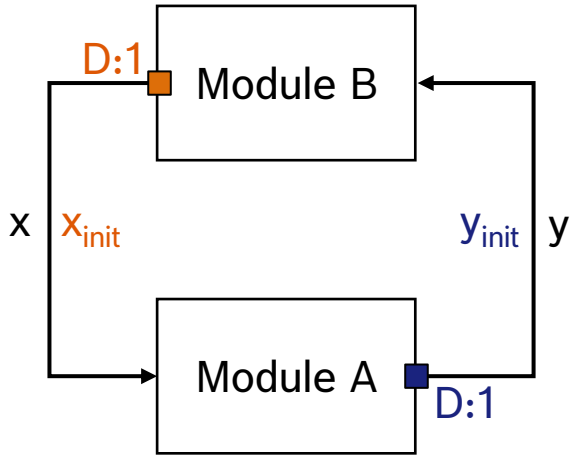

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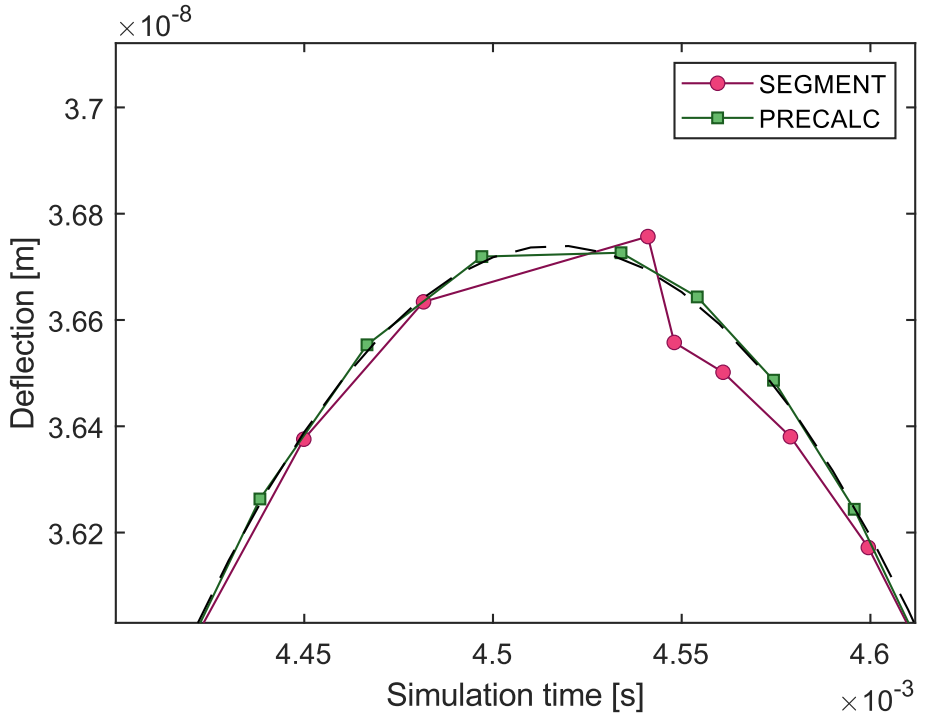

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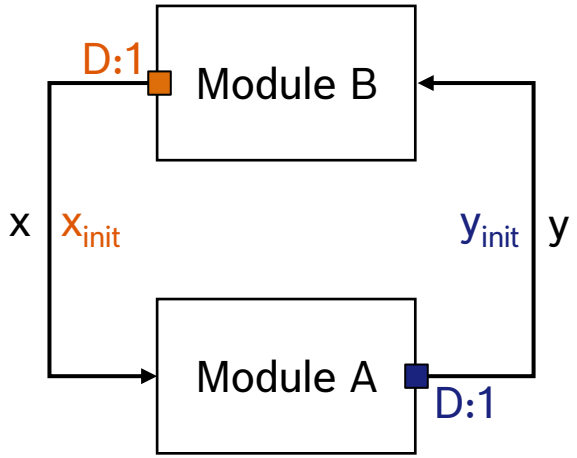

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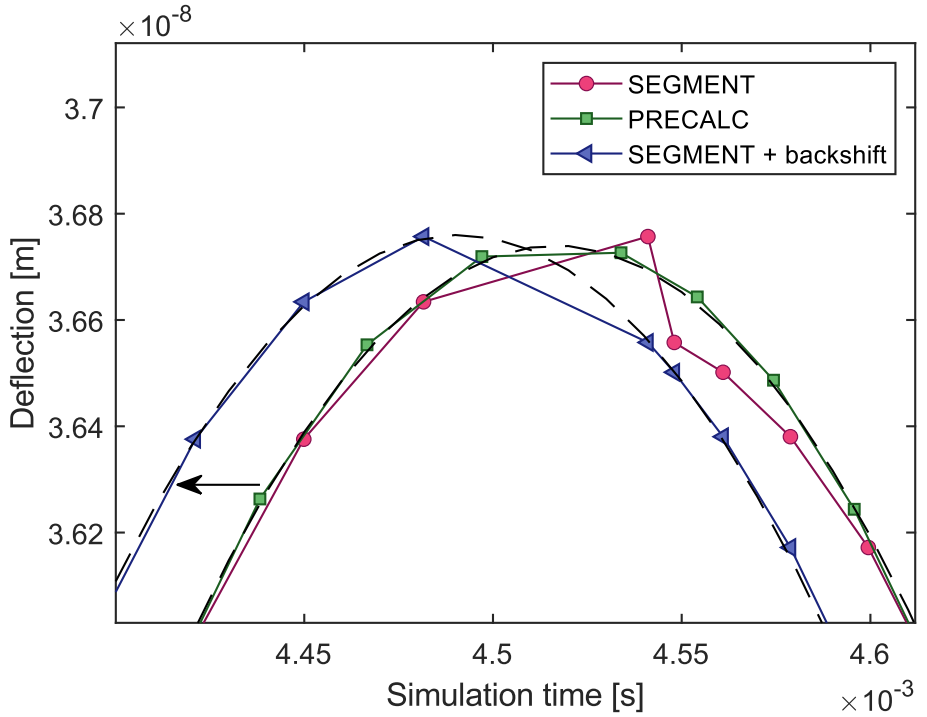

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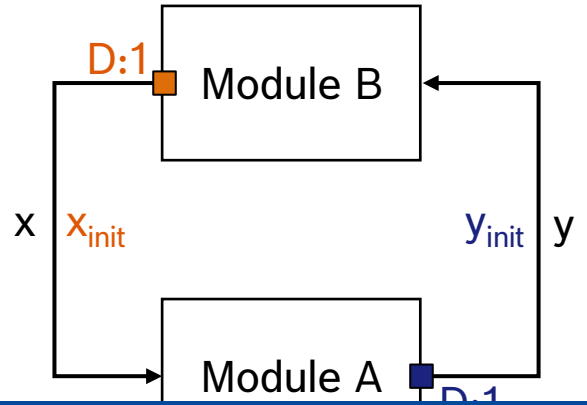

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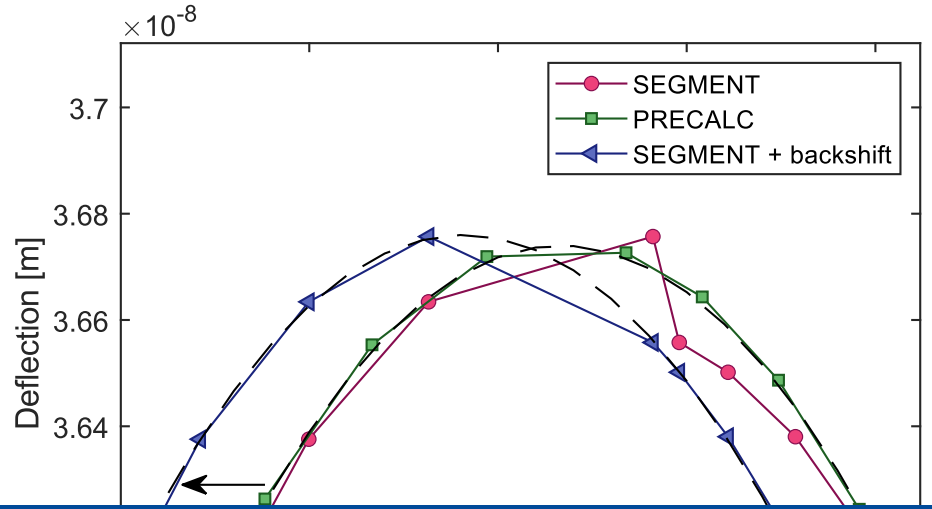

Feedback loops:
+ PRECALC
− SEGMENT

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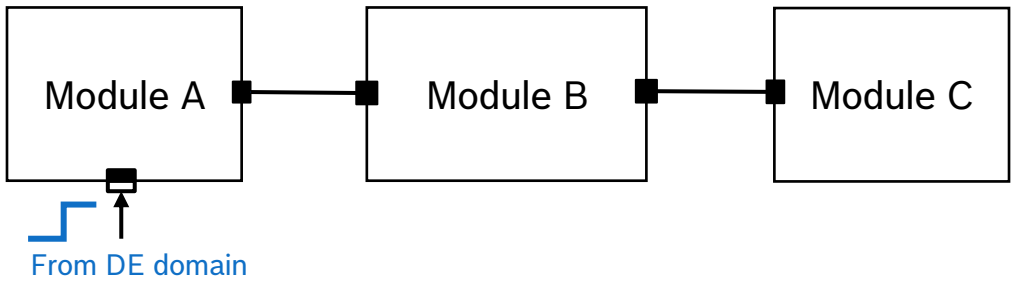
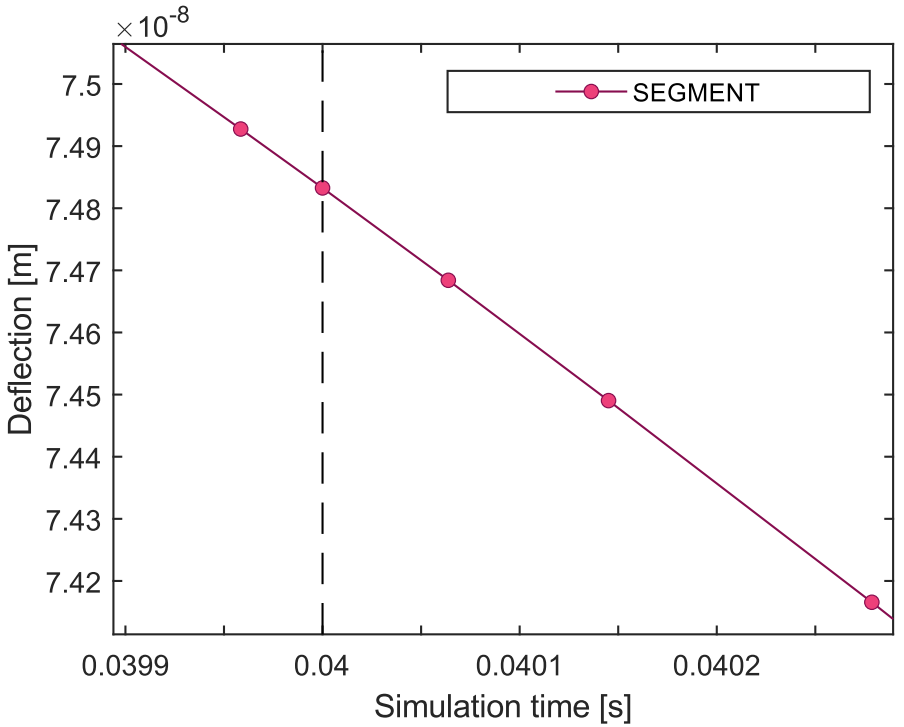
Analysis of Methodologies
Reaction to Discrete Events





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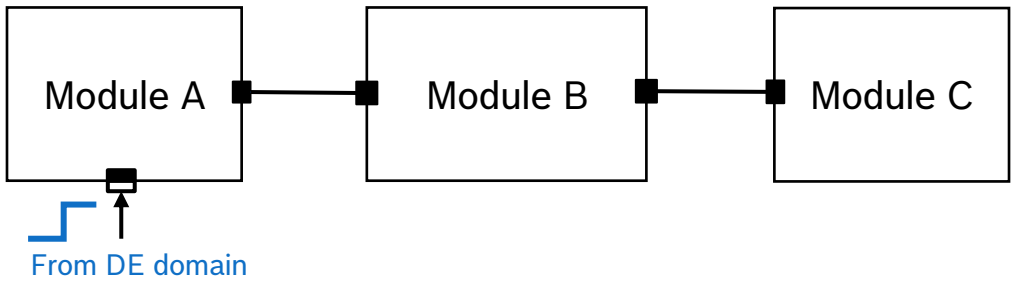

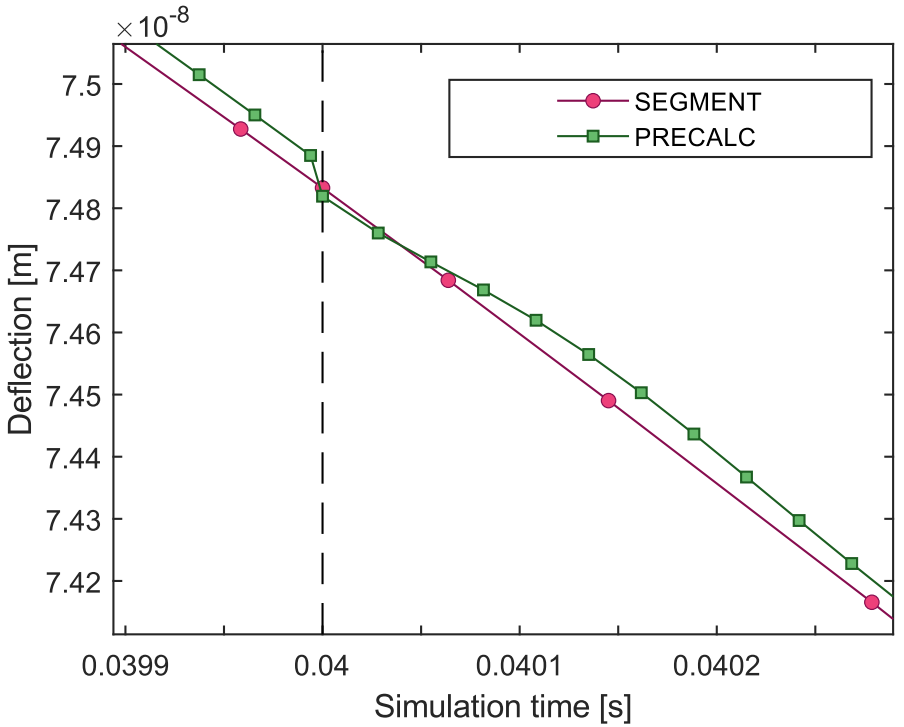

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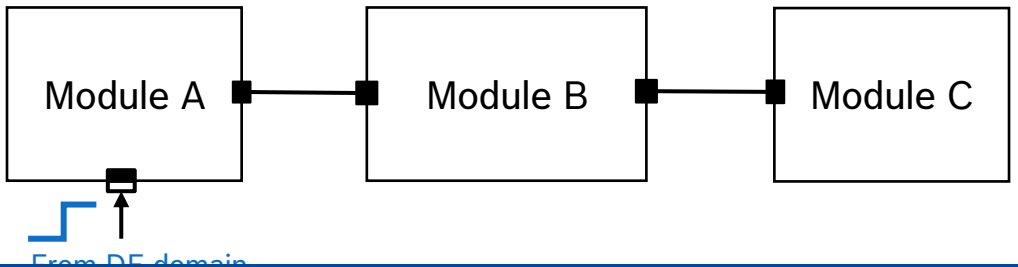

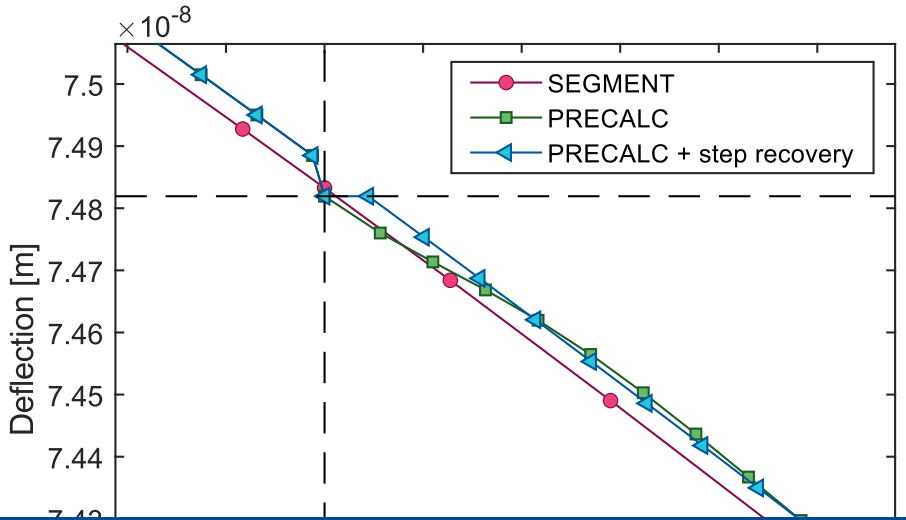

Reaction to discrete events:

\+ SEGMENT

\− PRECALC

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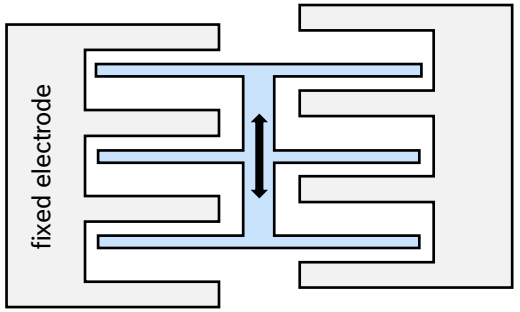
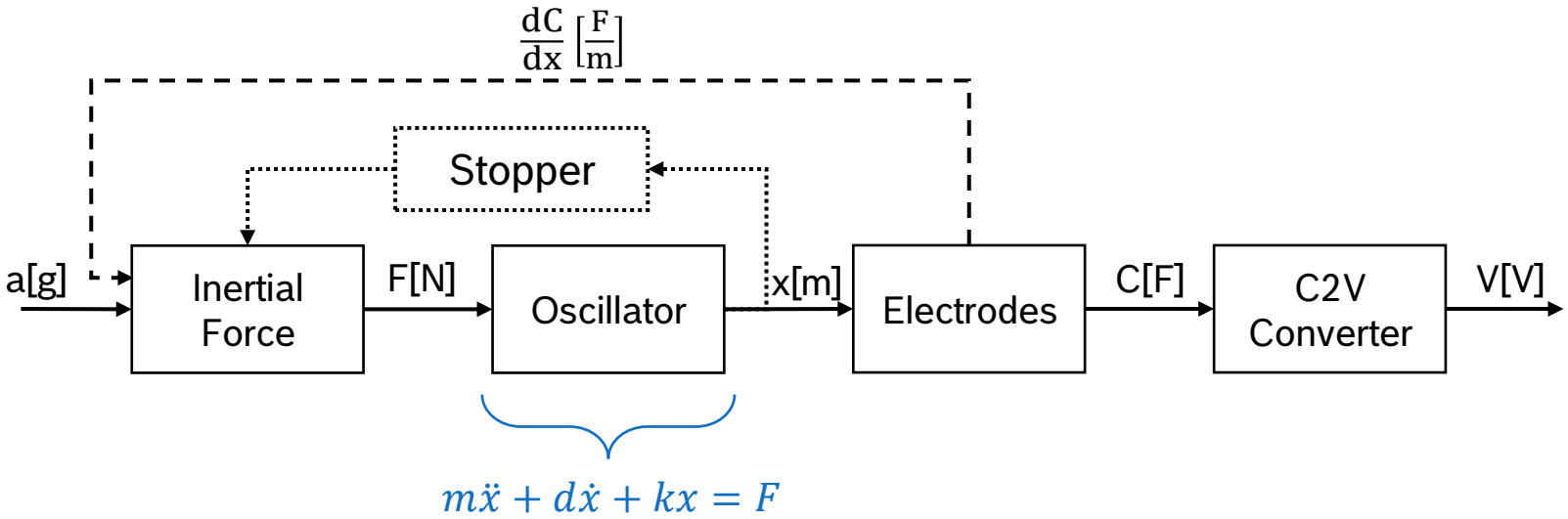
Experimental Evaluation

Simulation Setup





Experiment 1:
Analysis based on artificial stimulus

Experiment 2:
Real-world example

Experiment 3:
Performance estimation

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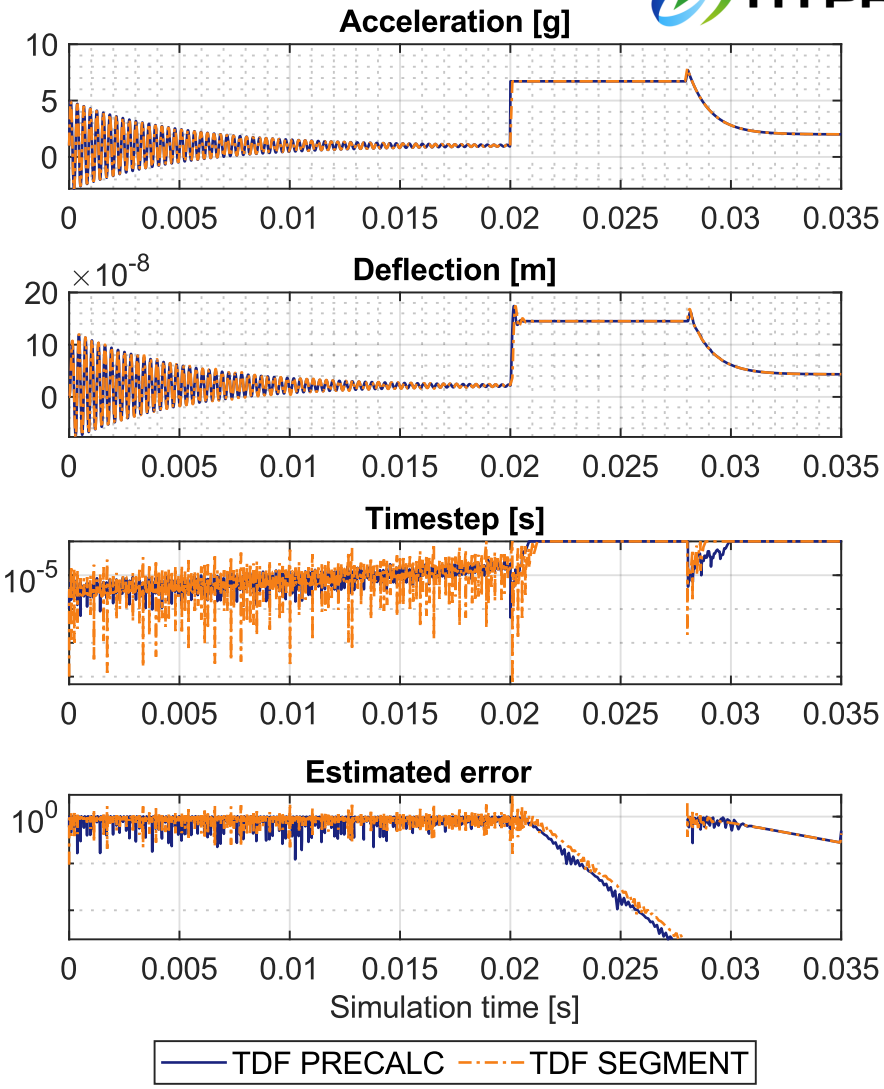
Results
Experiment 1

Artificial Stimulus

- **Section 1: Decaying Oscillation**
  - Visualization of step size control
  - Oscillation: Relative error becomes visible
  - Decay: Absolute error becomes visible
- **Section 2: Discontinuity (Jump)**
  - Robustness of the solver
- **Section 3: Constant**
  - Time step restriction becomes active
- **Section 4: Slow Changes**
  - Solver converges quickly against max. time step



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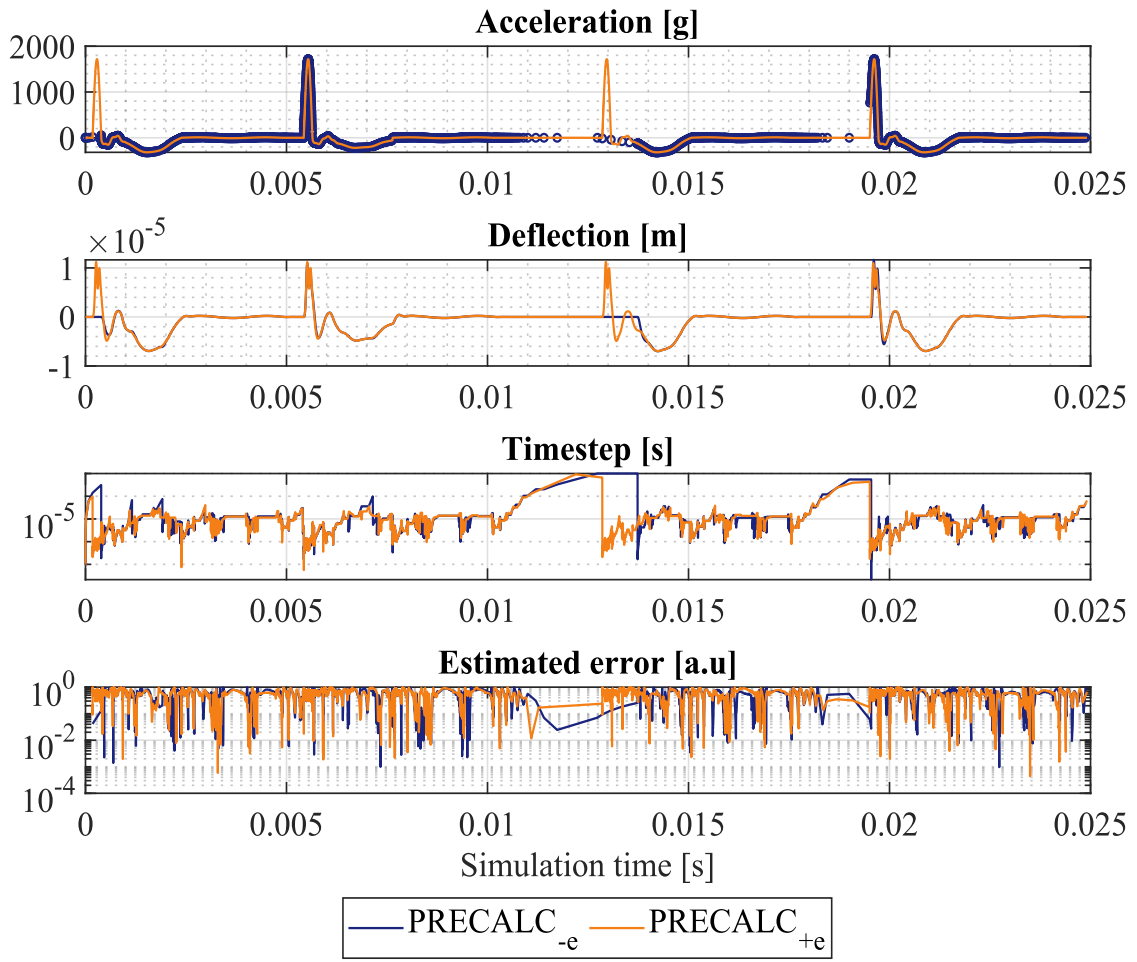
Results
Experiment 2

Repeated shock robustness

- **Challenge: Long break times**
  - Time Step Converges to the Maximum
  - Limited reactivity
  - Short shocks can be missed
- **Solution: Event-triggered shocks**
  - Precise start time of each shock
  - Solver automatically reduces the time step
  - Time savings during rest phases



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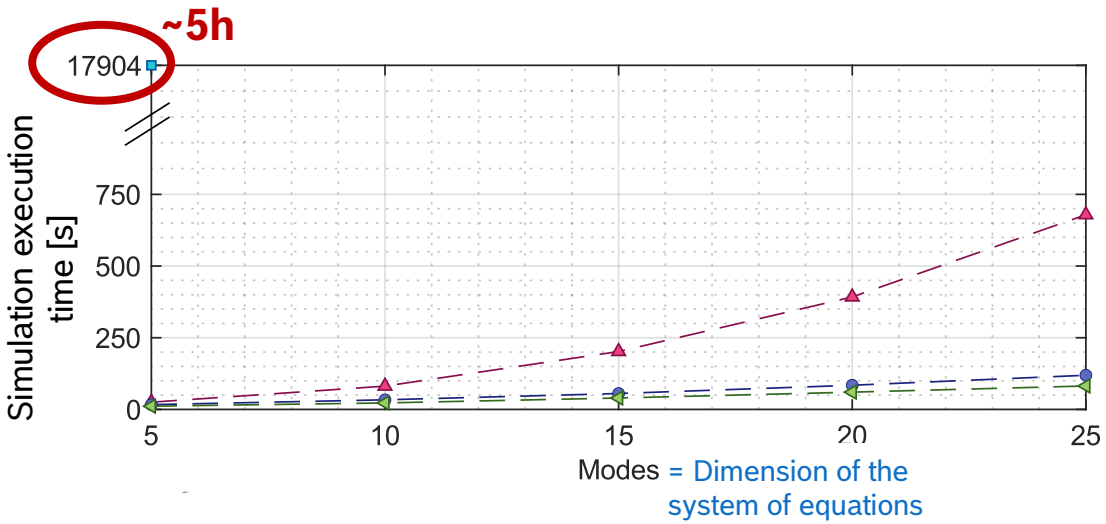
Results
Experiment 3

Repeated shock robustness

- **Opportunity: Long break times**
  - High potential for adaptive solver
  - Simulation would take several hours with a small fixed time step!
- **Challenge: Reinitializations of the solver**
  - Recurrent matrix inversions
  - Reduces the effectiveness of timestep control for large differential equation systems
- **Solution: Time Step Quantization**
  - Discrete number of allowed time steps
  - This limits the matrix inversions



= new approaches

PRECALC
Quant (H=60)

Optimized combination of speed and accuracy

Fixed ($t_{s,min}$)

Low speed, **high** accuracy

Fixed ($t_{s,mean}$)

Low accuracy, **high** speed

= Reference implementation

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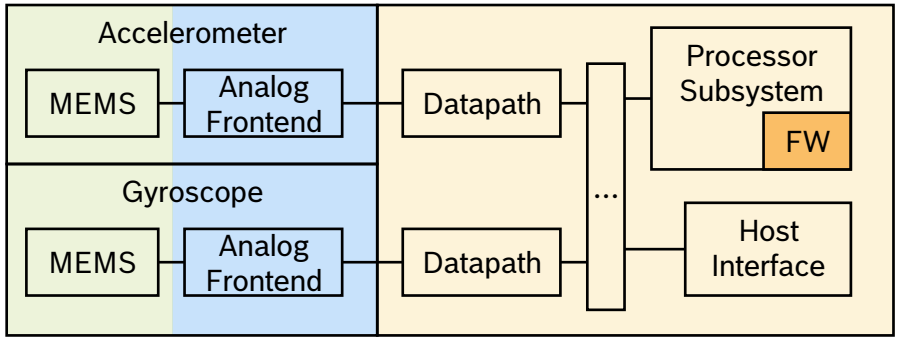
Conclusion and Summary



- Context and Motivation
  - MEMS sensors are complex heterogeneous systems
  - Fast product cycles require efficient development flow
- Heterogeneous virtual prototypes
  - Digital virtual prototypes very successful and reach **high simulation speed**
  - We need efficient methods for simulation of AMS models
- Adaptive step size control
  - PRECALC: pre-calculation of output samples, well suited for feedback loops
  - SEGMENT: segmentation of time steps, flexible handling of forced step size changes
    - due to discrete event
    - Multiple time controlling modules possible

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Outlook

- Introduction of new methods to the Accellera SystemC AMS Working Group
- Extension of existing LTF instances
  - They allow estimation of next timestep *ltf.estimate_next_value()*
  - Introduce new version of that method which returns estimated integration error
  - Enables adaptive time step control

- User defined solver algorithms
  - SystemC AMS uses trapezoidal method by default
  - For some applications, this might not be sufficient
  - Idea: allow the user to introduce his/her own solver

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