Improving WCET Precision for Synthesized Code from Simulink/Stateflow

Lili Tan

Saarland University

Germany

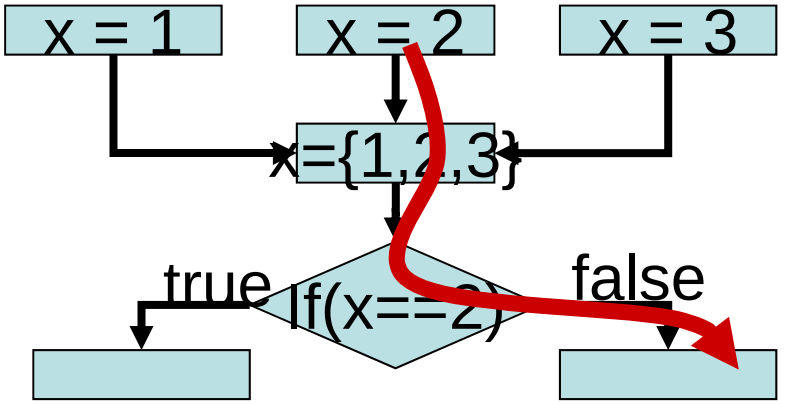
WCET: Worst Case Execution Time

- **WCET bound** required for scheduling
  - **Safe:** safety-critical embedded systems
  - Precise: recourses optimization

- **WCET** is generally not known

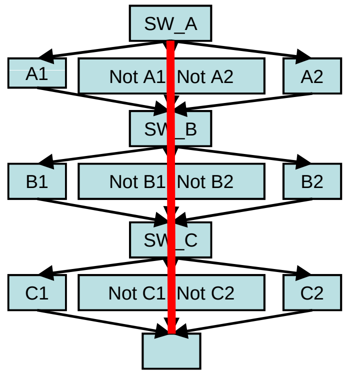
Static Timing Analysis

- Static timing analysis computes superset of execution paths
  - ➔ Safe guarantee in **WCET bound**



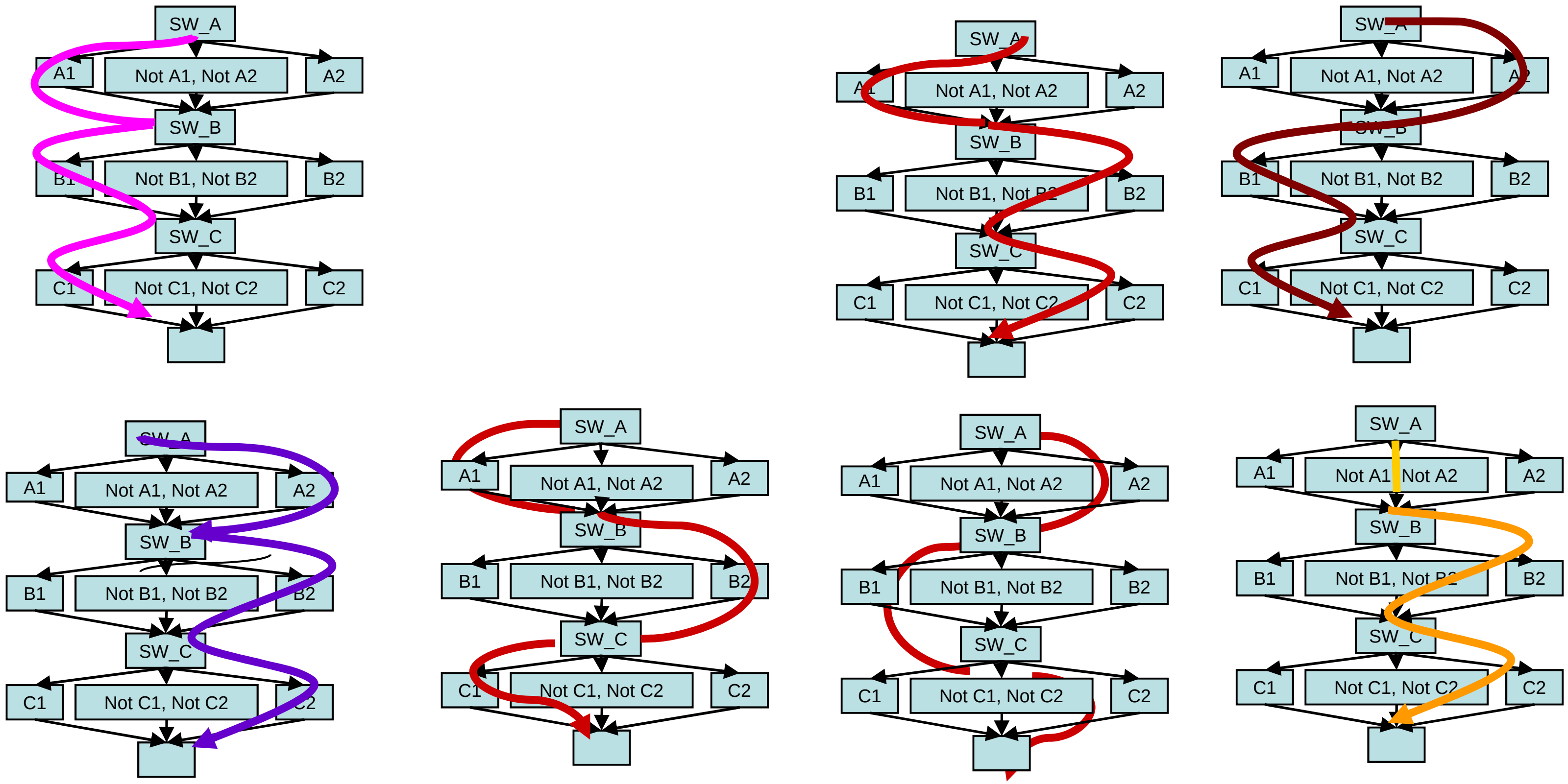
- Potentially overestimation
  - relations between conditions are often not tracked precisely
  - loses context information at control flow joins
  - Context ^context ^context…
  - → Lots of infeasible paths

The problem



Feasible / Infeasible paths ?

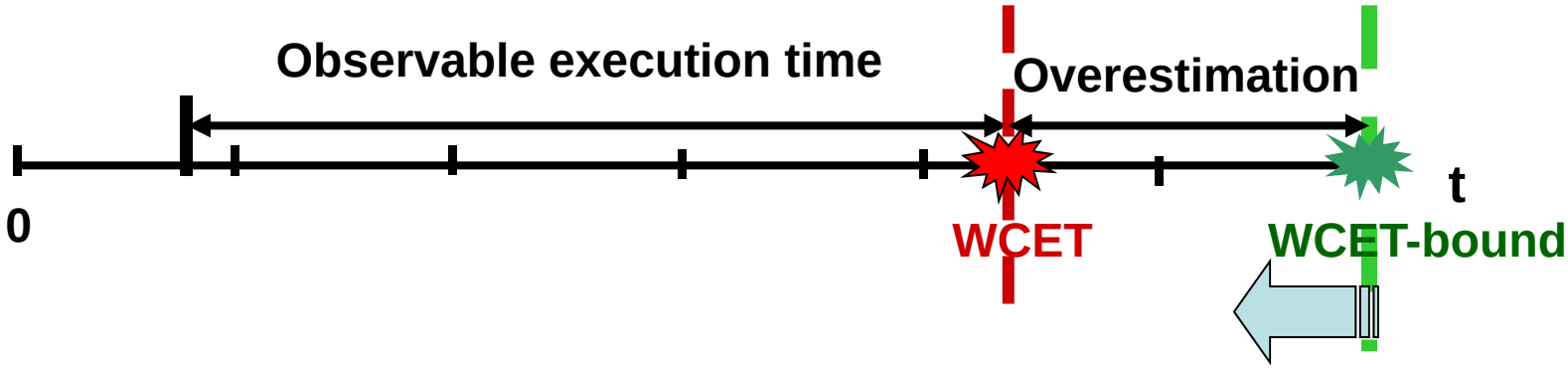
→ Potentially high overestimation



… and more …

Motivation

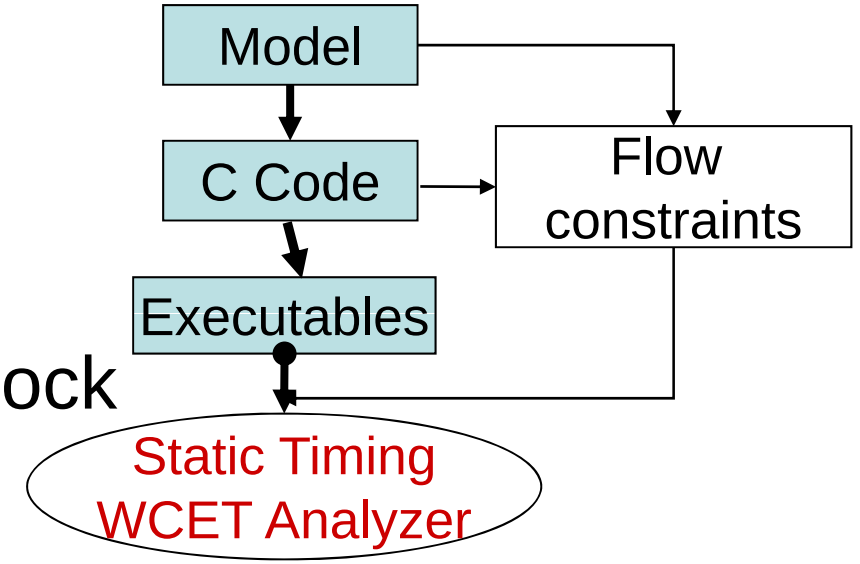
- Improve precision of static timing analysis



- Matlab Simulink/Stateflow widely used in industry
- Leverage context information from model
  → track execution context precisely

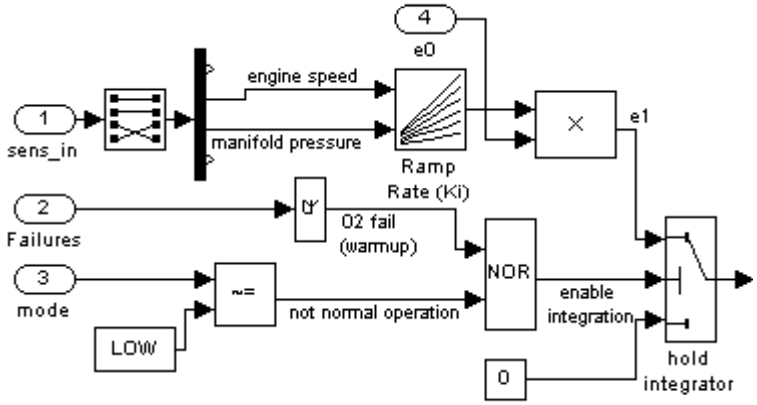
Ideas:

- Relations between conditions are often obvious in models and C code
- Deriving dependency information as flow constraints as input for WCET static analysis tool
  - From single block
  - To correlated blocks
  - To clustered sets of block



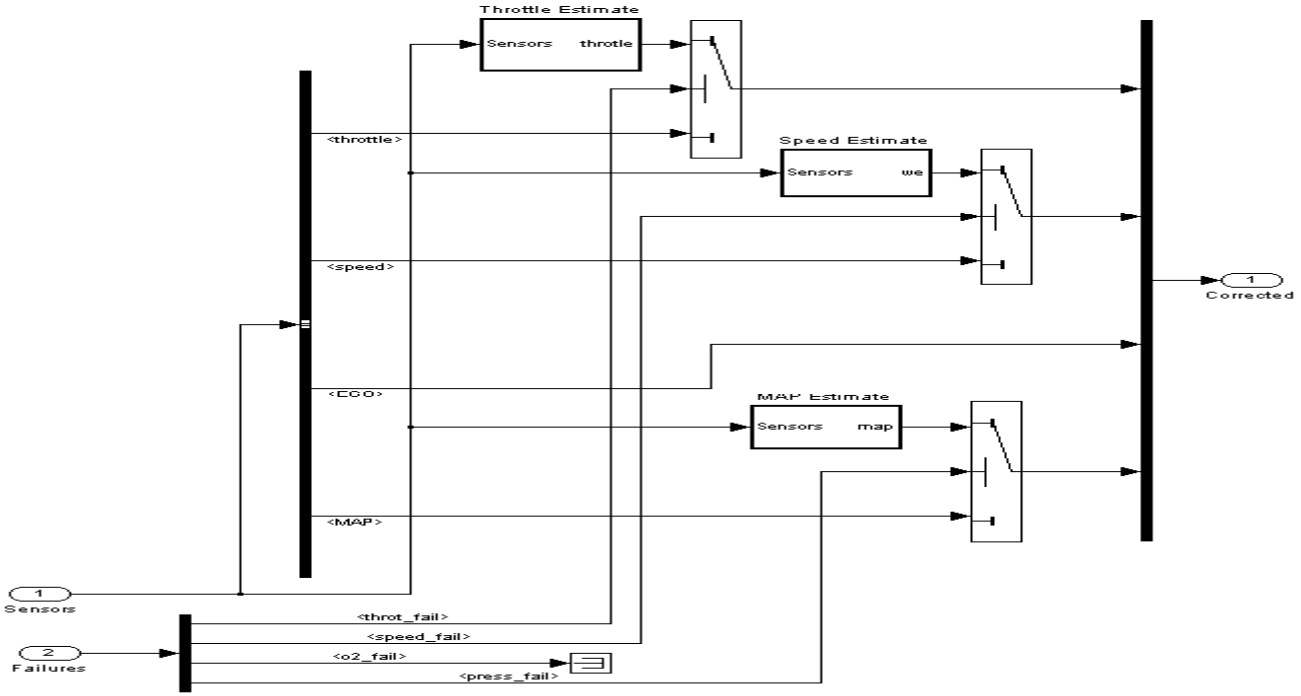
Approaches

- Single block: Use-Define



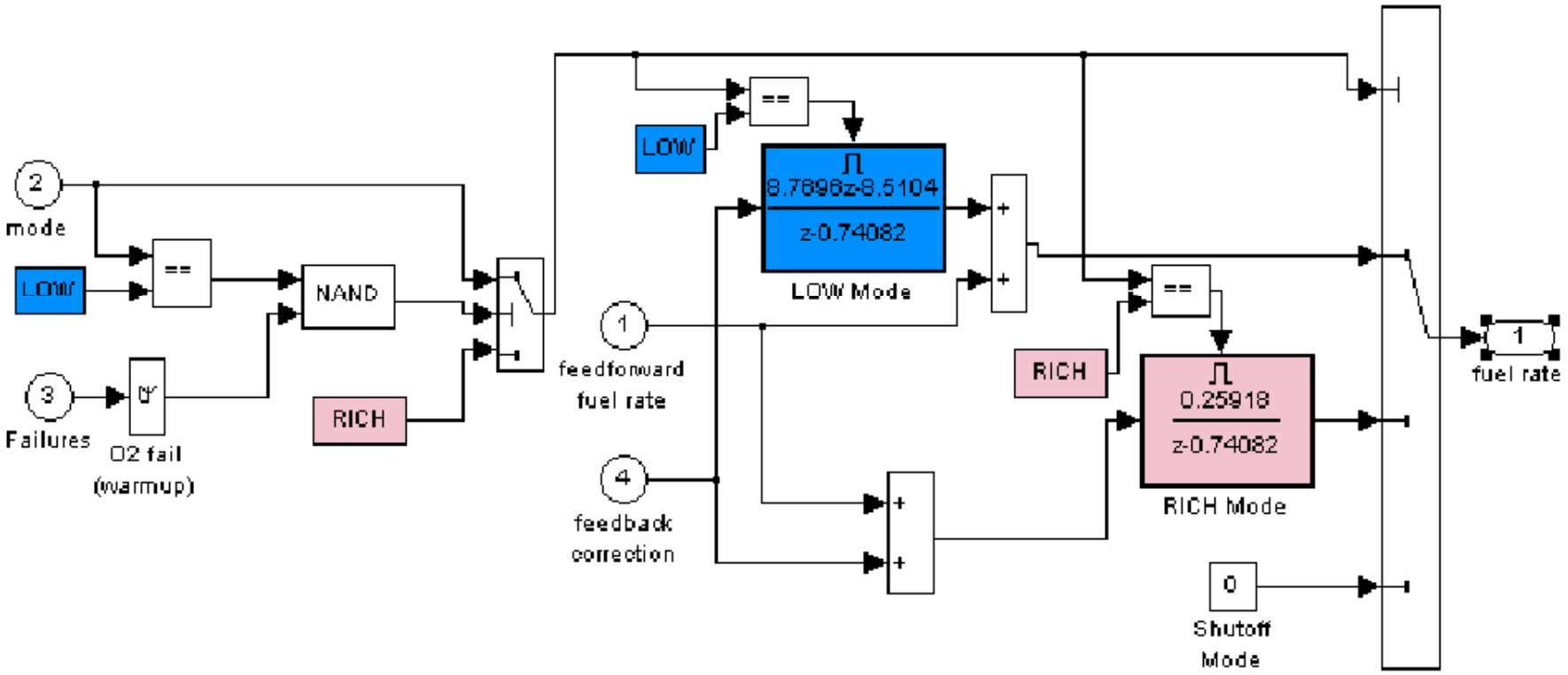
Approaches (cont.)

- Cross blocks: Correlation relations



Approaches (cont.)

- Clustered sets of blocks:
  - Mode-dependent execution context

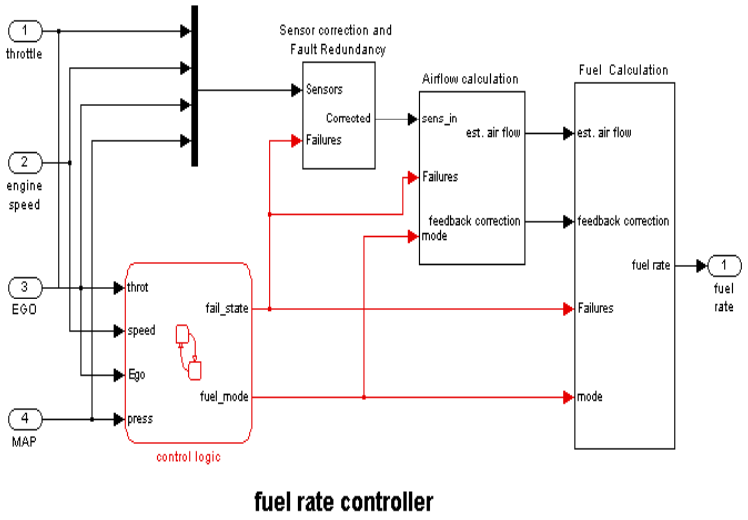


Evaluation setting

- Tool: aiT WCET Analyzer
  - Analysis executables as input
  - Used in aerospace industry, especially Airbus French
  - Extended to users inclusive automotive domain
  - Successes in the WCET Tool Challenge 2006

Evaluation setting (cont.)

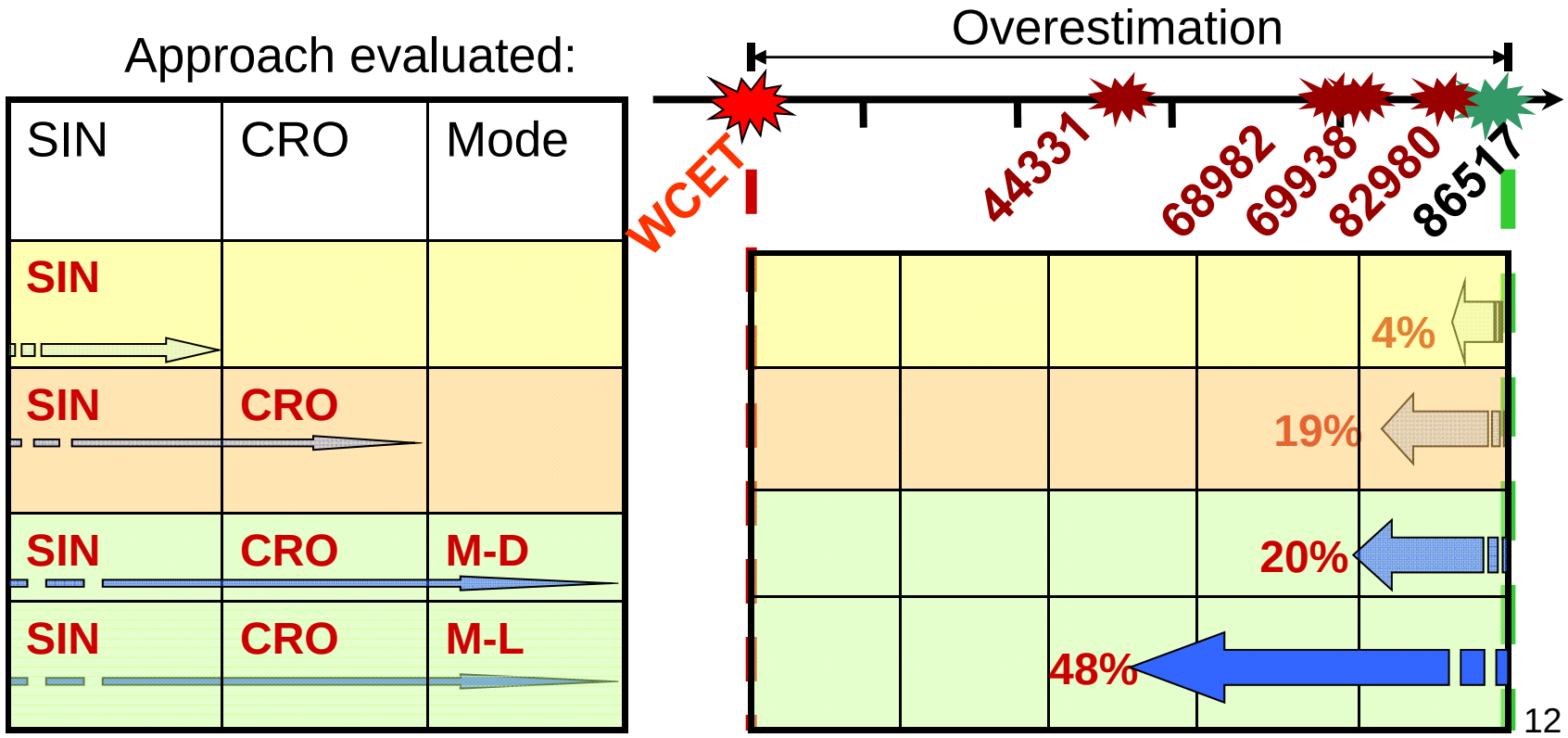
- Benchmark from Matlab : Fuel-rate control system
  - Automotive application
  - Typical PID control with reconfigurable control logic for operating modes
  - Size:
    - Model (.mdl) size: 196 KB
    - Generated C and h files
      - File count: 12
      - File size: 116K
      - K-LOC rating: 2.762
      - Average K-LOC: 0.23
    - Executables (.elf) size: 37 KB TriCore 1769B



fuel rate controller

Experimental results

- Precision improvement: 19%
  - More precise in mode-specified execution context, depending on scheduling requirement



Conclusion

- Developed concepts and methods to improve WCET precision by deriving flow constraints from models.
- Evaluated the proposed methods with industrial WCET tool and benchmark of Matlab:

  →Initial results is promising in precision improvement
- Future work
  - Apply to real industrial application
  - Extend to automatically implementation
    - Flow constraints generation and transformation from .mdl

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Thank you!

Lili Tan

tlili@hotmail.com

http//rw4.cs.uni-sb.de/people/lili.shtml

Saarland University

Germany