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Comparing Performance Analysis Methods on an Industrial Case Study

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BODERC Project

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Aim: improve high-level design of mechatronic systems

Includes

- **multi-disciplinairy design space exploration, focus on performance**
- **analysis of system-level decisions**
- **predict consequences of design decisions as early as possible**

Carrying Industrial Partner:

océ

TU/e technische universiteit eindhoven

University of Twente The Netherlands

CHESS

Imtech ICT

PHILIPS

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Collaboration on case study

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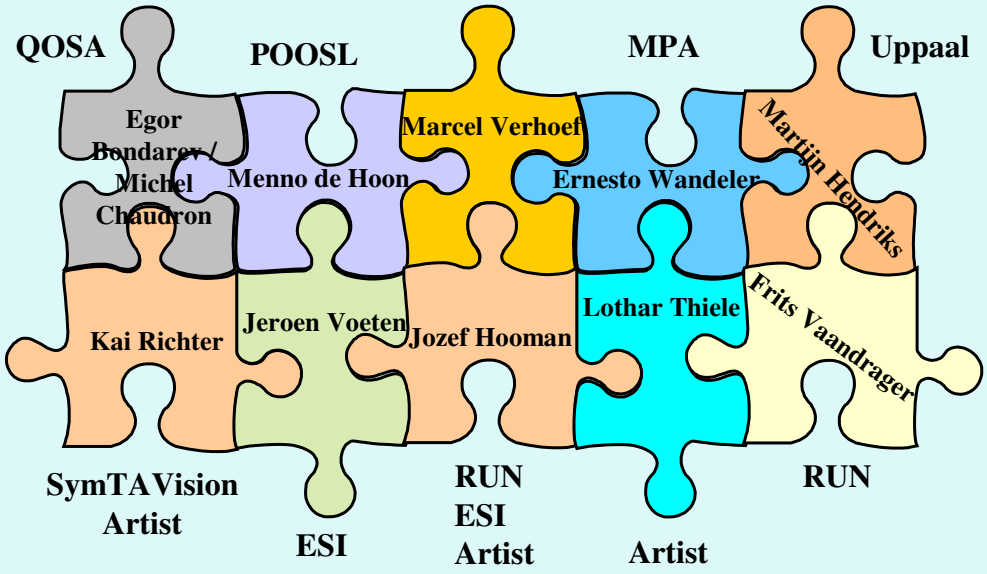

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Agenda

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- Why comparison of techniques?
- Suitable benchmark
- Early results
- Lessons learnt

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Business perspective (1)

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- **Why performance analysis?**
  - **continuous increase in functionality demands**
  - **continuous drive to reduce cost price**
  - **tighter time-to-market demands**
  - **rapidly evolving technology**
- **over dimensioning not longer viable ($)**
- **need for early design choice impact analysis**
- **and continuous monitoring over life cycle**
- **still not always recognized in industry!**

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Business perspective (2)

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"Does The Product Work?"

"Does The Product Work Given a Set of Hard Resource Constraints?"

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Fighting The Complexity Battle

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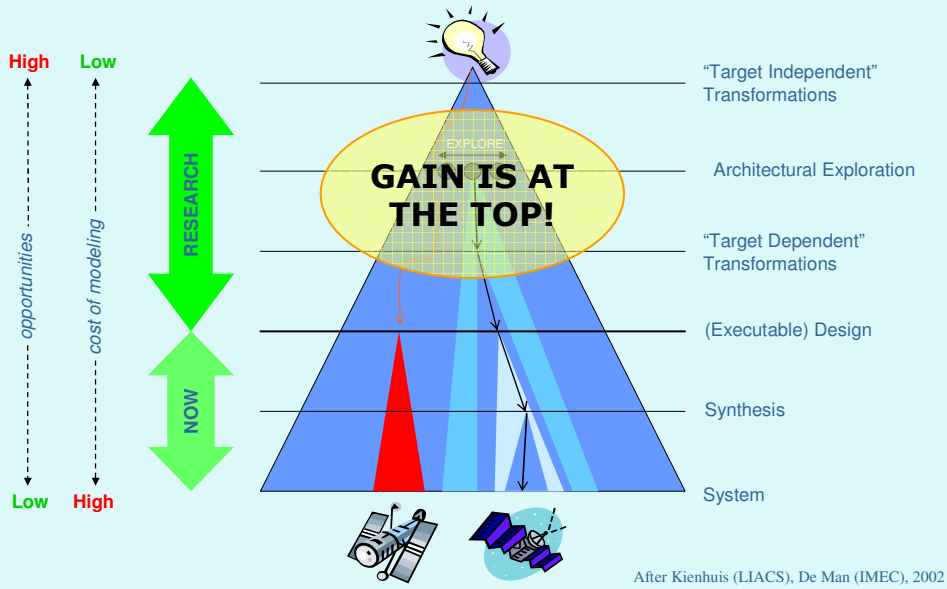

After Kienhuis (LIACS), De Man (IMEC), 2002

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Business perspective (4)

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- **finding quantitative answers in the early life cycle is very hard, there are many unknowns**
- **"shooting at a moving target"**
- **need for a light-weight approach that can deal with highly interactive nature of the design process**

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Why comparison?

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- **Trade-off between *effort* and *insight gained* not well understood**
  - **Investment: modeling effort**
  - **Investment: analysis effort**
  - **Return-on-investment: question answered? what accurracy?**
  - **Return-on-investment: question answered on time?**
- **Problems industry faces**
  - **Many techniques available (DES, QN, STOCH); which one fits my problem? How do I select the proper tool?**
  - **How steep is learning curve; do I need to become an expert?**
  - **Fit with design cycle; disruptive to current way of working?**
  - **Sufficient tool support?**

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Overview performance models

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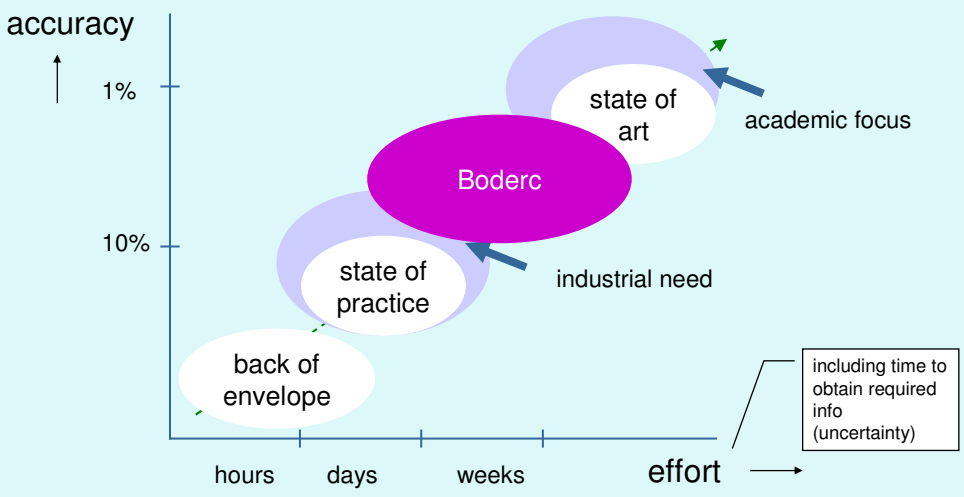

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Aim of our research

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- Understand pros ***and cons*** of techniques
- Build a taxonomy: problem ↔ methods
- Useful combinations?
- Compensate weakness of *'x'* with strength of *'y'* ?
- Fit in design cycle: early ↔ late, throughout?
- Fit in design process: how to introduce *'x'*

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Benchmarking

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- Simple case, such that all techniques can deal with it
- Sufficiently complex to provoke problematic issues
- Extendable to introduce new "sub-problems"
- How to avoid "Lies, True Lies, Statistics" problem?

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The In-Car Radio Navigation System

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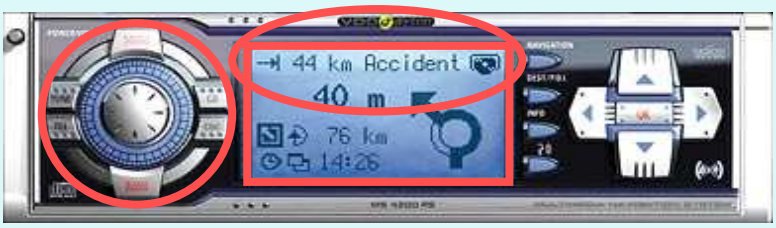
- **Car radio with built-in navigation system**
- **User interface needs to be responsive**
- **Traffic messages must be processed in a timely way**
- **Several applications may execute concurrently**



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System Overview – Change Volume

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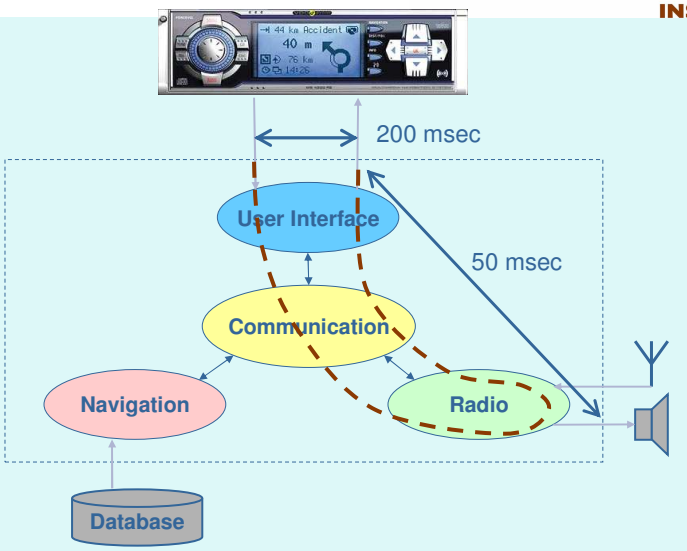

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Application A: Change Audio Volume

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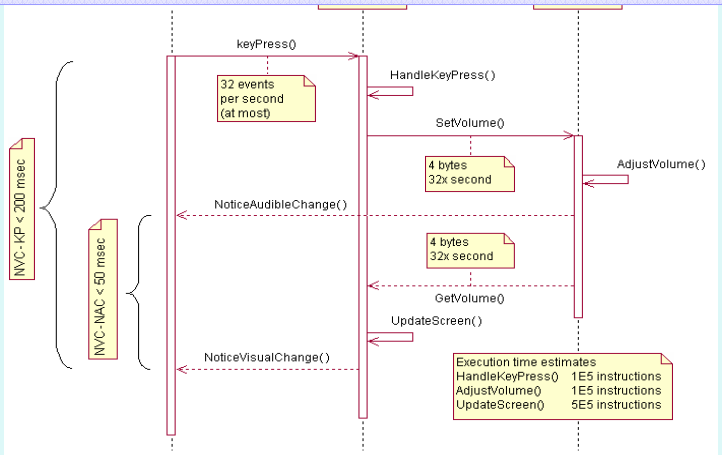
Computation Resource Demand



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System Overview – Handle TMC

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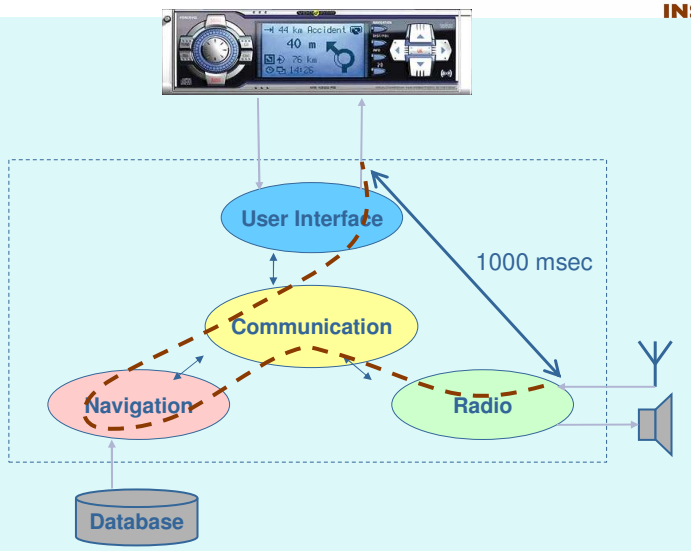

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Proposed Architecture Alternatives

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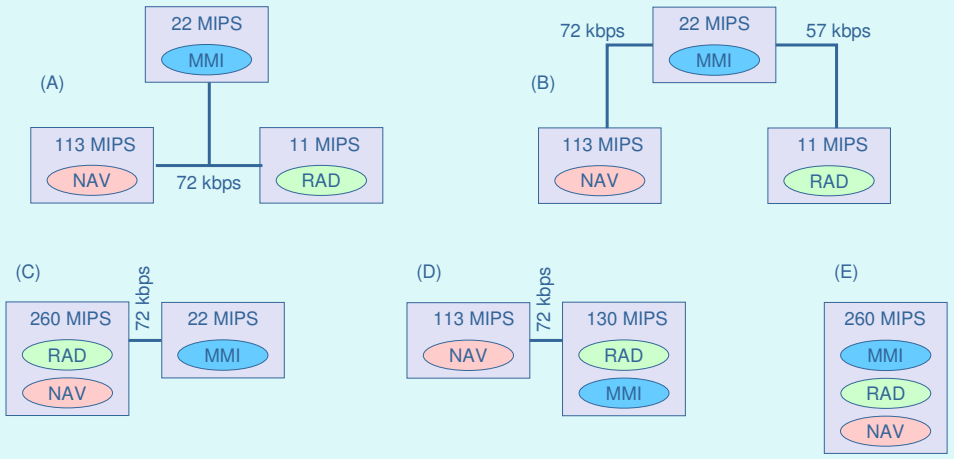

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Analysis questions

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1. How do the proposed system architectures compare in respect to end-to-end delays?
2. How robust is architecture A? Where is the bottleneck of this architecture?
3. Architecture D is chosen for further investigation. How should the processors be dimensioned?

- This presentation: focus on question 1 on architecture A

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Method: MPA (1)

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- Modular Performance Analysis
- Developed at ETH Zurich (Lothar Thiele et al)
- Performance networks analysed with real-time calculus
- Analytic method, deterministic queuing theory
- Adaption of Network Calculus (Boudec, Thiran)
- Describes event streams by interval bound functions
- Information is lost: t → Δt
- Evaluation is very fast (no simulation)

- http://www.mpa.ethz.ch

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Method: MPA (2)

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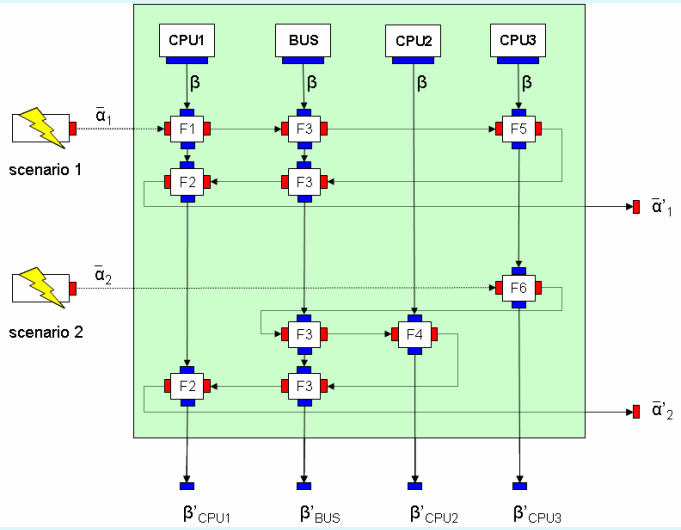

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Method: SymTA/S (1)

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- Symbolic Timing Analysis for Systems
- Developed at TU Braunschweich (Rolf Ernst et al)
- Classical (formal) scheduling analysis techniques
- Symbolic simulation
- Calculate resource local optima
- Optimize system level by iteration over local optima
- Heterogeneous architectures
- Complex task dependancies, context aware analysis
- Rapid design space exploration by sensitivity analysis

- http://www.symtavision.com

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Method: SymTA/S (2)

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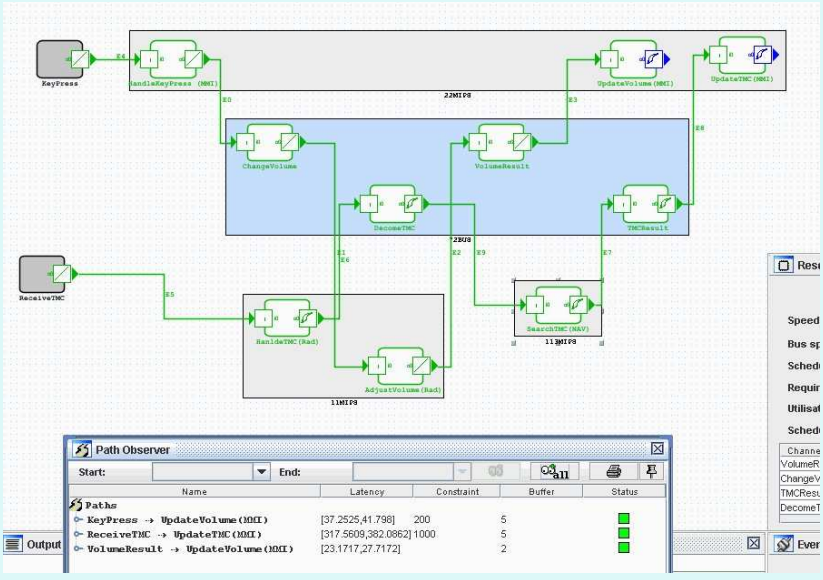

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Method: Uppaal (1)

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- Model checker for timed automata
- Co-developed at Uppsala (S) and Aalborg (DK) by (Wang Yi, Kim Larsen et al)
- Integrated tool, graphical modeling interface
- Validation (simulation) and verification (model checking)
- Networks of timed automata
- Expressive and powerful language
- TA models prone to state space explosion problem

- http://www.uppaal.com

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Method: Uppaal (2)

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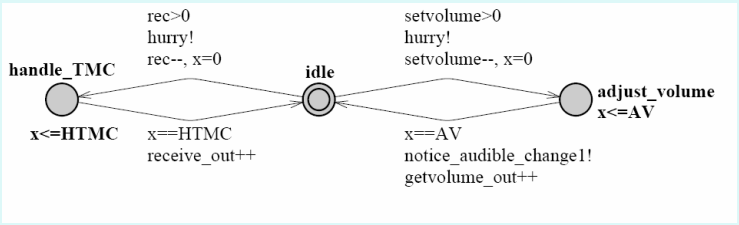

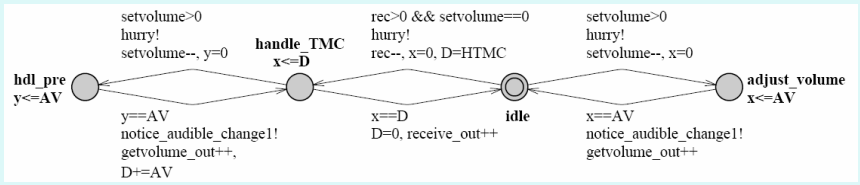

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Method: POOSL (1)

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- Parallel Object-Oriented Specification Language
- Languages combines primitives for specifying data manipulations, concurrency and timing
- SHE method: Software / Hardware Engineering
- SheSIM tool for model construction and simulation
- Rotalumis for high-speed batch-oriented simulation
- Formal semantics based on probabilistic timed labeled transition systems
- Symbolic execution

- http://www.es.ele.tue.nl/poosl/

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Method: POOSL (2)

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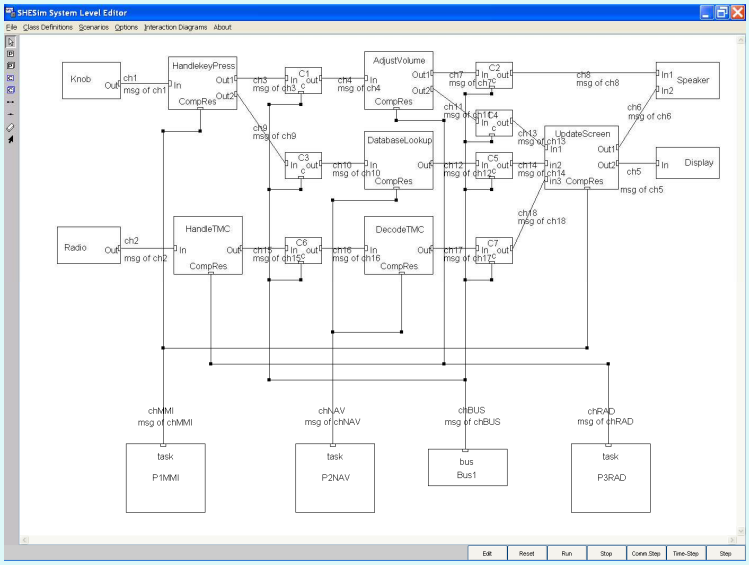

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Analysis

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- **Played with many environment models**
  - Pure periodic with zero offset (synchronous)
  - Pure periodic with fixed offset (synchronous)
  - Pure periodic with unknown offset (asynchronous)
  - Periodic with jitter (j ≤ p)
  - Periodic with bursts (j = 2p, d = 0)
  - Sporadic (periodic with only upper bound to period)
- **Some results easy to verify by hand**
  - AddressLookup is fully independent and has highest priority
  - ChangeVolume is only dependent on itself

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Results - WCRT

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Table 1. Uppaal worst-case response time analysis results (in milliseconds)

Requirement \ *Event model*	*po* ($F = 0$)	*pno*	*sp*	*pj* ($J = P$)	*bur* ($J = 2P$, $D = 0$)
HandleTMC (+ ChangeVolume)	357.133	381.632	382.076	> 400.000 (df)	> 500.000 (rdf)
HandleTMC (+ AddressLookup)	172.106	239.080	239.080	329.989	420.898
K2A (ChangeVolume + HandleTMC)	27.716	27.716	27.716	> 27.715 (bf)	> 27.715 (bf)
A2V (ChangeVolume + HandleTMC)	41.796	41.796	41.796	> 41.795 (bf)	> 41.795 (bf)
AddressLookup (+ HandleTMC)	79.075	79.075	79.075	79.075	79.075

Table 2. Worst-case response time results – comparison with other tools

Requirement \ *Tool*	*Uppaal (po)*	*Uppaal (pno)*	*POOSL (pno)*	*SymTA/S (pno)*	*MPA (pno)*
HandleTMC (+ ChangeVolume)	357.133	381.632	266.94	382.086	390.0862
HandleTMC (+ AddressLookup)	172.106	239.080	244.26	253.304	265.8491
K2A (ChangeVolume + HandleTMC)	27.716	27.716	27.7067	27.717	28.1616
A2V (ChangeVolume + HandleTMC)	41.796	41.796	41.7771	41.798	42.2424
AddressLookup (+ HandleTMC)	79.075	79.075	78.8989	79.076	84.066

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Results – POOSL case (1)

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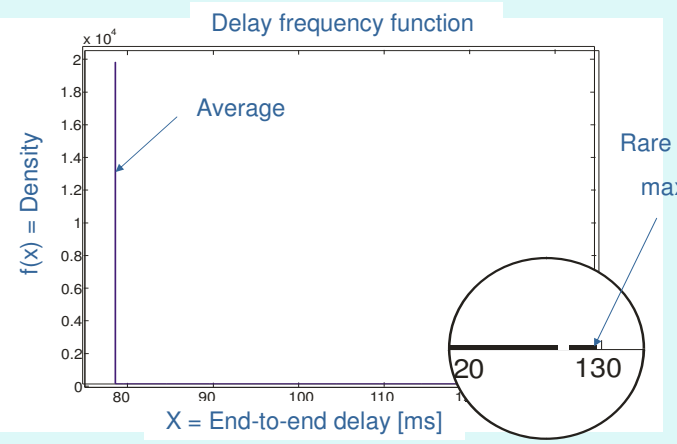

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Results – POOSL case (2)

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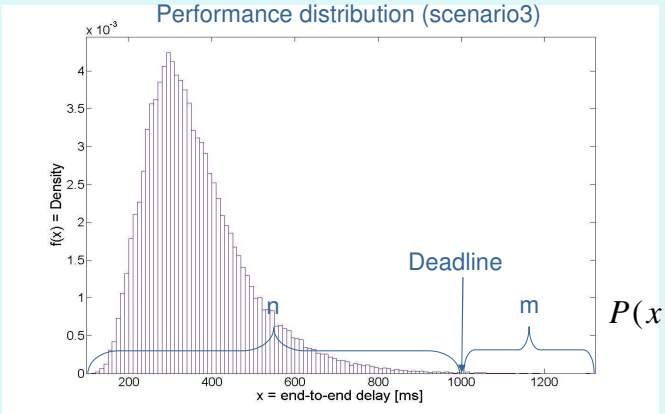
- **Probability of deadline misses**
- **More suitable design tradeoffs**
- **Accuracy depends on simulation length**
  - **Distribution fit**



$$P(x < deadline) = \frac{m}{n+m}$$

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Results – POOSL case (2)

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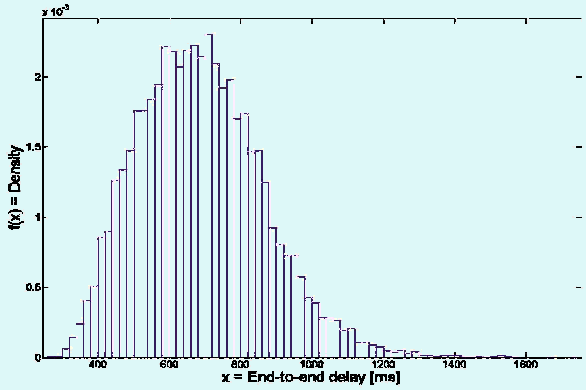
Performance distribution (scenario 3)



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Results – POOSL case (2)

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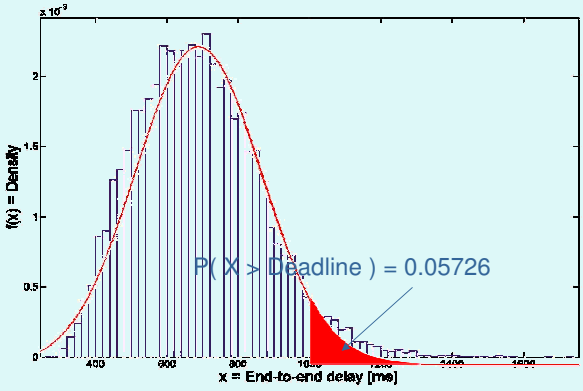
Performance distribution (scenario 3)



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Observations & lessons learnt

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- **Comparing results is as hard as getting the results**
  - Did we ***really*** model the same thing?
  - Simulation / computation effects or true "problem"?
  - Interaction with experts is needed to make comparison!
- **Methods are typically**
  - Either biased towards application domain; can cause mismatch
  - Or very generic; can cause huge modeling effort
- **Methods can be used complementary**
  - Provide answers to different types of questions
  - Model validation by moving to another paradigm

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Questions?

http://www.esi.nl/boderc
http://www.ee.ethz.ch/~leiden05

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