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Department of Computer Science 7
Computer Networks and Communication Systems

Model Driven Testing with Timed Usage Models in the Automotive Domain

Modeling and Test Case Generation

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ISSRE, Bengaluru-Mysuru, India, 2009

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TECHNISCHE FAKULTÄT

AUDI

Motivation

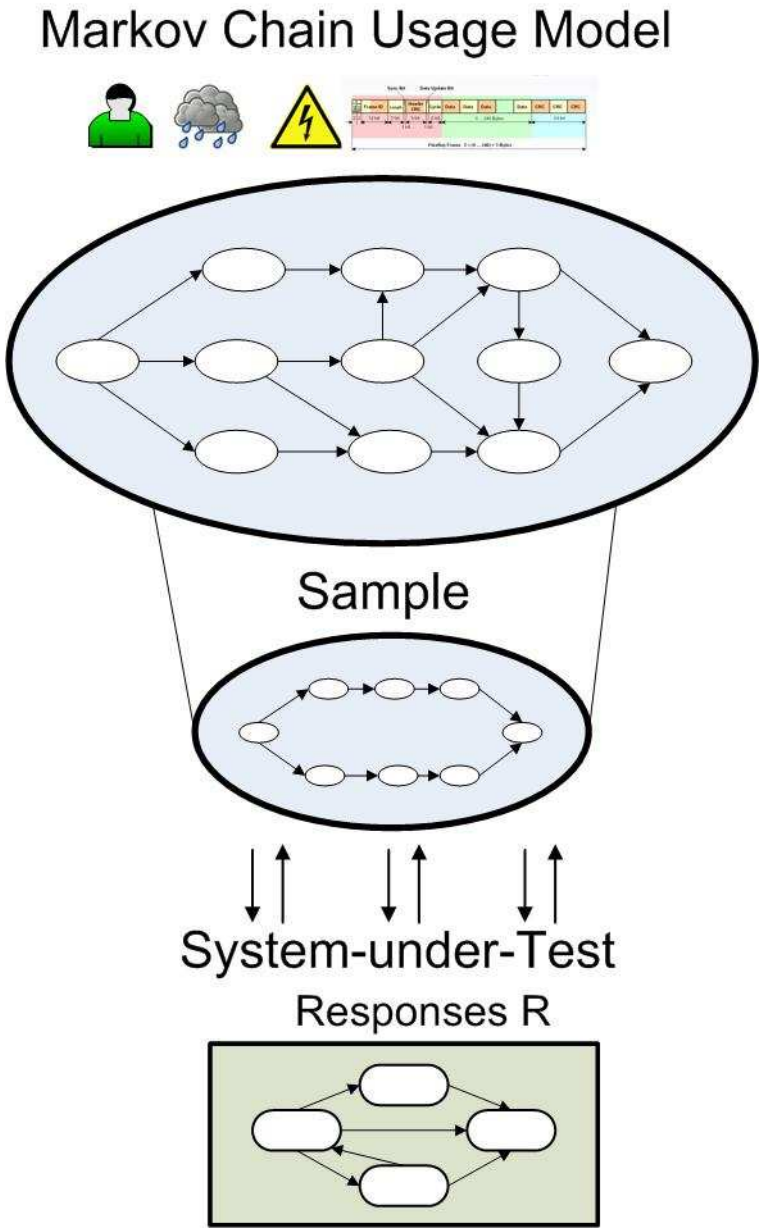
- Development of hybrid and electronic vehicles
- Automobiles turn into time-sensitive hybrid systems
- Variability in timing of usage has impact on
  - System behavior
  - Ability of test cases to discover failures
- Exhaustive testing is impossible
- Testing time is scarce and should be used efficiently

Overview

- Motivation
- **Model Driven Testing**
  - **Classic Markov Chain Usage Models (MCUMs)**
  - **Testing in the Automotive Domain**
- Timed Usage Model
  - Semi-Markov Process
  - Computations and Test Planning
  - Test Case Generation
- Case Study
- Conclusion

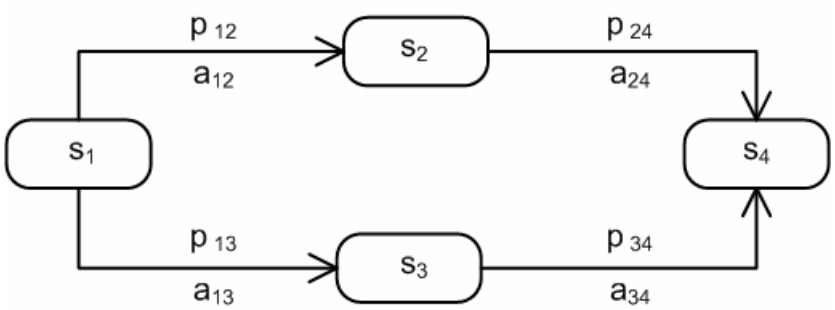
Model Driven Testing

- Usage Model
  - Usage states and transitions
- Test Case Generation
  - Supported by computations
- Computations
  - Expected number of occurences of a state in a test case
  - Long-run probabilities
  - Expected length of a test case in terms of states/transitions



Model Driven Testing

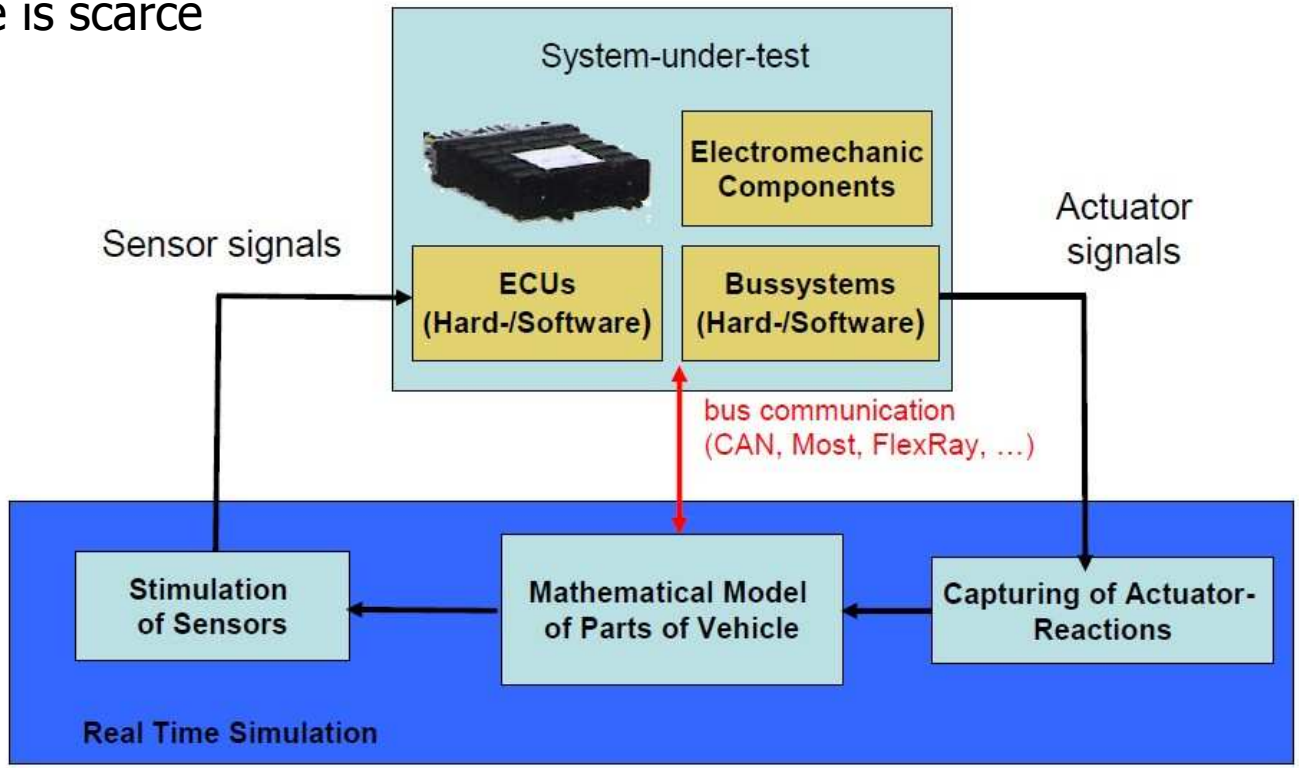
- Markov Chain Usage Model (MCUM):
  - Markov Chain with special characteristics:
  - A set of usage states $S = \{s_1,\ldots,s_n\}$.
  - A set of arcs $A = \{a_1,\ldots,a_n\}$ representing usage state transitions
  - Transition probability p_{ij} from state s_i to s_j
  - One start-state and final state



- Problems:
  - Each transition = one time unit
  - No integration of time
  - Timing aspects of requirements not in the model
    - Computations and test case generation need additional data or models to consider time and timing

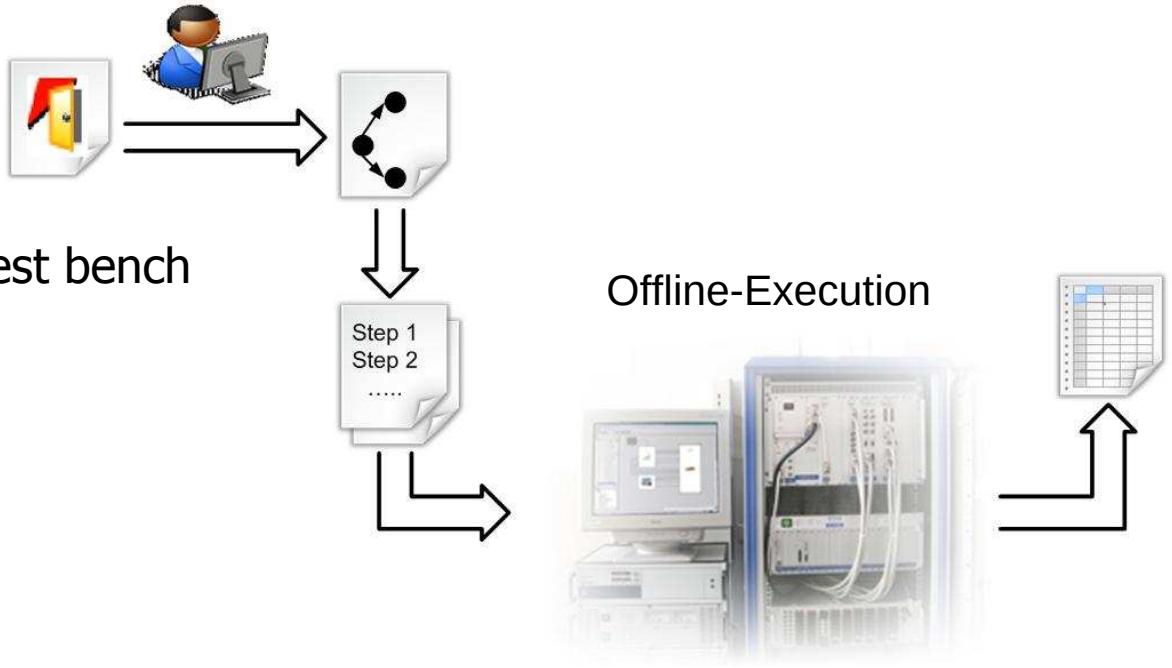
Testing in Automotive Domain

- Execution on Hardware-in-the-loop simulators (HiL)
  - SUT feels like being in the real car
  - HiLs are expensive
  - Testing time is scarce



Testing in Automotive Domain

- Testing Process
  - Test case generation
  - Offline execution
    - Hard to estimate testing time
- Goal:
  - Efficient use of test bench



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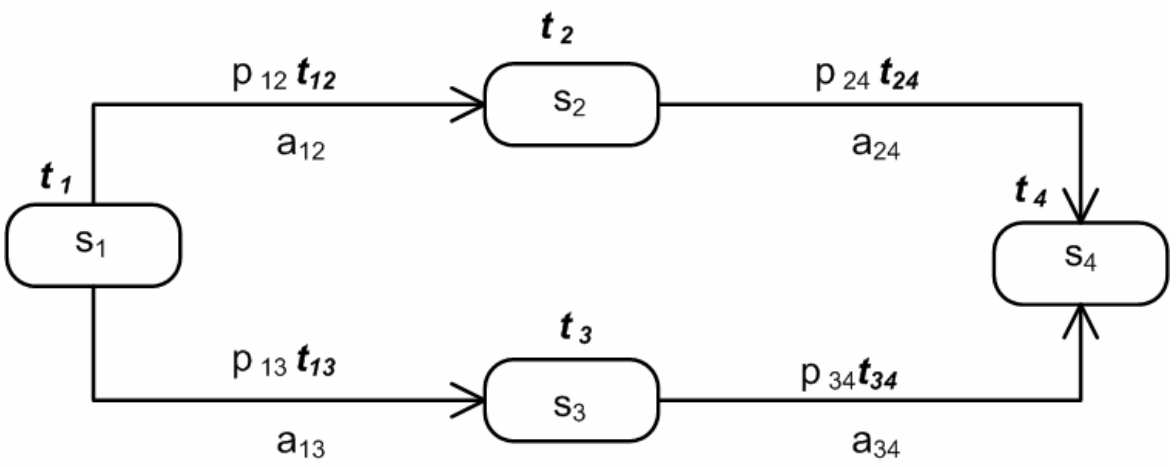
Timed Usage Models

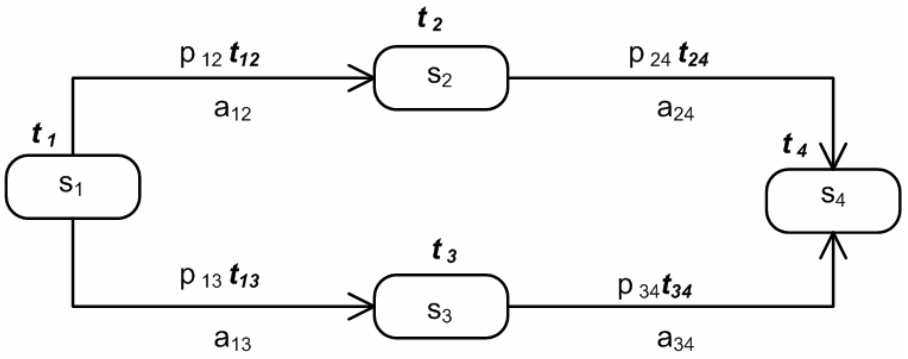
- Integration of in timing by new attributes:
  - Sojourn time in usage states: ti, i.e. distribution of time Fi(t)
  - Execution duration of transition: tij, i.e. distribution of time Fij(t)
- Distributions of time exchangeable with usage profiles
- Distributions for Fi(t) and Fij(t) can be:
  - Deterministic
  - Uniform
  - Bell-shaped
  - Memoryless



Timed Usage Model

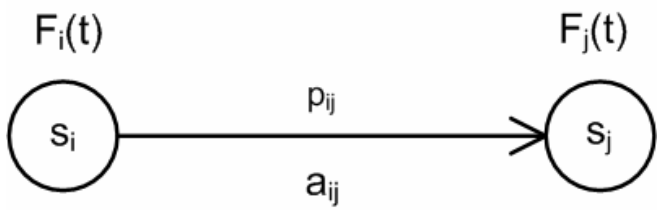
- Integration of non-exponential timing
- Timing variability in usage reflected by model
- Distinction of different user types also possible in timing of usage
  - Exchangeable with usage profiles

- Important for:
  - System reactions
  - non-functional requirements
  - Computations and statistics
  - Algorithms
  - Test case quality

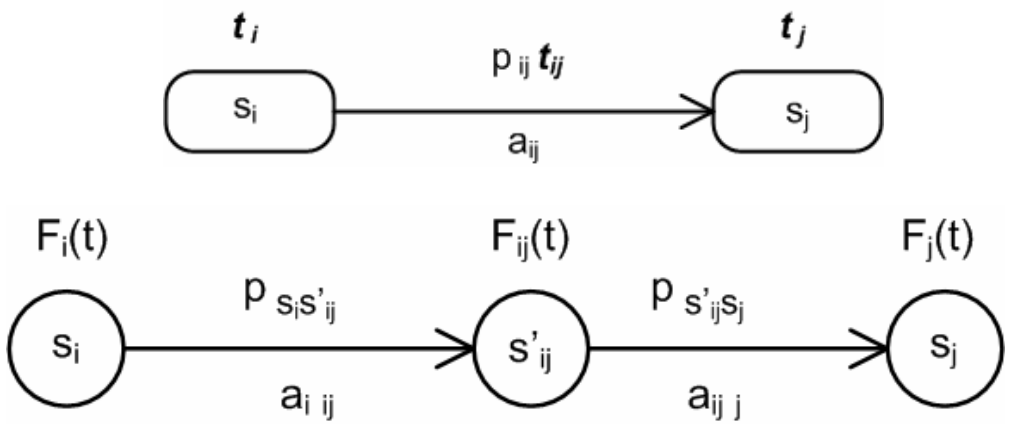


Timed Usage Models

- Semi-Markov Process (SMP)
  - Change of states according to Discrete Markov Chain
  - Random time in states, described by distribution $F_i(t)$



- Mapping of elements from Timed Usage Model to SMP



Timed Usage Models

- Computations on basis of the SMP
  - Execution duration
  - Mean residence time of states and transitions
  - Expected residence time of states and transitions
  - Expected execution time of stimulus
  - …
- Test case generation from new model
  - Random walk for stimuli and timing
  - Most probable test case in the sense of stimuli and timing
  - Minimal complete arc coverage, combinable with random or boundary values for timing

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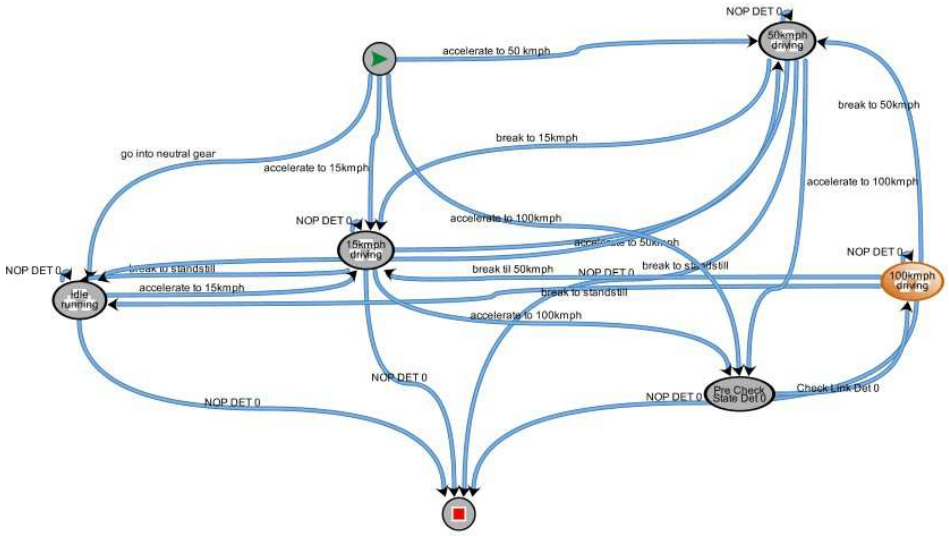
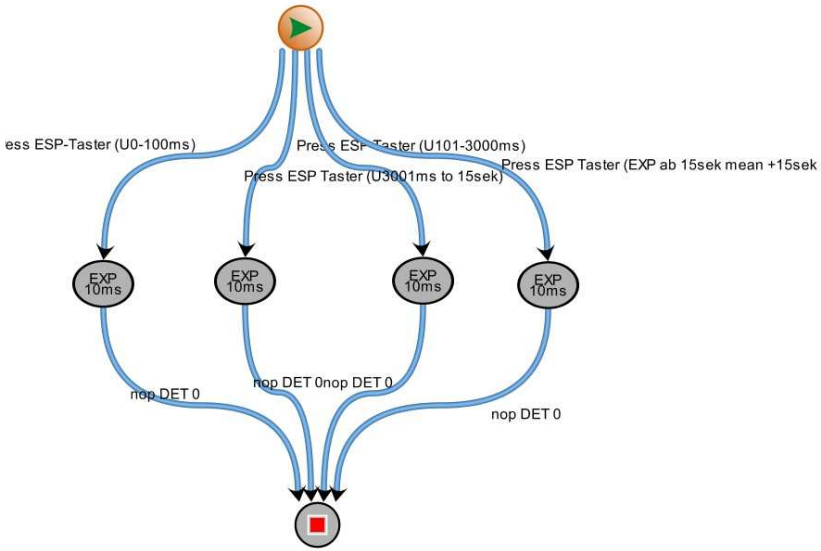
Case study

- Electronic stability program (ESP) operational concept
  - Time sensitive handbag switching mechanism



Submodel speeds of vehicle

Submodel push duration



Case study

- ESP operational concept

Classic computations

State ID	stat. distrib.	visit. prob.	exp # of visits
S9998	0.04	1.00	1.00
S1	0.04	1.00	1.00
S234	0.01	0.22	0.38
S4	0.08	1.00	2.00
S999	0.04	1.00	1.00

New computations

State ID	**Mean res. time**	exp # of visits	**exp. res. time**
S9998	**0.00**	1.00	**0.00**
S1	**9.00**	1.00	**9.00**
S234	**10.00**	0.38	**3.75**
S4	**0.01**	2.00	**0.02**
S9999	**0.00**	1.00	**0.00**

Case study

- Issues:
  - Determination of proper distribution
  - Resolution of time
    - capabilities of test bench
  - Impact of data characteristics not considered

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Conclusion

- Time and timing variability in usage model systematically integrated
- Computations become more useful
  - Test effort can be better assessed
  - Test planning is supported
  - Test-bench can be used more efficiently
- Enhanced algorithms for test case generation with timing information
- Currently Timed Usage Models are drawn at AUDI AG for energy management, safety, and air conditioning functionalities

Thank you for listening!

Questions?