Technische Universität Braunschweig

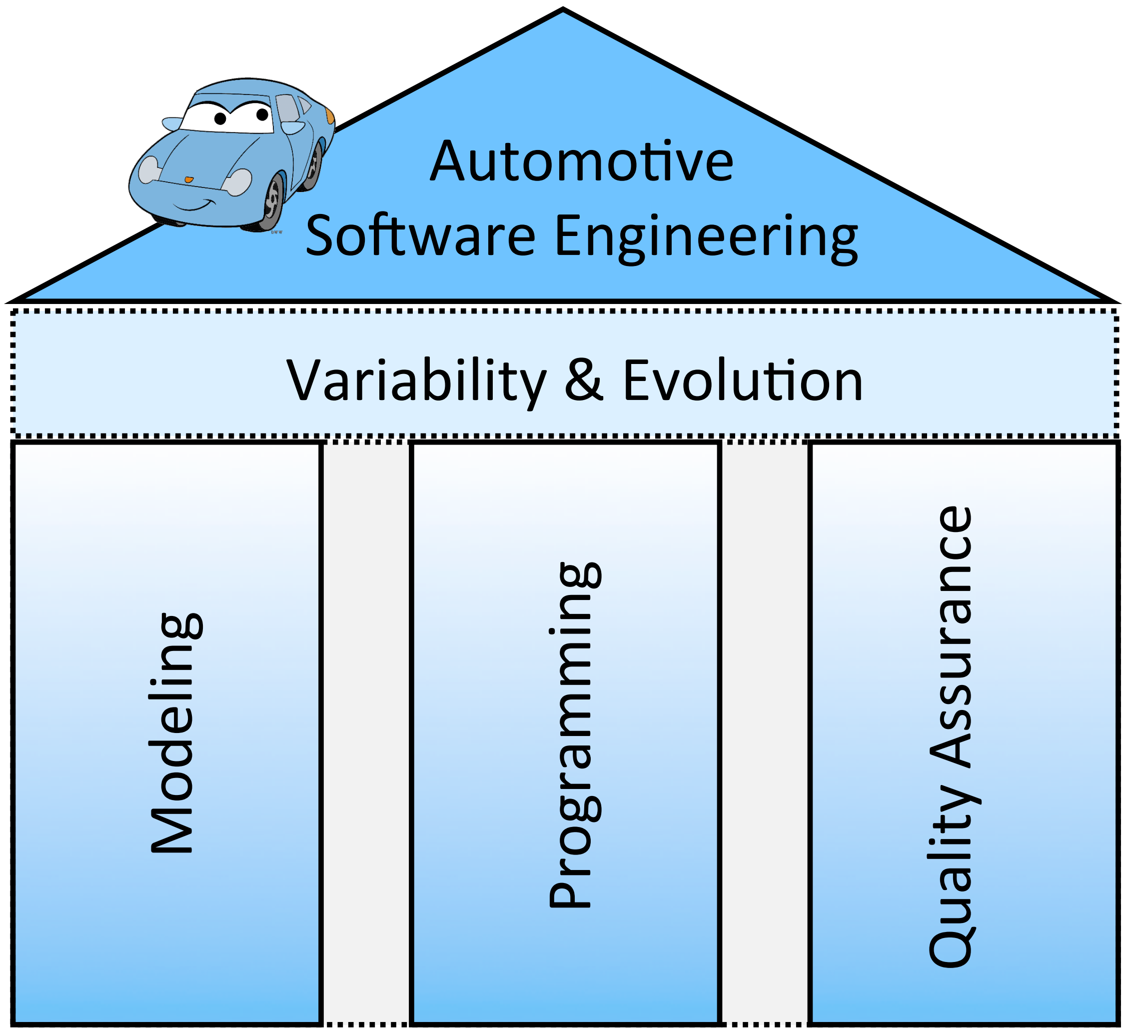
ISF

Efficient Incremental Testing of Variant-Rich Software Systems

Prof. Dr.-Ing. Ina Schaefer
(joint work with Malte Lochau and Sascha Lity)
Institute of Software Engineering and Automotive Informatics, Technische Universität Braunschweig

CREST, London, 19 November 2012

ISF - Fields of Research



Agenda

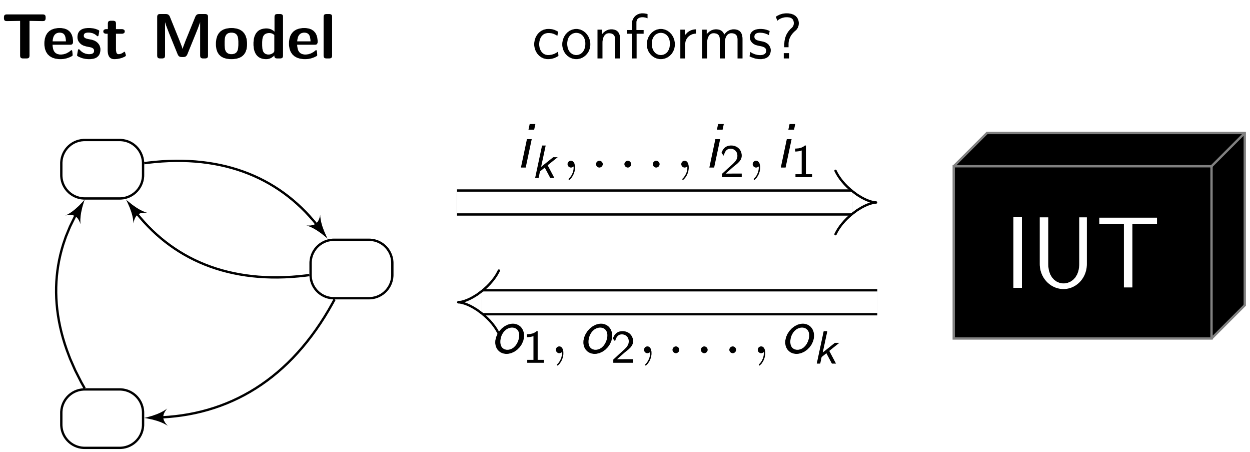
- Model-based Testing – Basic Principles
- Efficient Testing of Software Product Lines
  - Combinatorial Testing by Subset Selection
  - Regression-based Incremental Testing

Objectives of Testing

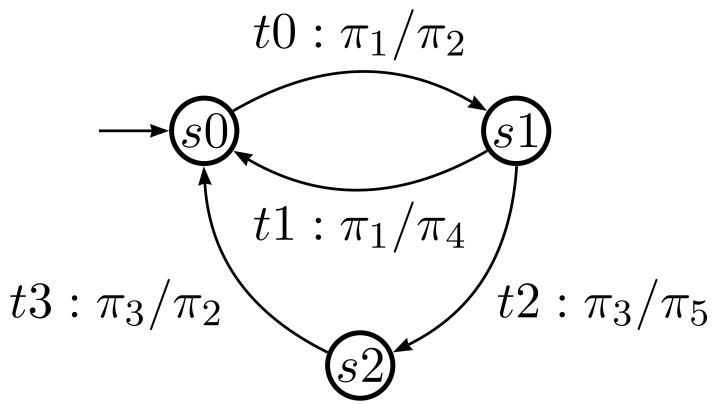
A software test is the dynamic verification of a system with a set of test cases against the expected system behavior in order to

- Observe erroneous behavior during system execution,
- Detect conceptual faults in software,
- Correct errors in implemenation.

Model-based Testing - Concept



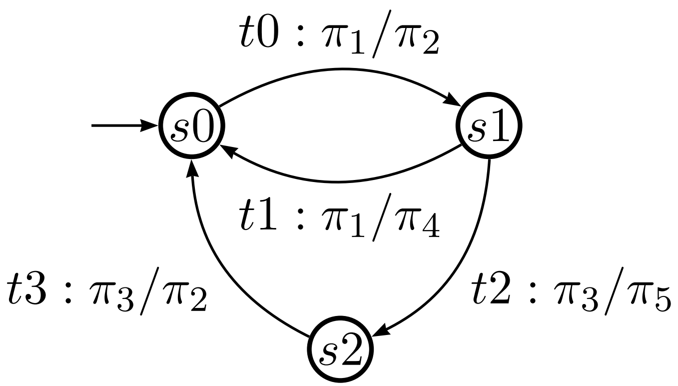
State Machine Test Model



State machines as test models

- S is a finite set of states
- $s_0 \in S$ is an initial state
- $L \subseteq \Pi_I \times \Pi_O$ is a set of transition labels
- $T \subseteq S \times L \times S$ is a transition relation

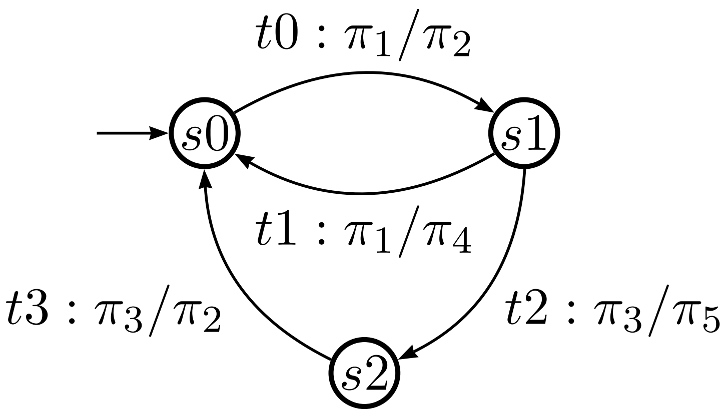
State Machine Test Case



State machine test artifacts:

- Test case: $tc = (t_0, t_1, \ldots, t_k) \in T^*$ is a sequence of k transitions
- Test run: $exec(tc, tm) = (l_0, l_1, \ldots, l_k) \in L^*$
- Test result: *iut* **passes** $tc :\Leftrightarrow exec(tc, iut) \approx_{te} exec(tc, tm)$

State Machine Test Suite



- Infinite set of all valid test cases: $TC(tm) \subseteq T^*$
- Derive finite test suites: $ts \subseteq TC(tm)$
- Coverage criteria C: finite sets $tg = C(tm)$ of test goals such that $\forall g \in tg : \exists tc \in ts : covers(tc, g)$

Advantages of Model-based Testing

- Systematic and automatic test case generation
- Usable in early development phases (Model-in-the-Loop)
- Automatization of test execution
- Regression planning by change impact analysis on models

Efficient Model-based Testing of Software Product Lines

We use a combination of two approaches:

Combinatorial Testing:

Selection of Representative Subsets from a large set of possible variants

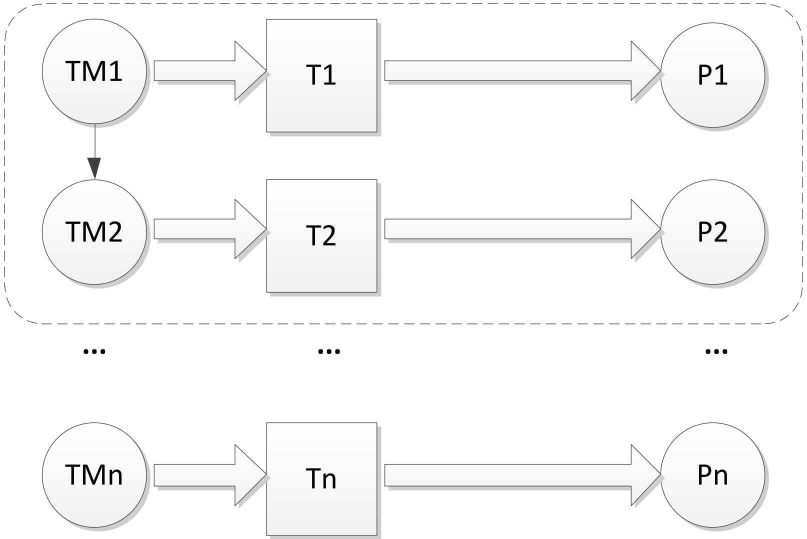
Incremental Regression-based Testing:

Reuse Test Cases and Test Results in order to efficiently test the selected variants

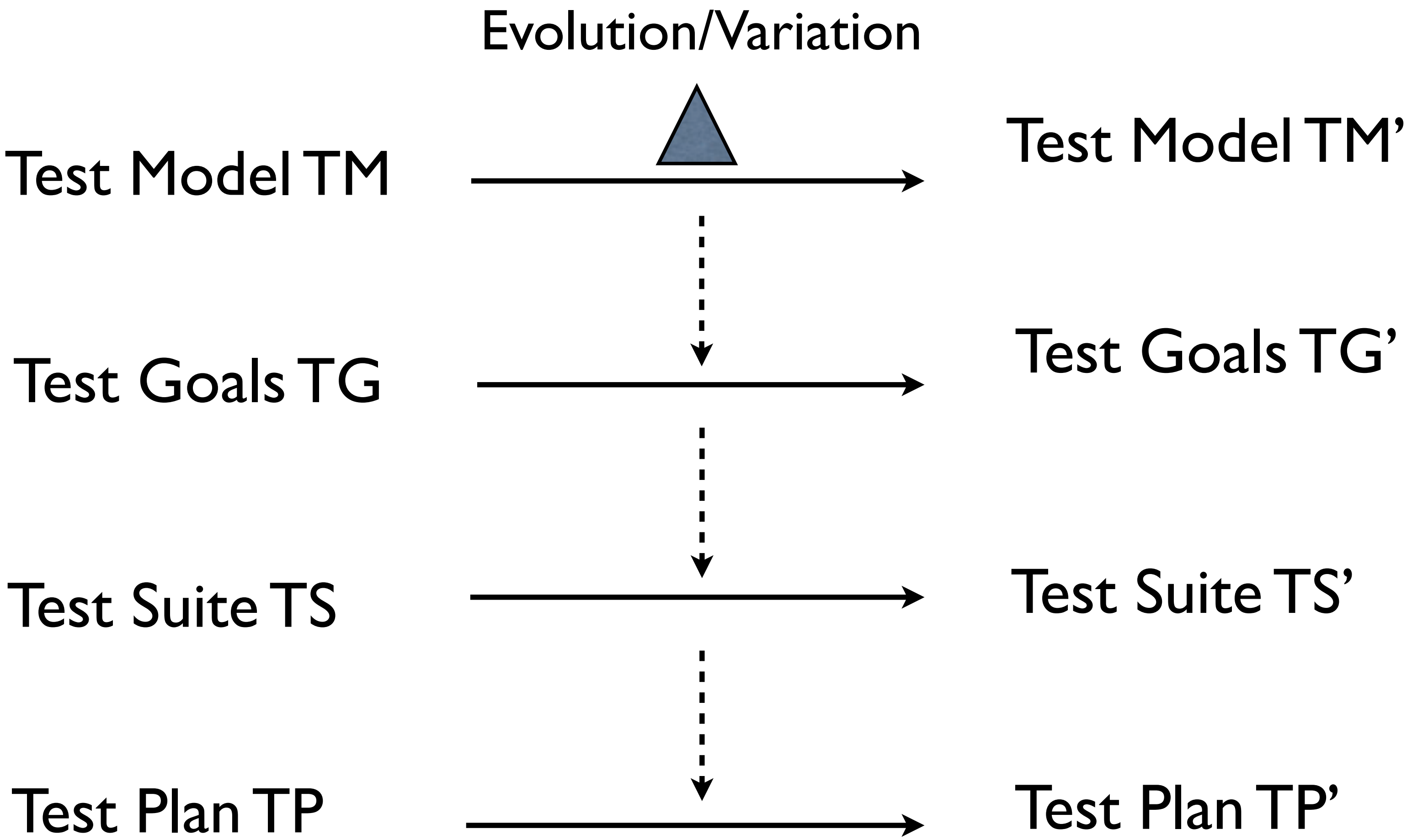
Efficient Testing of Feature Interactions

Subset Selection Heuristics (Lochau/Oster et al., Perrouin et al.):

- Start from Set of Valid Feature Combinations (Feature Model)
- Select Representative Set of Product Variants Covering all Pairs of Features (using Set Coverage Algorithms)



Incremental Model-based Testing



Delta-Modeling of Variant-Rich Systems

Core Product

Product Delta$_1$

[...]

Product Delta$_n$

- Product for valid feature configuration.
- Developed with Standard Techniques

- Modifications of Core Product.
- Application conditions over product features.
- Partial ordering for conflict resolution.

Delta-Modeling - Background

Instances of Delta-Languages:

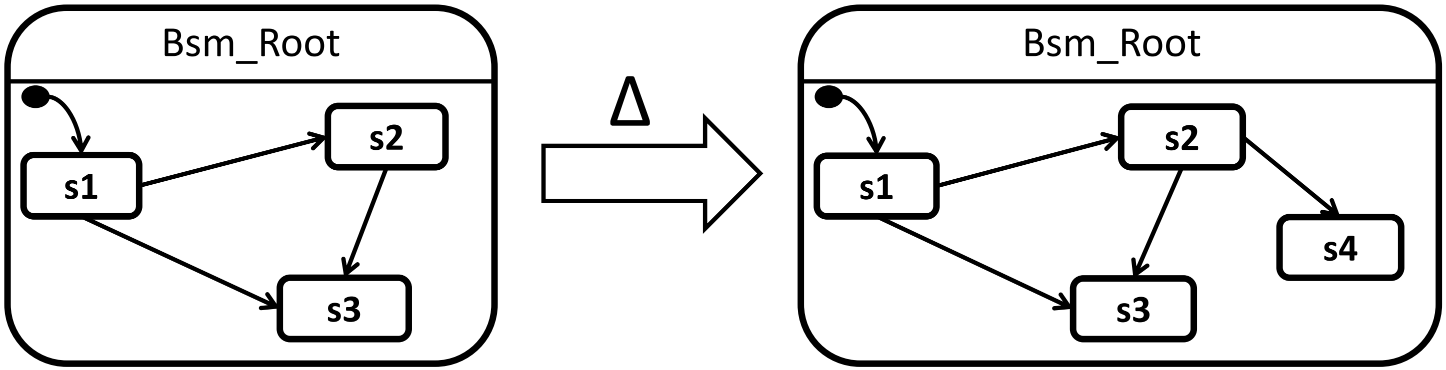
- Software Architectures (Delta-MontiArc)
- Programming Languages (Delta-Java)
- Modeling Languages (Delta-Simulink, Delta-State Machines)

Advantages of Delta-Modeling

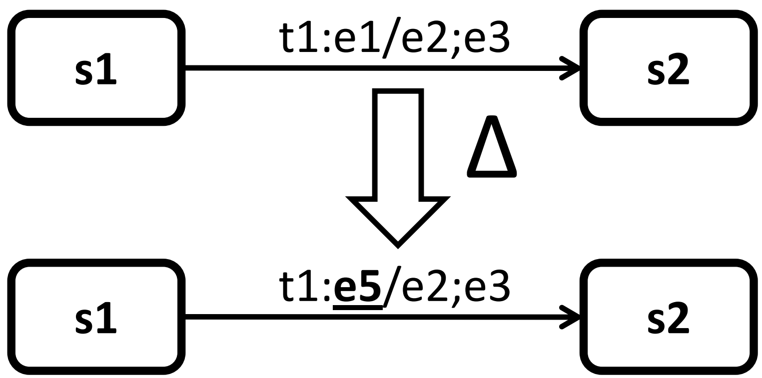
- Modular and flexible description of change
- Intuitively understandable and well-structured
- Traceability of Changes and Extensions
- Support for proactive, reactive and extractive SPLE

Delta-oriented Test Models (Examples)

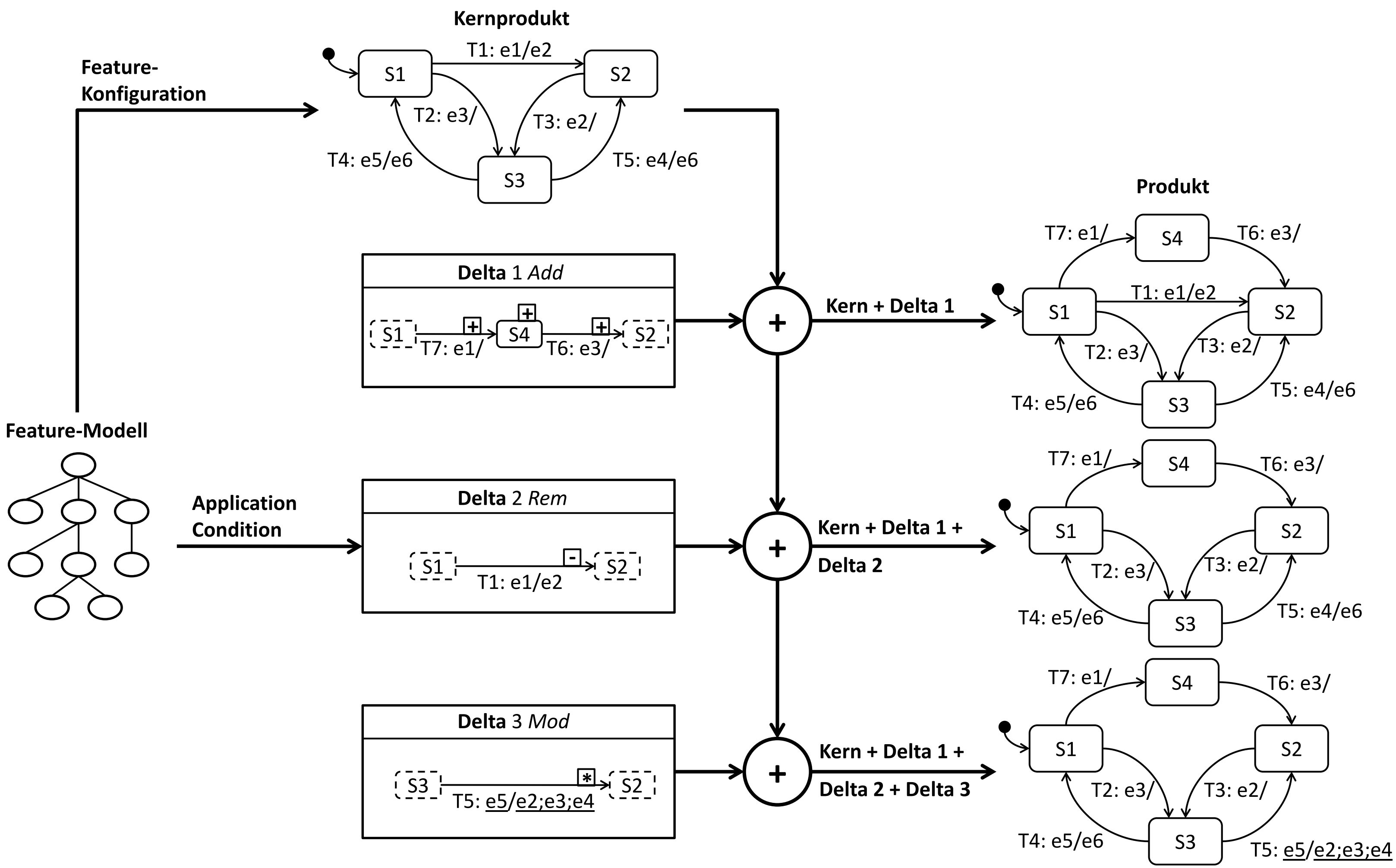
Adding a State to a State Machine:



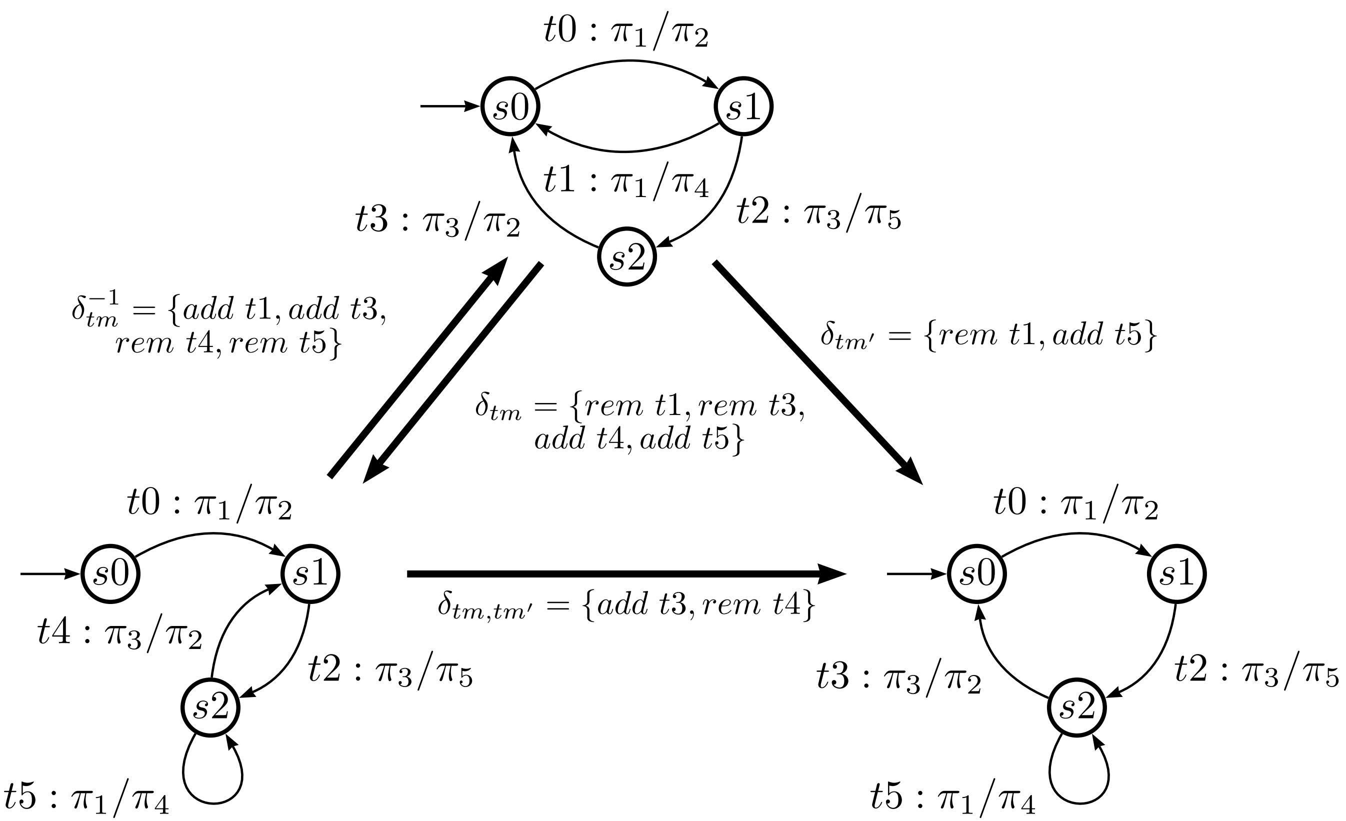
Changing the transition labels:



Delta-oriented Test Modeling



State Machine Regression Delta



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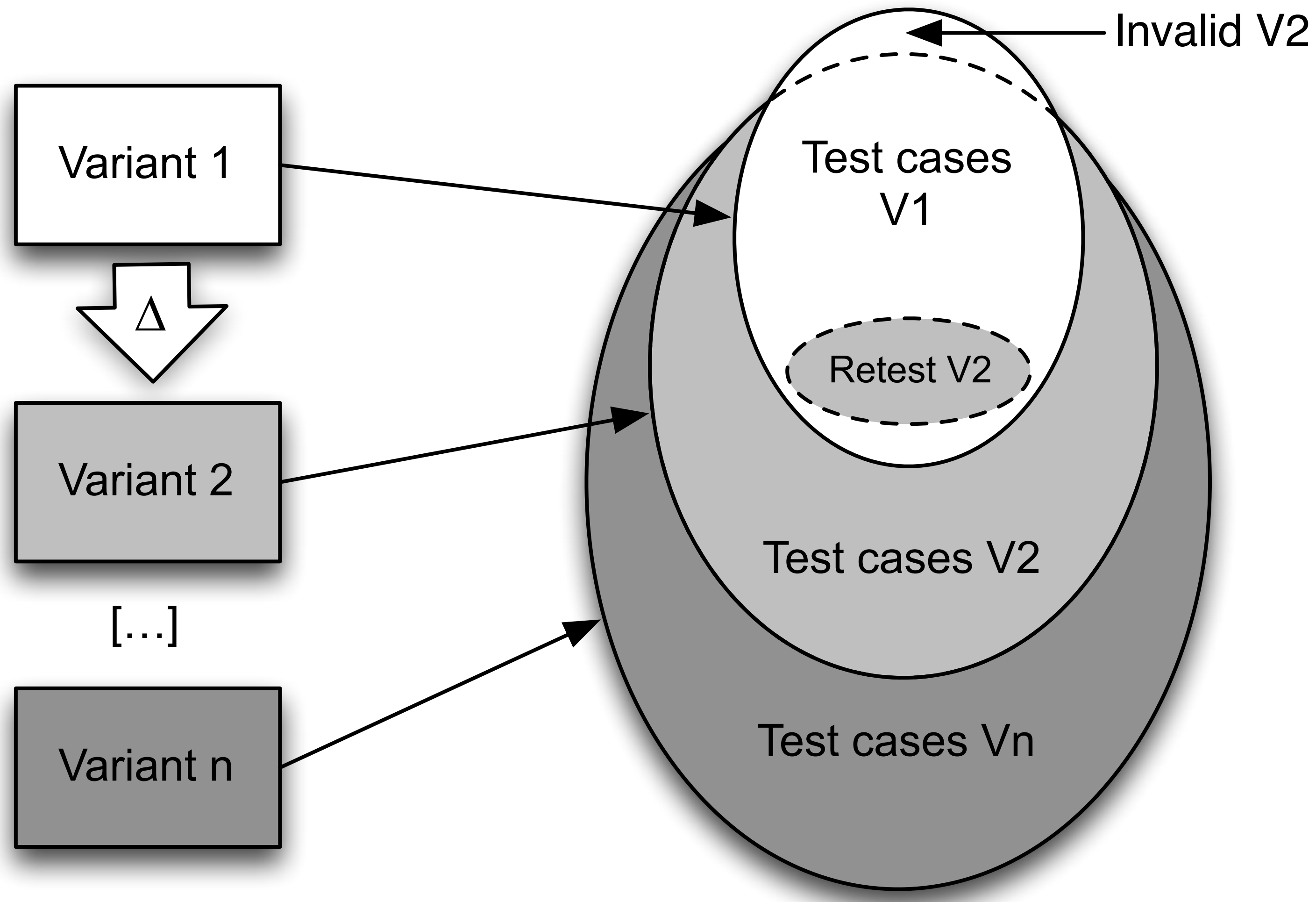
Classification of Test Cases by Delta-Analysis



Delta Testing - Procedure

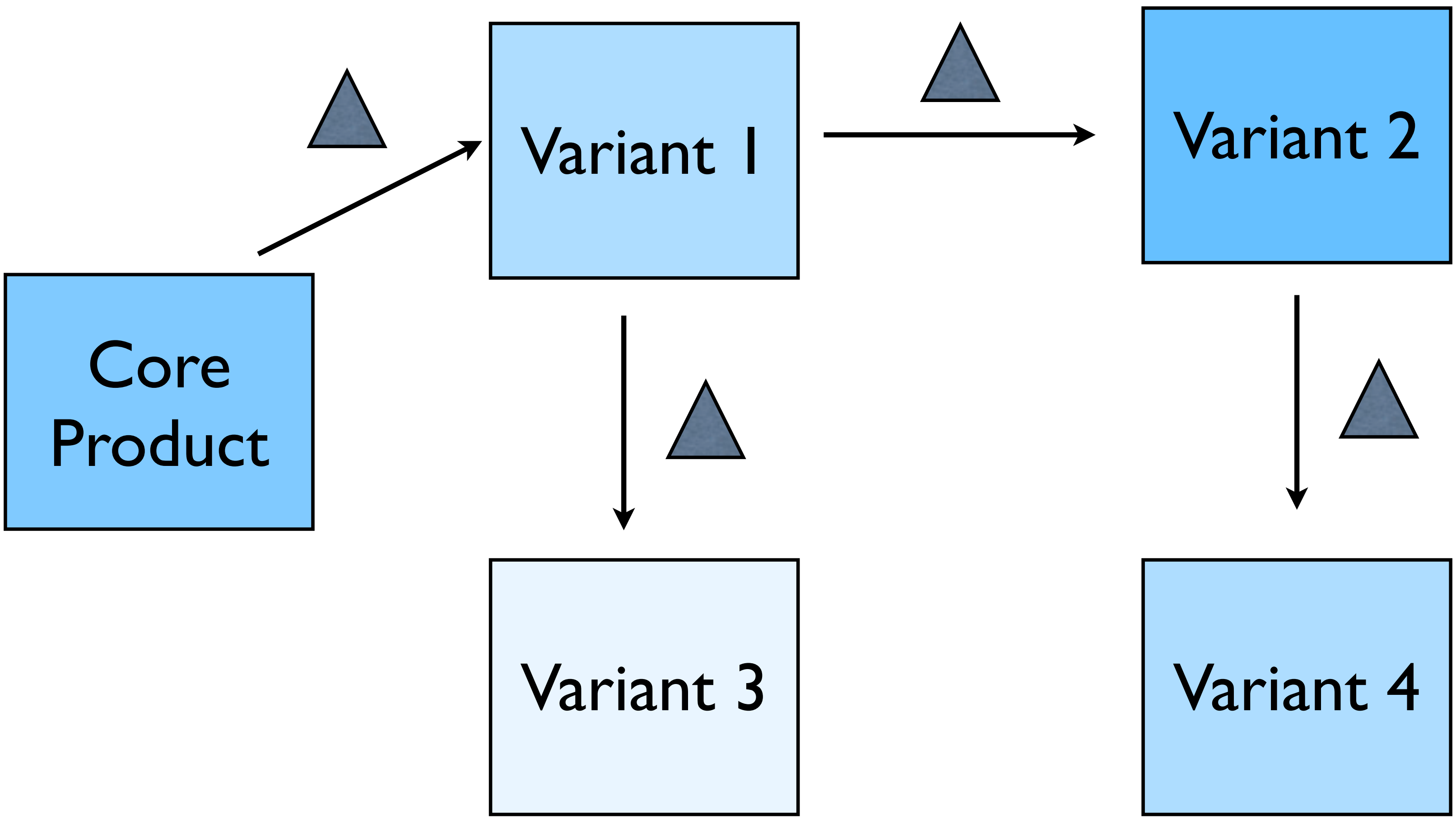
0. Fully test first product variant

1. Generate test cases for subsequent variants
   - Still valid and reuseable test cases?
   - Invalid test cases?
   - New test cases?

2. Selection of test cases by delta analysis:
   - Always test new test cases
   - Select subset of reuseable test cases for re-test

3. Optionally minimize resulting test suite by redundancy elimination

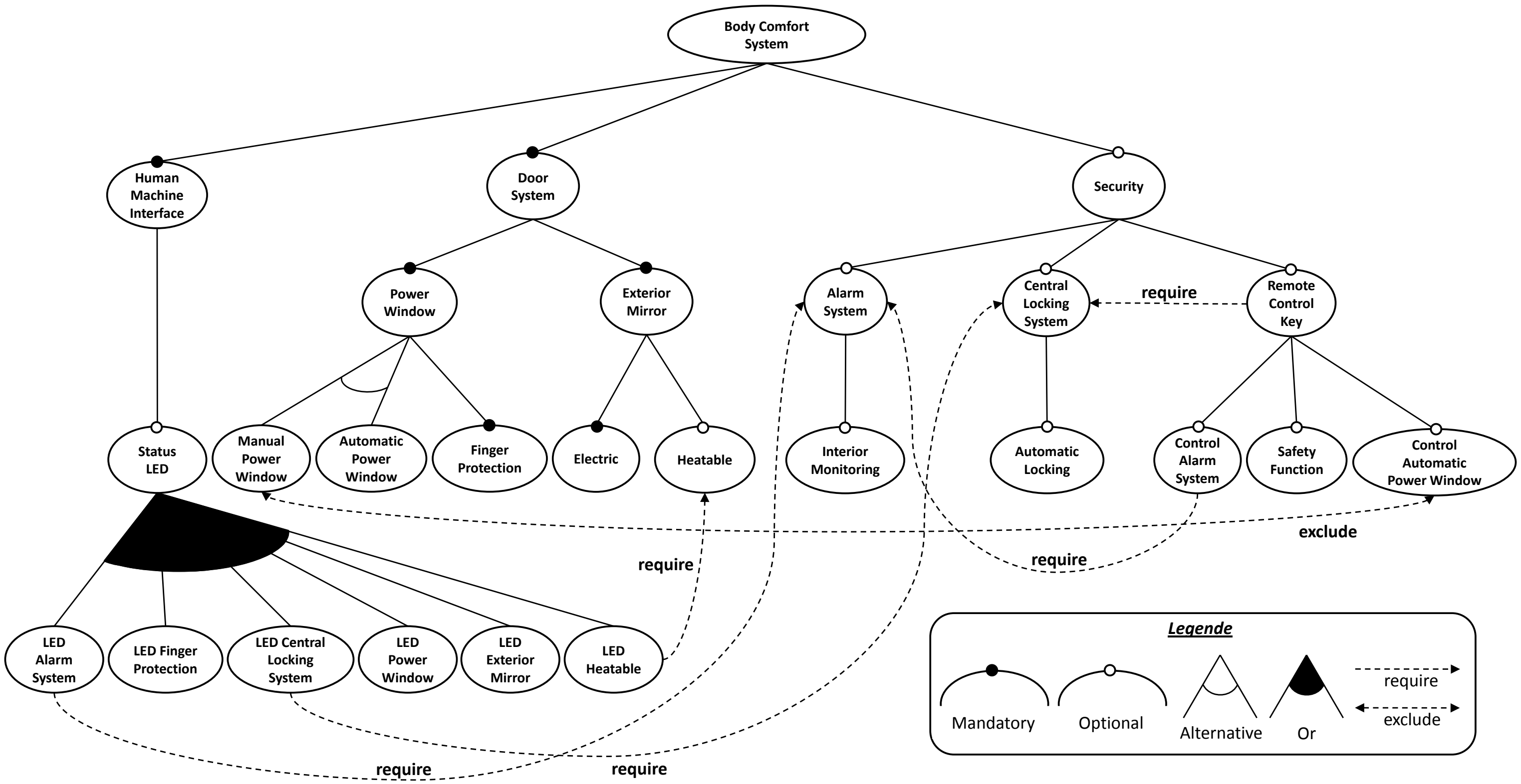
Delta-Testing Strategy



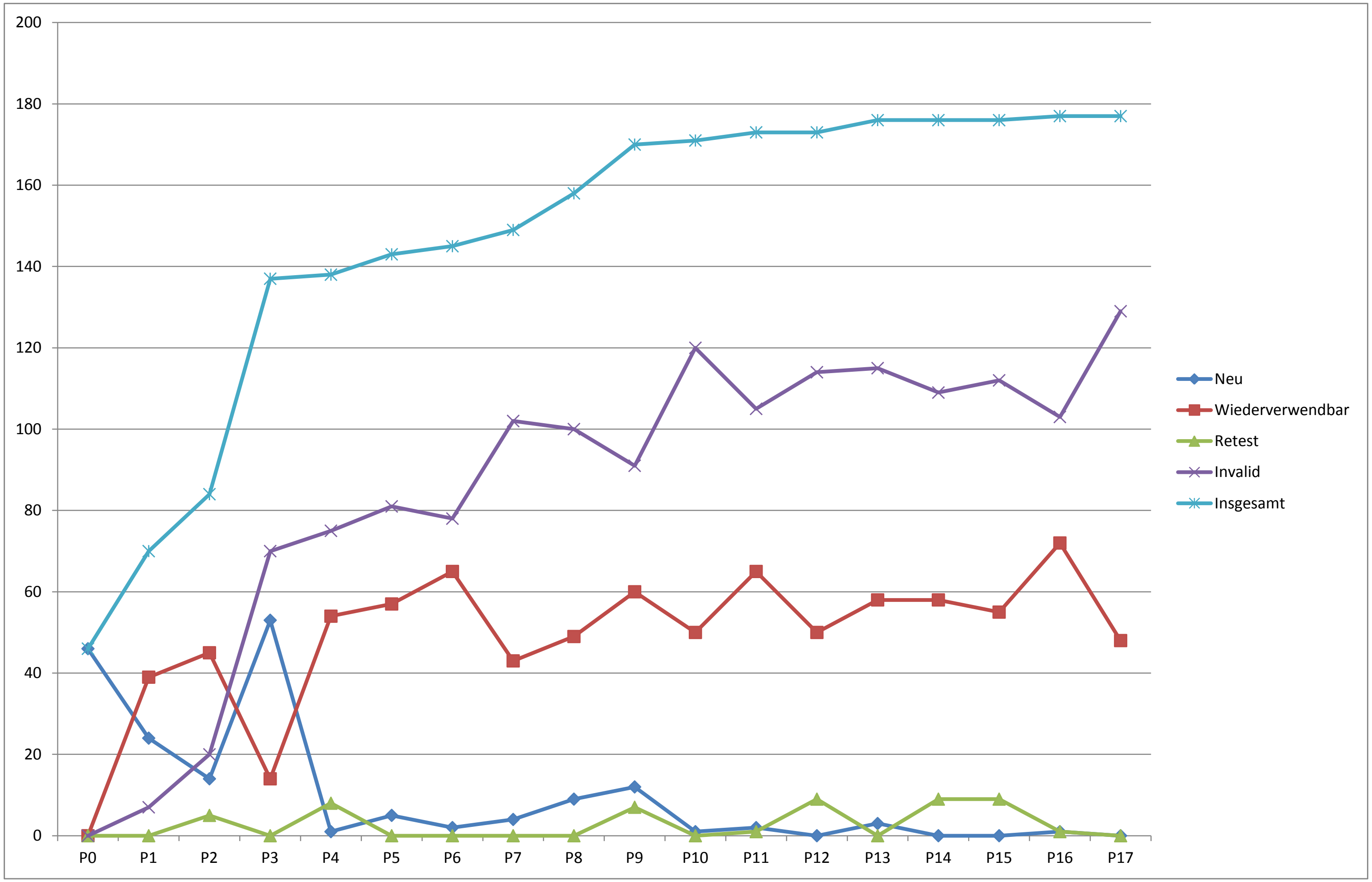
Case Study – Body Comfort System

28 Features, 11161 Product Variants, 1 Core Product, 40 Deltas

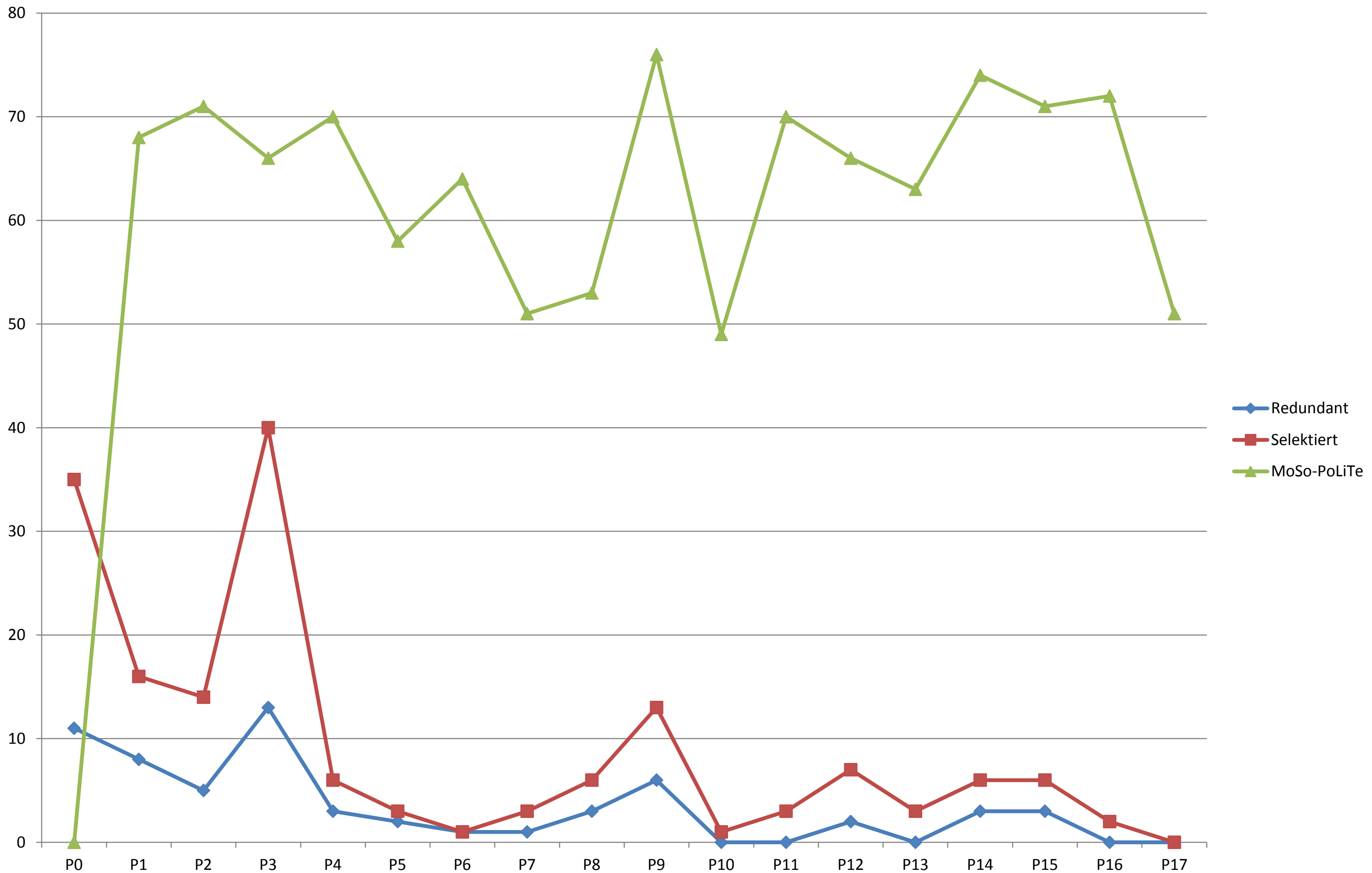
16 Products for Pair-Wise Feature Coverage



Case Study BCM – Delta-Testing Results

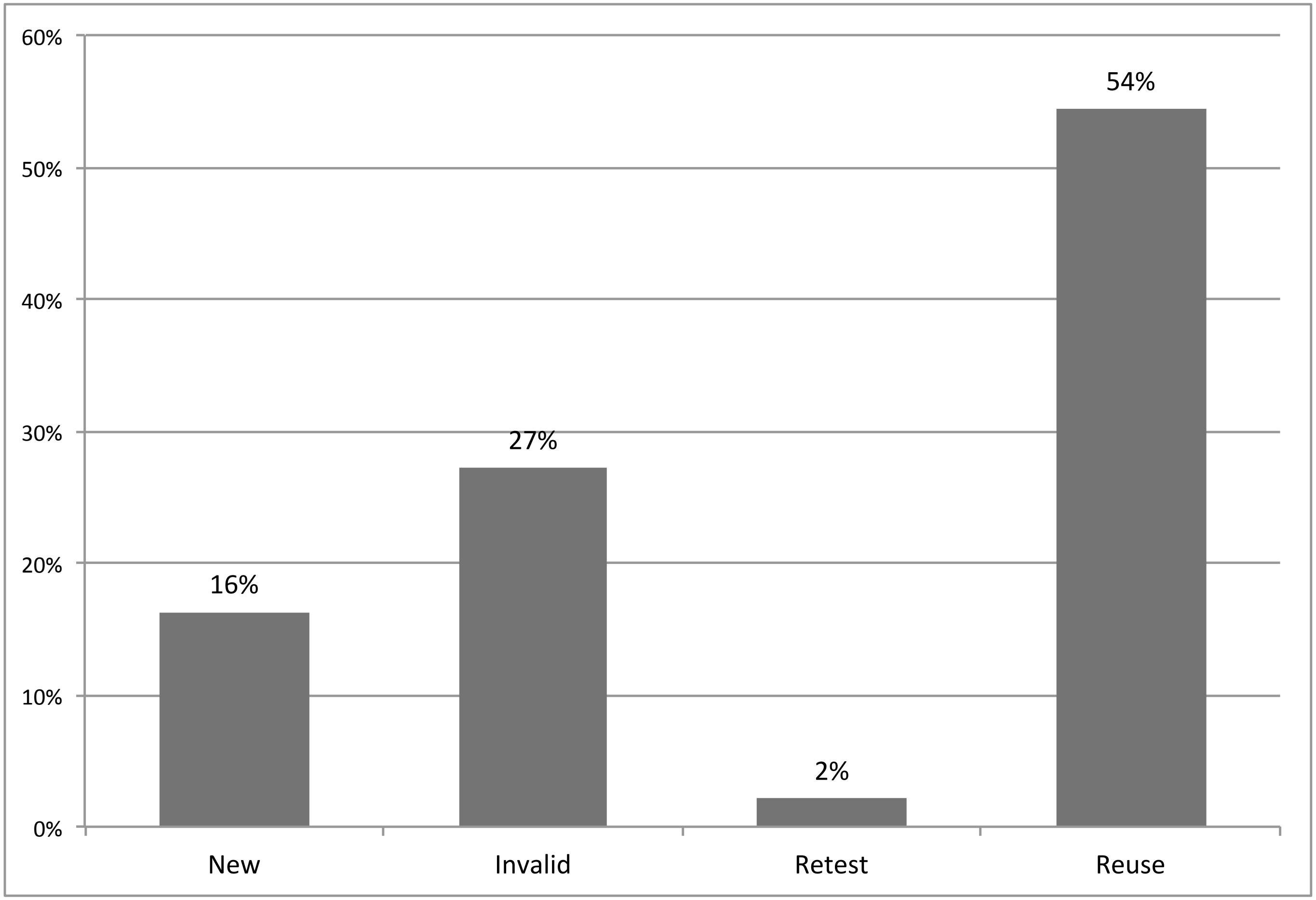


Case Study BCM – Delta-Testing Results (2)



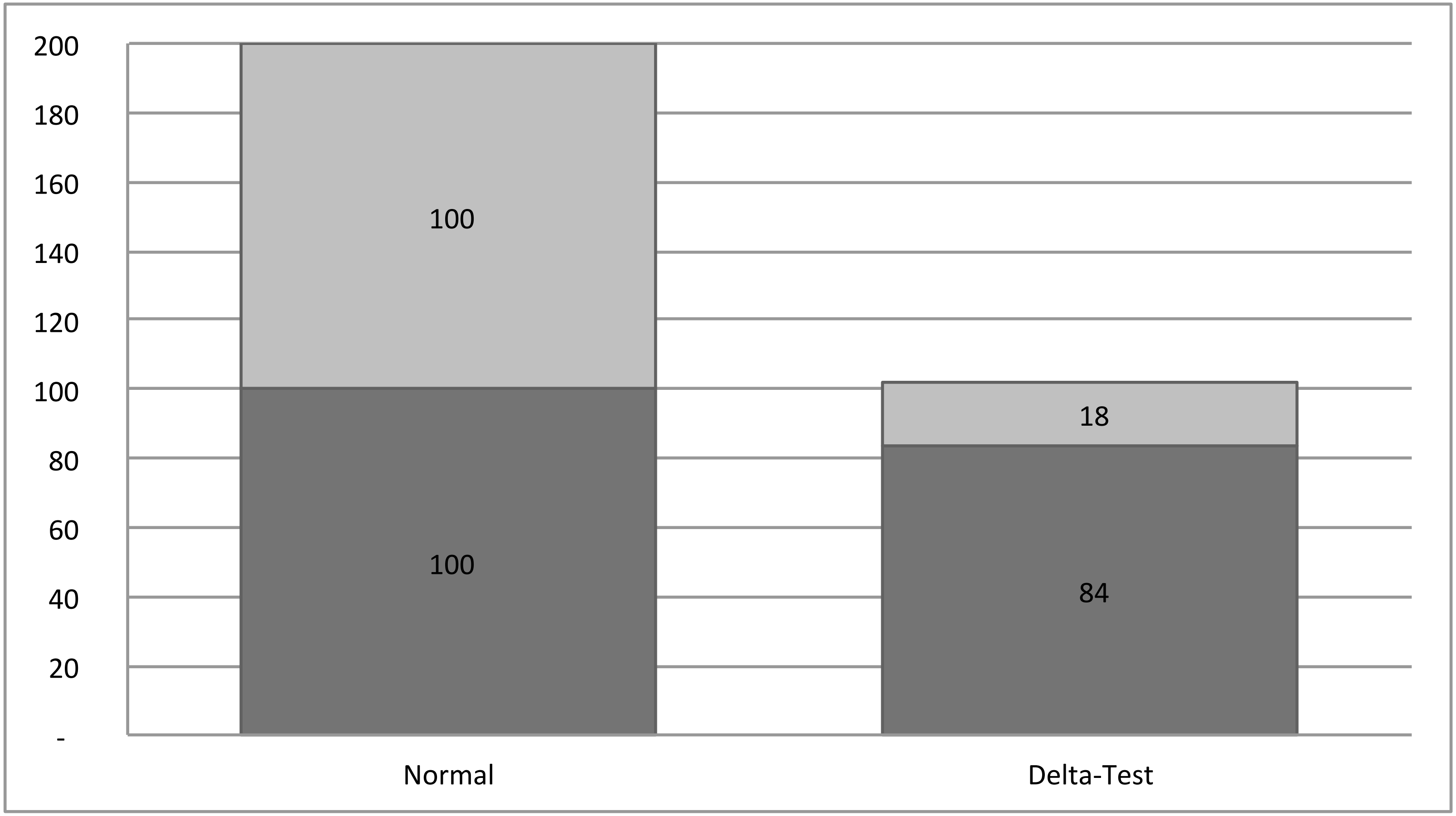
Requirements-based Delta-Testing - Classification

Pilot Study in Automotive Domain (Relative Figures)



Requirements-based Delta-Testing – Estimated Test Effort

Pilot Study in Automotive Domain (Relative Figures)



Possible Strategies for Re-Test Selection

- Manually by Test Engineer
- (Semi-)Automatical Classification of Test Cases into Variants
- Formulation of Requirements in Delta-Sets with Linking of Test Cases to Requirements
- Model-based Impact Analysis of Changes by Delta Analysis

Conclusion

- Model-based testing allows systematic test case generation and automatic test case execution.
- Subset selection heuristics reduce number of product variants to a representative subset which is tested.
- Incremental delta-testing reduces test effort between product variants by test case and test result reuse.