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A Metaheuristic Approach to Test Sequence Generation for GUI-based Applications

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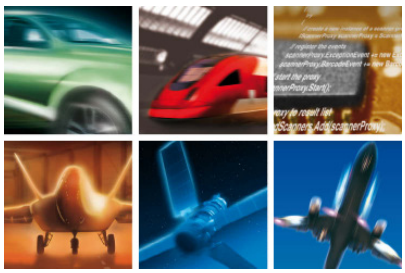

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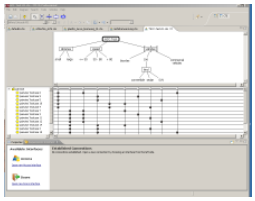
Overview

- Motivation
- Classification-Tree Editor CTE XL Professional
- Objectives for SBST application
- Application of ACO
- Objective Function
- Test Environment
- Fully Automatic Testing of CTE XL Professional
- Conclusion, Outlook

Motivation

- Many GUI based applications in all application domains
- Tester's task to define, execute and evaluate most interesting input sequences
- Input sequences are sequences of user actions (mouse events, keyboard events etc. such as clicks, drag and drop, keystrokes)

- Existing tools:
  - Many Capture + Replay Tools available, but limited applicability
    (e.g. B&M uses TestComplete and QF Test)
    - Definition of test sequences
      - by capturing user actions
      - developing test scripts
    - Only replay part is "automatic"



  - ➢ Test suites require constant maintenance
  - ➢ Labor intensive

- ➢ **Automatic generation of input sequences is quite desirable**

Typical Berner & Mattner Products

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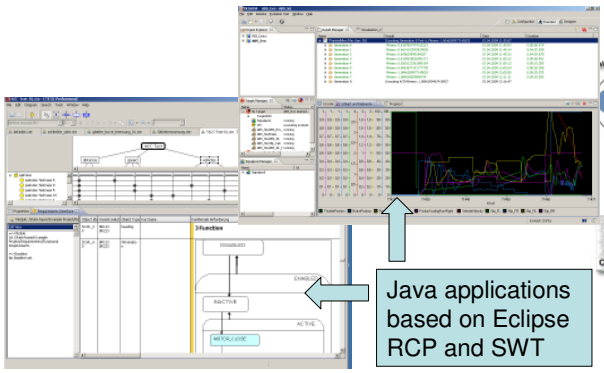
Systematic test case design for specification-based testing

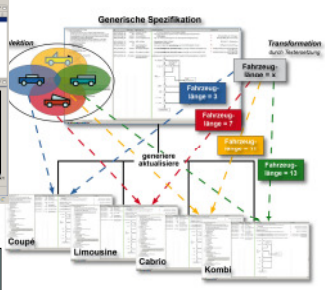
MESSINA

Virtual Integration and Testing of AUTOSAR-SWC

MERAN

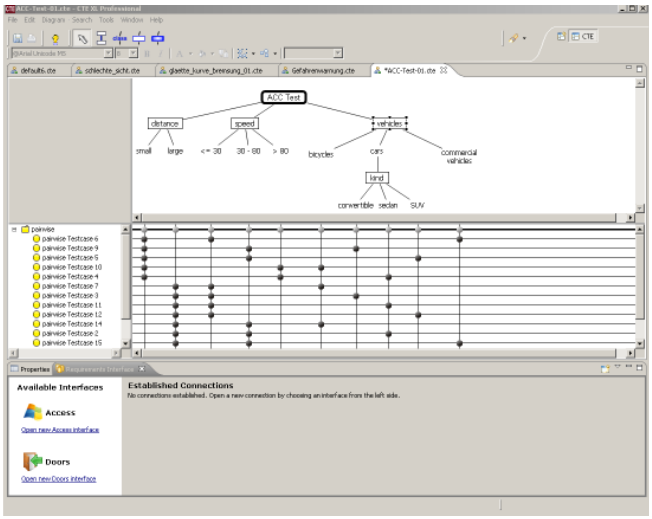
Variant management and model-based development for specifications in DOORS





Java applications based on Eclipse RCP and SWT

CTE XL Prof.



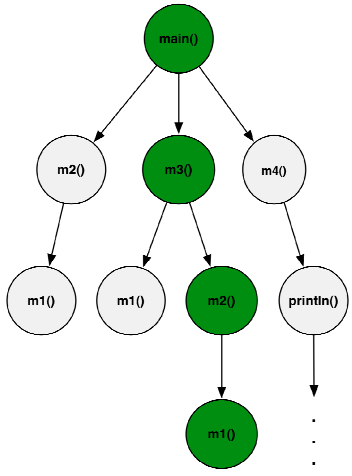
Drawing area for classification trees

Combination table for test case specifications

Panel for establishing RM connections

Objectives for Application of Search-Based Testing

- search for interesting test sequences
- fullest possible execution of the program functions in different contexts
- in our case:
  - find sequences that generate large amounts of different call stacks (the more CSs a sequence generates, the more aspects of the SUT are tested (McMaster et al.) ⇒ call trees with many leaves most interesting for fault detection)
  - check for exceptions occurring during the execution
- Alternatively:
  - Check for memory leaks,
  - Check for code coverage,
  - Check for performance bottlenecks,
  - Check for assertion violations
  - …



Application of Ant Colony Optimization

Reasons for using ACO

- ACO usually applied for sequence generation problems, e.g. TSP. Independent of mutation and crossover.
- Mutation operator problems for sequence generation
  - Easy generation of infeasible sequences (not all actions are available in all contexts)
  - Neighbourhood of a sequence leads to artificial definitions
- Crossover operators introduce similar problems (exchanging sequence parts will lead to infeasible sequences)

Ant Colony Optimization

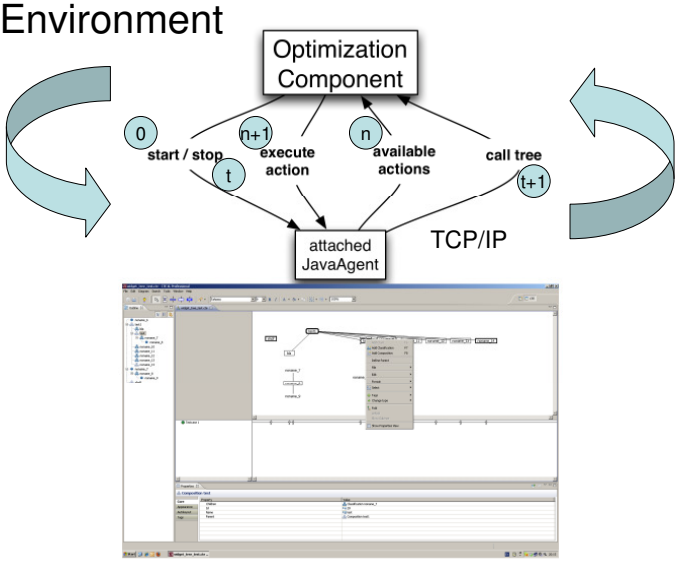
- Idea:
  - C = component set (here: C = set of feasible actions)
  - Generate trails (sequences of user actions) by selecting components $c_i \in C$ considering pheromone values p_i
    - Pseudo random proportionate selection
  - Assess trails (# Call Tree Leaves)
  - Reward components c_i that appear in “good” trails by increasing their pheromones p_i
    - After each generation
      - Only top k trails are considered
      - $p_i' = p_i \cdot (1-\alpha) + \alpha \cdot r_i$ where α is the evaporation / learning rate and r_i the average reward of the trails that c_i appeared in

Objective Function

For each generated sequence of user actions the size of its call tree is calculated by the number of leaves: # CT leaves.

Call Trees for multiple threads are combined into one call tree. Redundancies are eliminated.

Test Environment



Test Environment

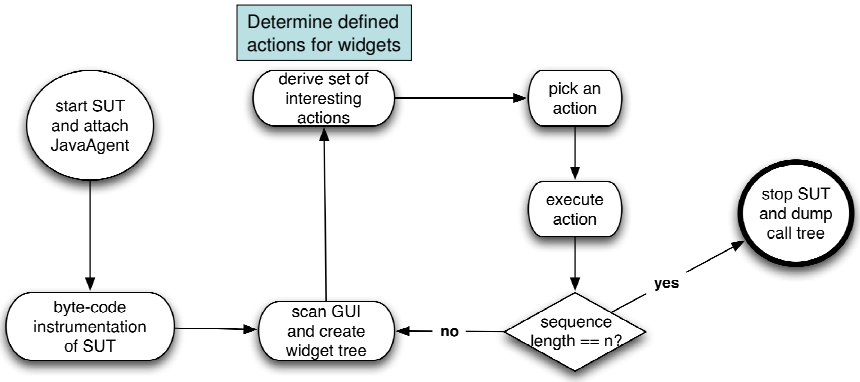
Optimization Component

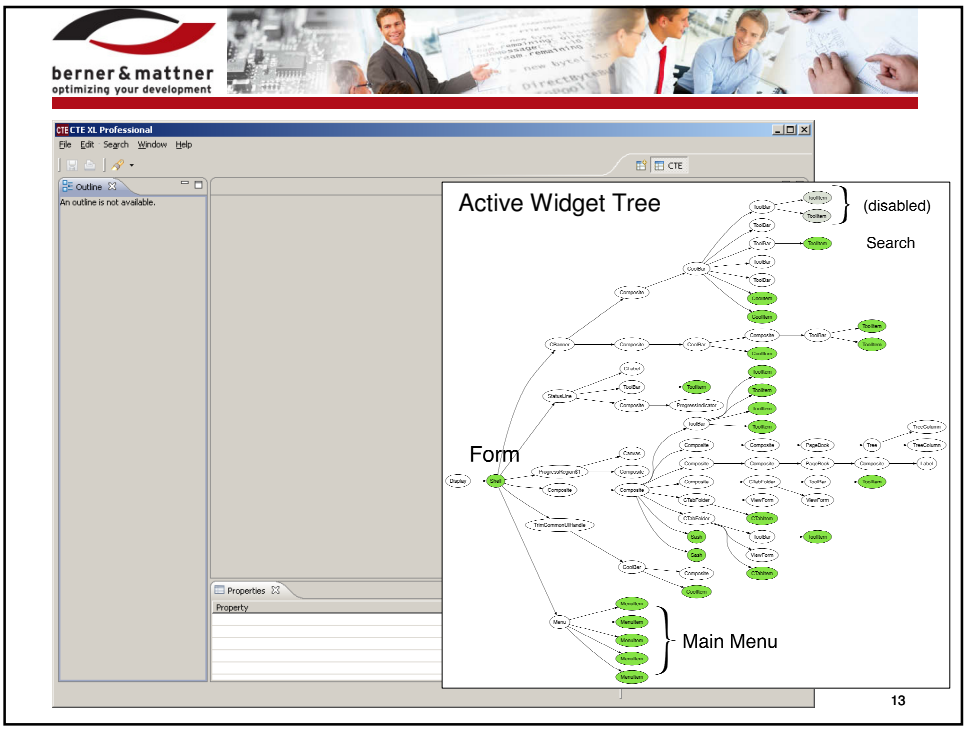
- implements the search (ACO)
- maintains the pheromones for each named action according to call trees
- selects most promising actions
- analyse exceptions

Java Agent

- independent of source code
- attaches to SUT
- instruments bytecode to obtain call tree (includes third party modules)
- scans the GUI to create a widget tree for each execution state
- defines unique identifiers for each action
- executes selected actions
- returns overall call tree
- monitors exceptions

Test Environment – Sequence Generation

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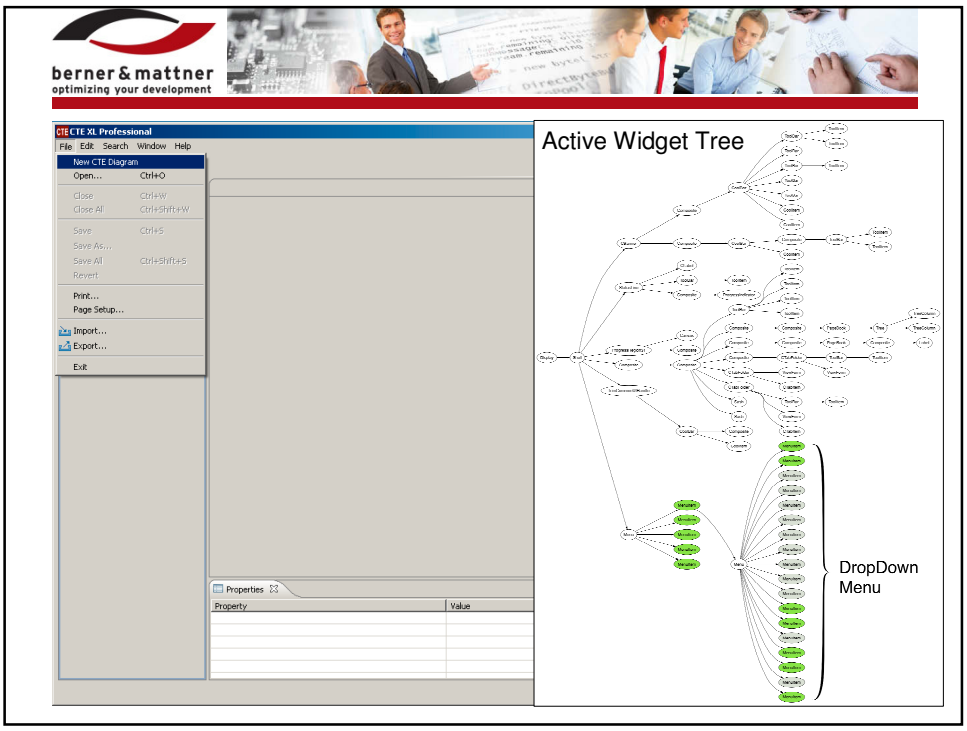
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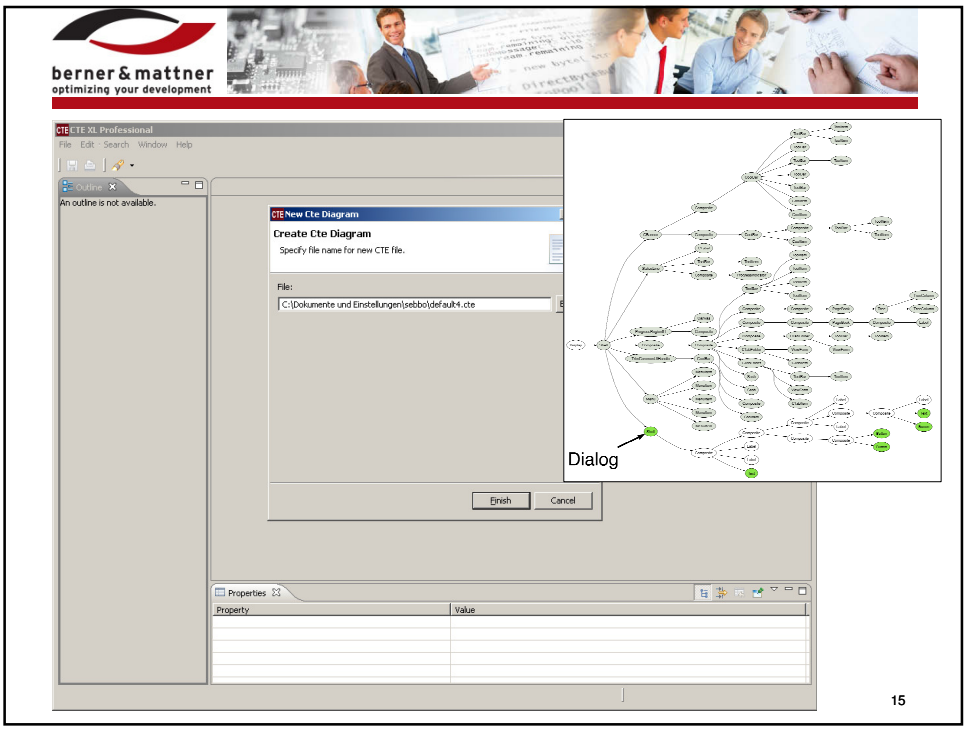
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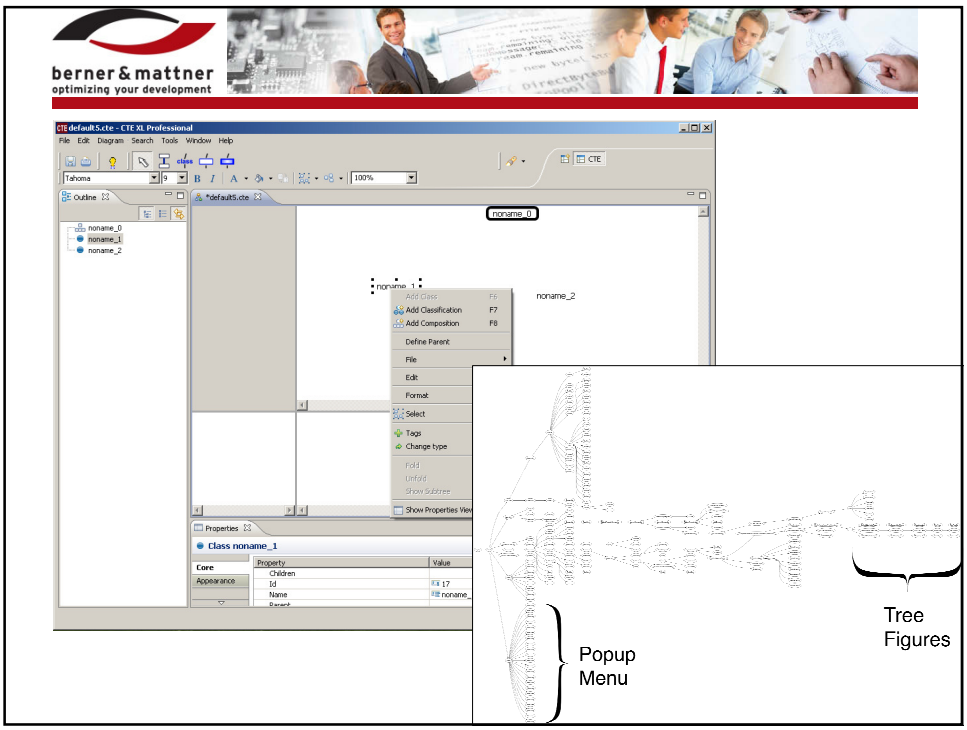
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Unfold
Show Subtree
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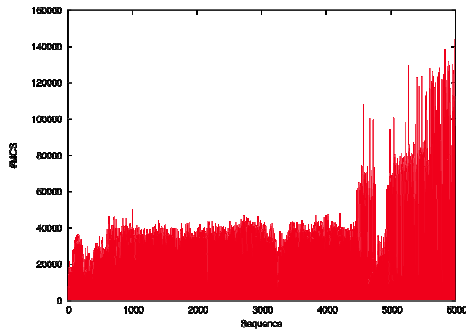
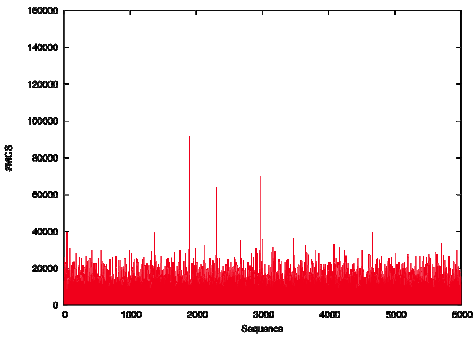
Id
Name
Popup
Menu
Tree
Figures

Experiment

ACO Run



Random Run



desc	k	α	ρ	popsize	generations	seqlength	pheromone default	max #CS	duration
aco	15	0.3	0.7	20	300	10	30000	144082	12.5 h
random	all	0.0	0.0	20	300	10	1	91587	12.5 h

Conclusion

- High demand for automatic GUI testing in industrial practice
- Typical application: CTE XL Professional (Eclipse RCP, SWT)
- Functional testing for logical errors difficult, because guidance to unknown logical errors hard to formalize
- Functional testing for exceptions, memory leaks, … possible

- Test environment allows to
  - determine all possible user actions in each execution state
  - selects most interesting actions
  - assesses overall quality of test sequences by analyzing the call tree
  - generates long test sequences with most highest variety

- Evaluation
  - Application of search successfull
  - Initial experiments confirm better performance than random testing

Outlook

- Experiments on generating entire test suites to be performed
- Possible improvement of algorithm to be more explorative

- Evaluate more advanced objective functions (not only number of call tree leaves)

- Increase efficiency
  - Sequence generation is expensive ➔ parallelization of search and test
  - ACO good choice? ➔ disregards linkage among actions (context of actions not considered for pheromone value calculation)

- Fault sensitivity of generated sequences ➔ empirical evaluation