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# Using Meta-model Coverage to Qualify Test Oracles

## AMT'13 – Miami

Olivier Finot, Jean-Marie Mottu,

Gerson Sunyé, and Thomas Degueule

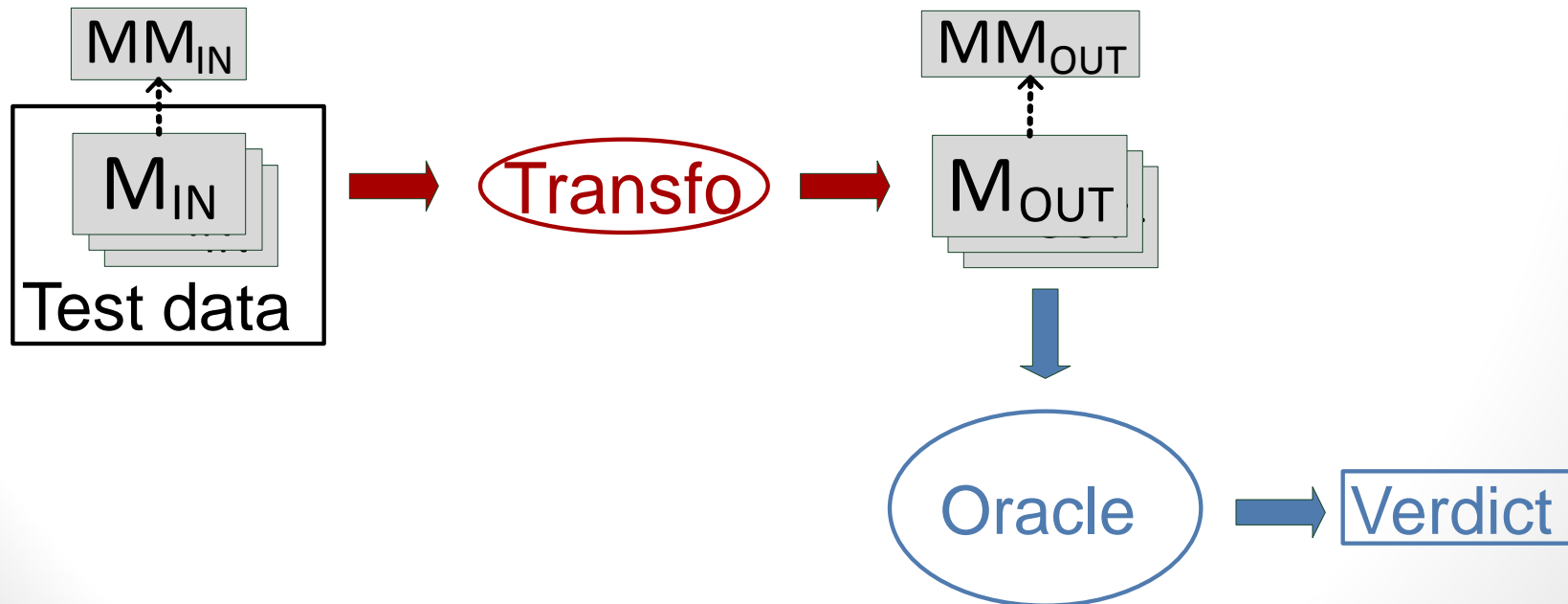


# Outline

- Introduction: Model transformation testing
- Problem: Tediousness of analysing models
- Previous work
- Problematic: Difficult to qualify test oracles
- Meta-model coverage to qualify test oracles
- Tool & experimentation
- Perspectives
- Conclusion

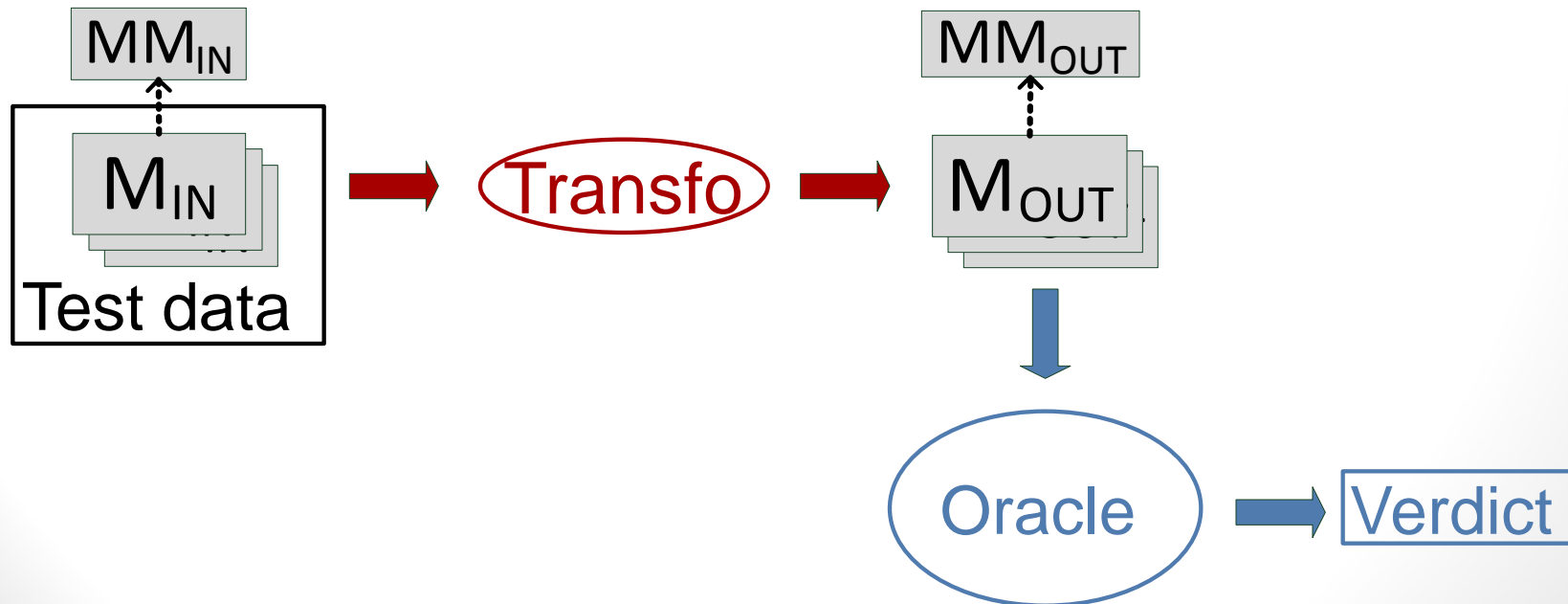
# Model Transformation Testing

- Ensure model transformation quality
- Prevent fault propagation
- Test models are generated
- Test oracles control that output models satisfy the specifications

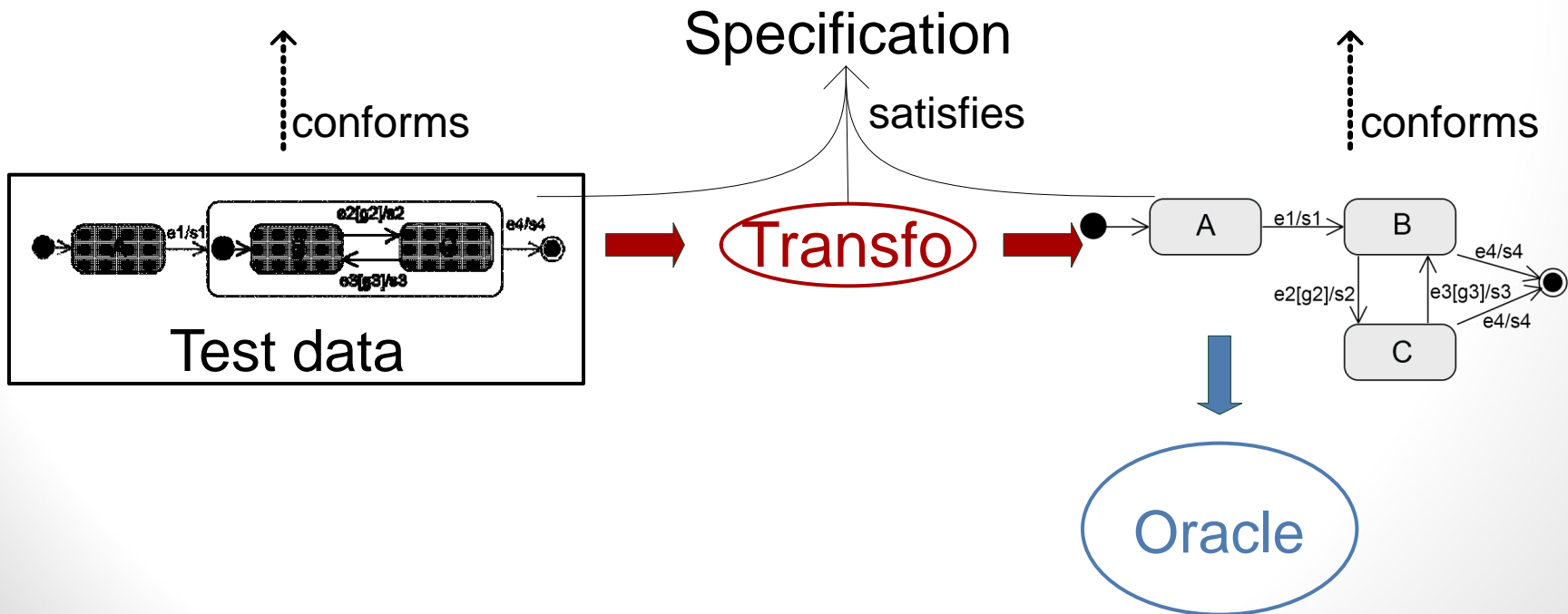
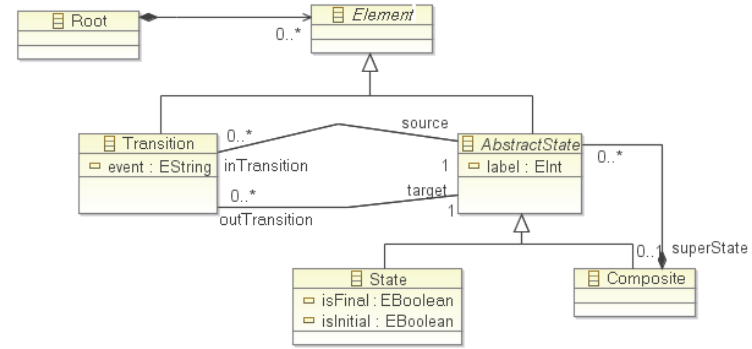
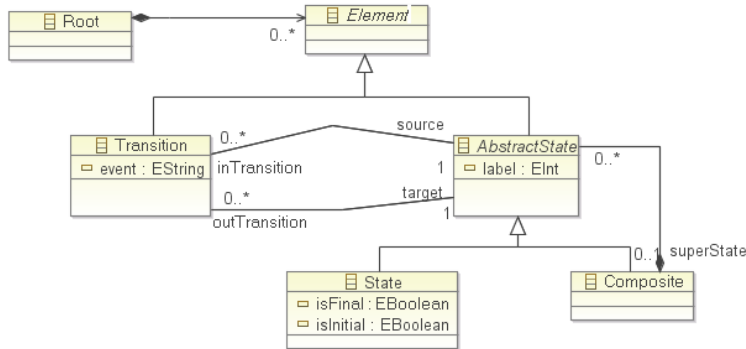


# Qualify Test Oracles

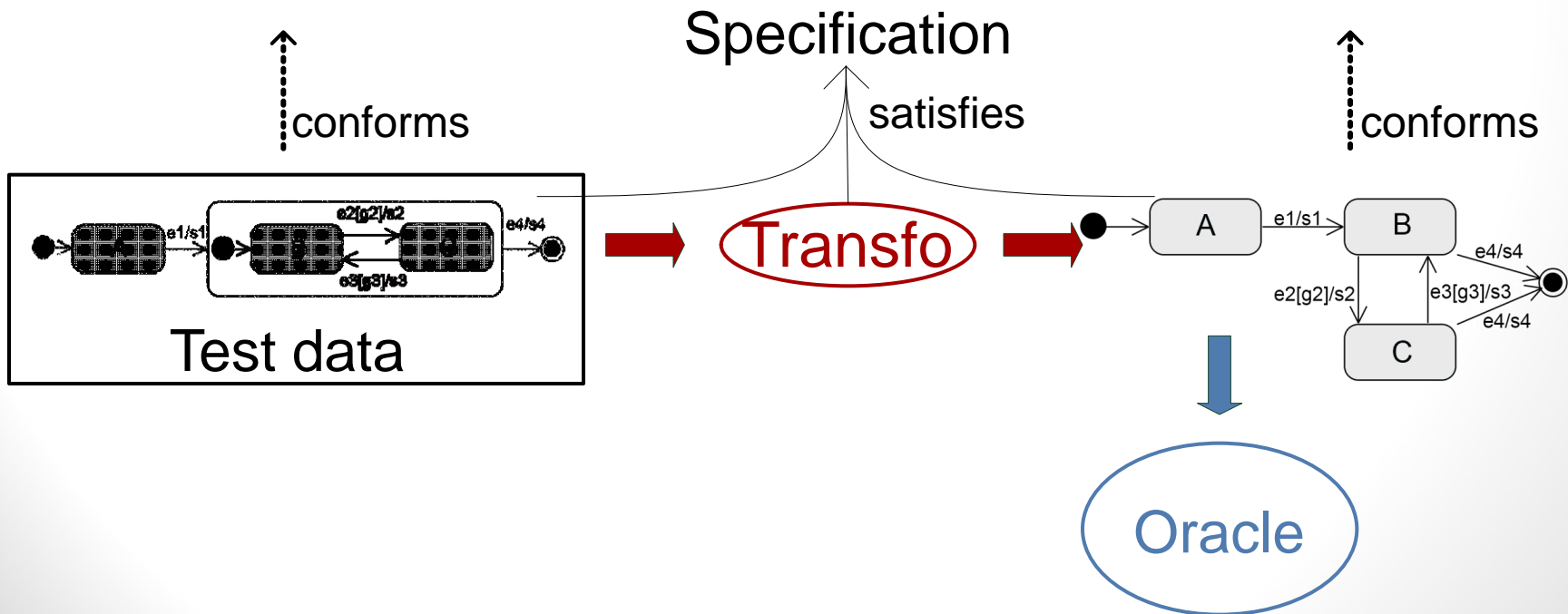
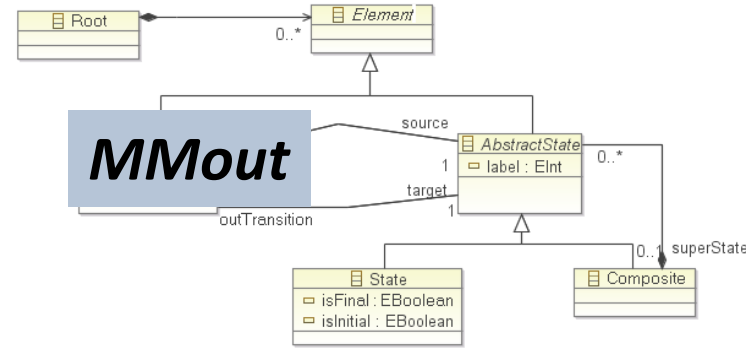
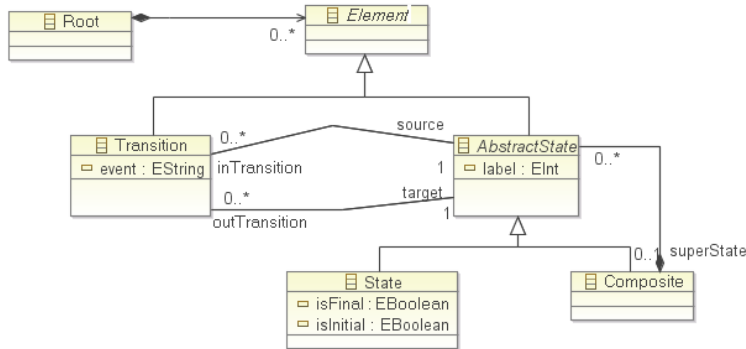
- Our objective is to evaluate the test oracle quality
  - Test data are already qualified
    - especially because they are generated.
  - Test oracles are usually hand writing
    - then they should be qualified.



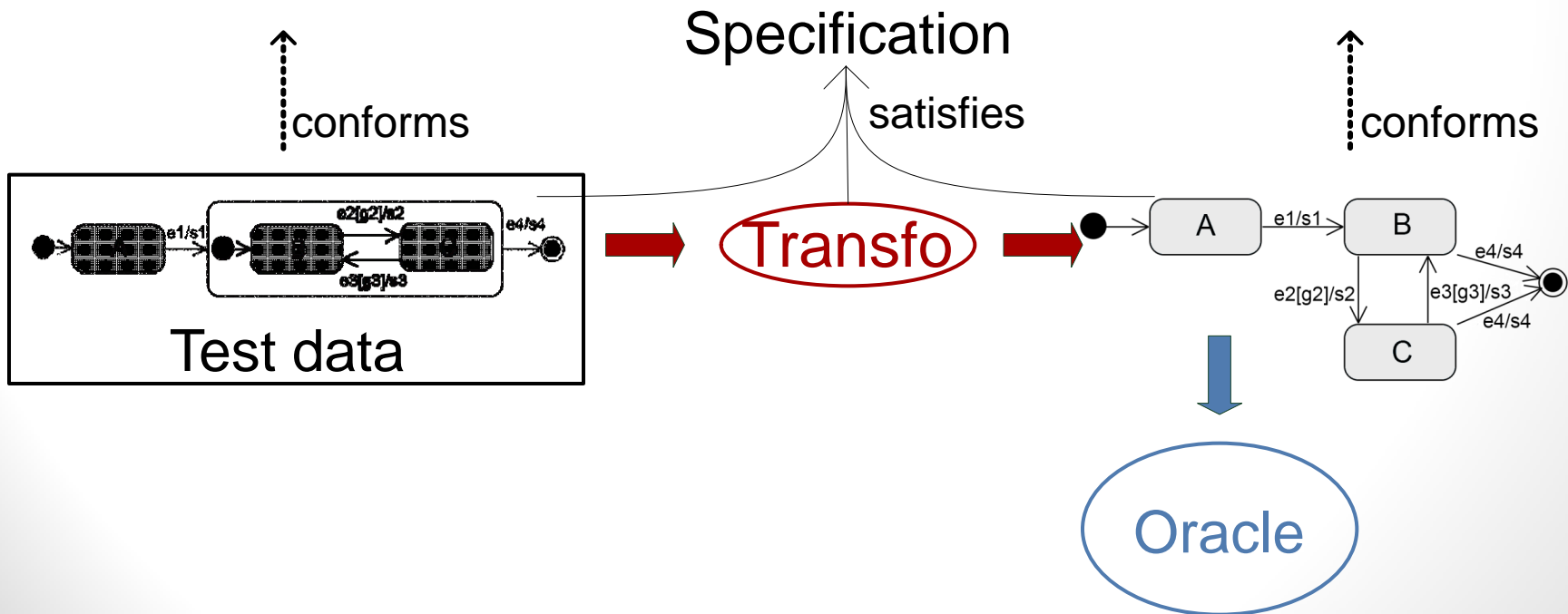
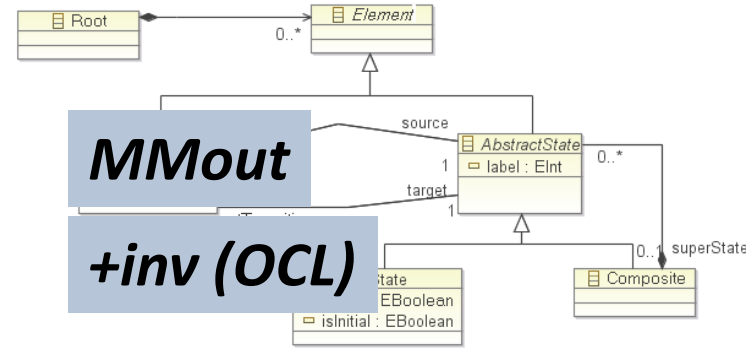
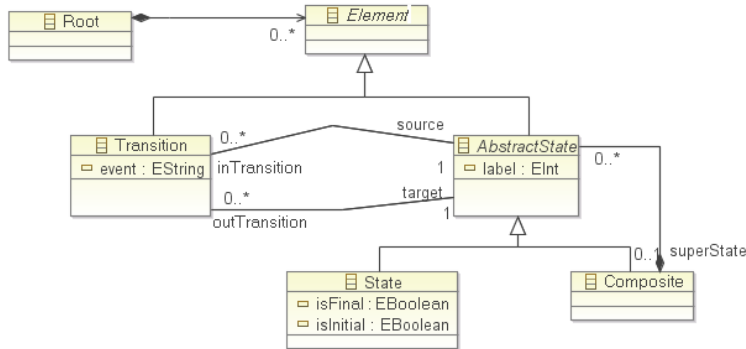
# Problem: Tediousness of Analysing Models



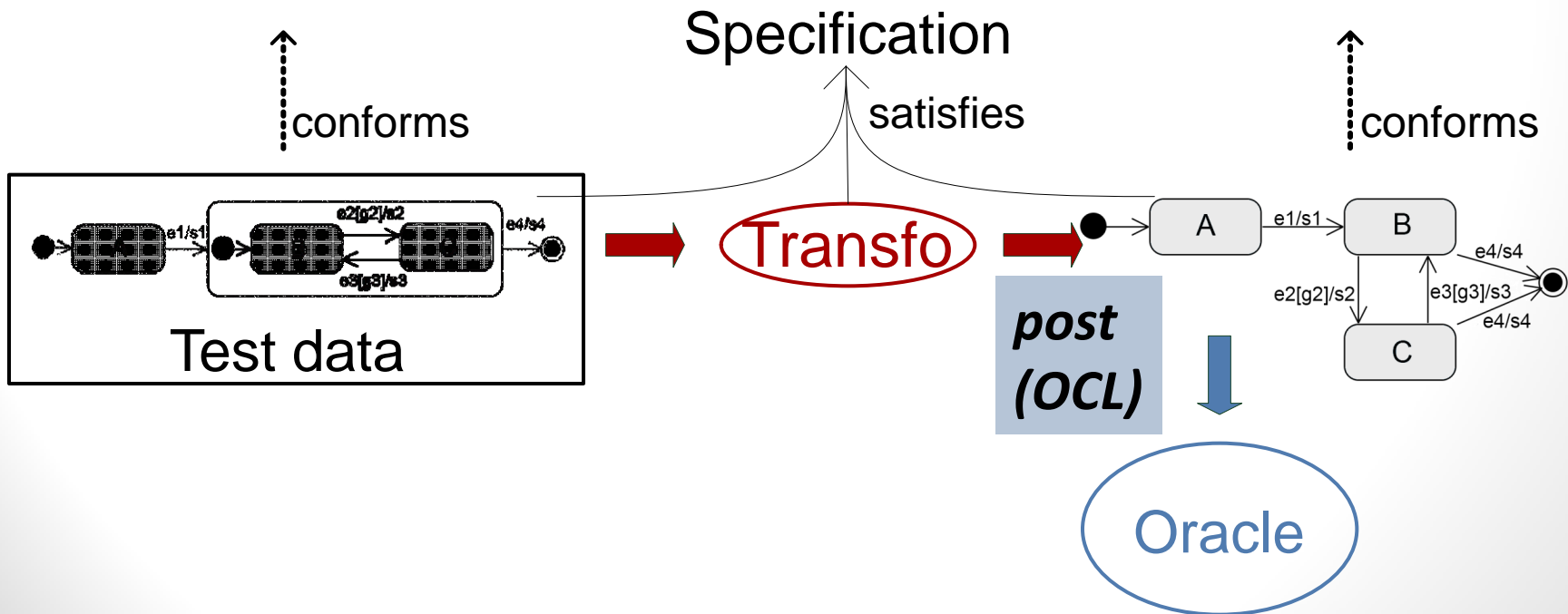
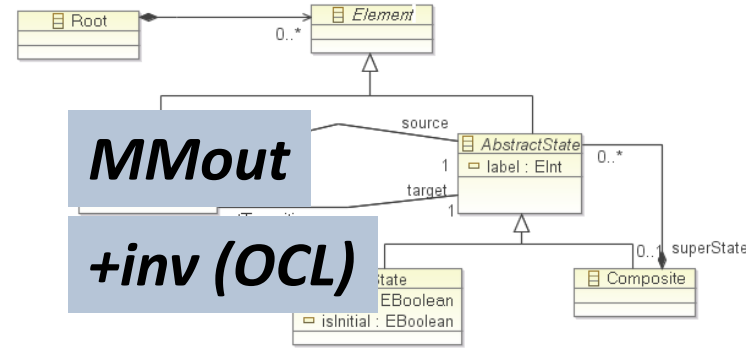
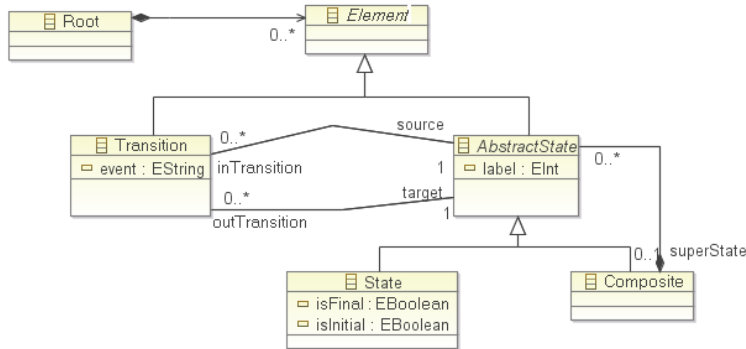
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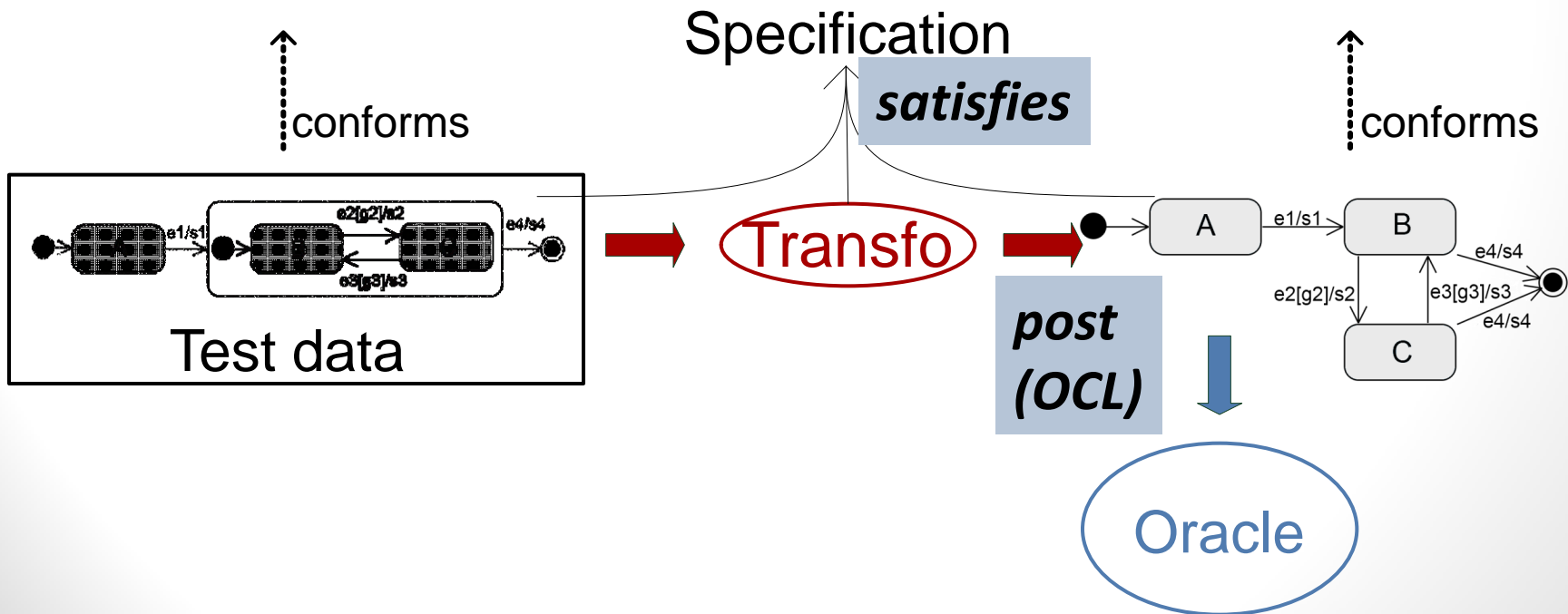
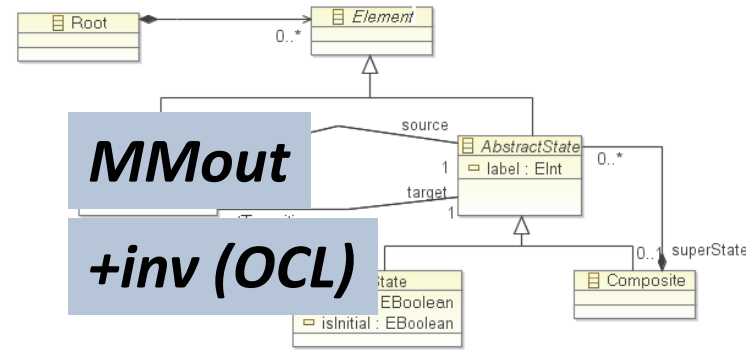
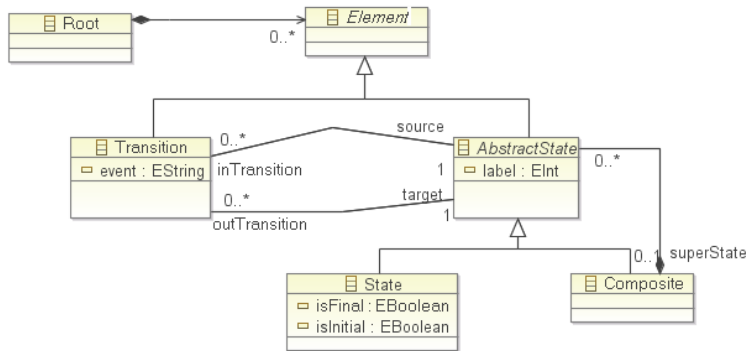


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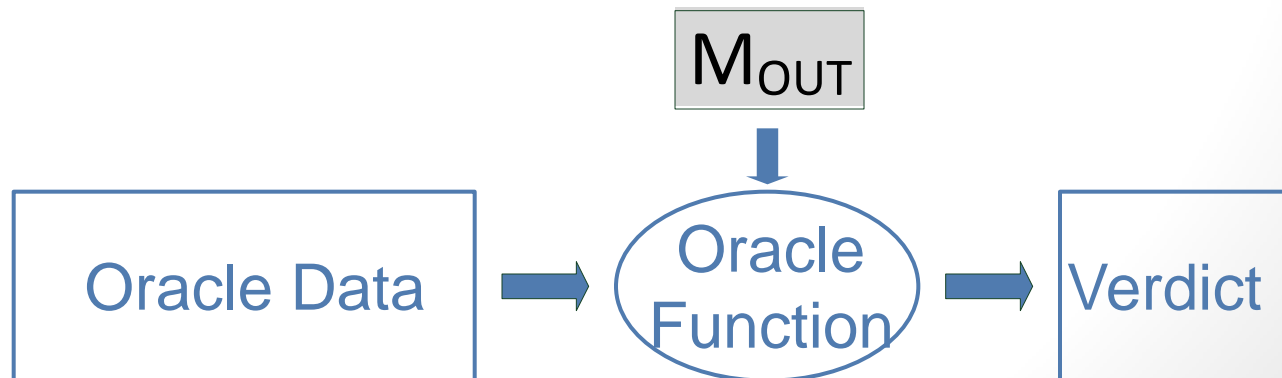


# Problem: Tediousness of Analysing Models



# Previously: Test Oracle Functions

- 2008: Identify oracle functions to test model transformations
- Published in:  
*Mottu et al. Model Transformation Testing: Oracle Issue.*  
**MoDeVva'08** colocated with ICST'08
- An oracle function processes output models. It is parameterized with an oracle data and returns a verdict.
  - For instance an oracle function can use:
    - a model comparison to compare output and expected models,
    - or contracts.



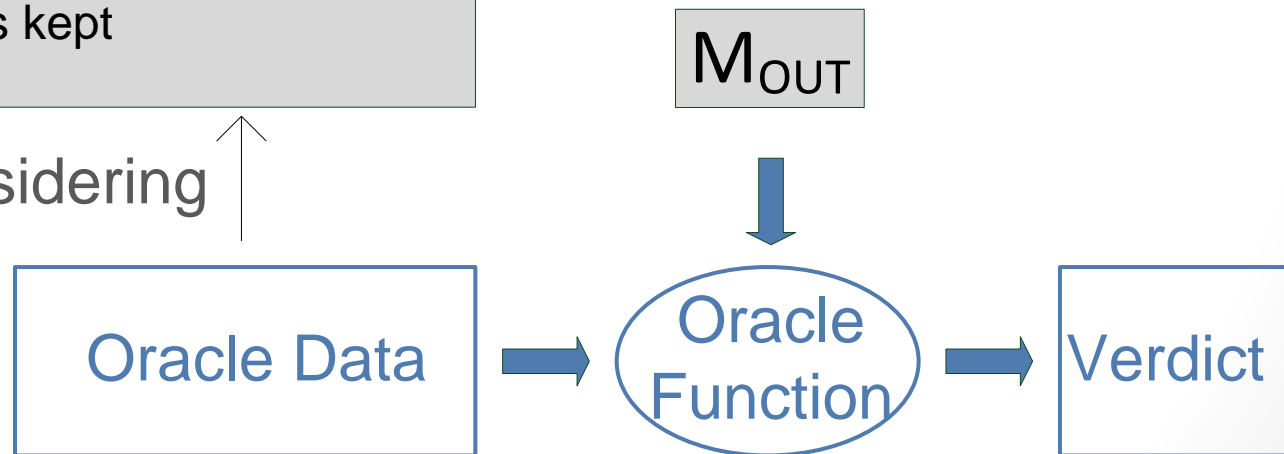
# Previously:

# Partial Oracle

- Oracle returns partial verdict
  - 2013: Partial oracle
  - Published in: *Finot, Mottu, et al.* Partial Test Oracle in Model Transformation Testing. **ICMT'13**

- No more composite states
- Simple states kept
- Transitions between simple states kept
- Final states kept
- etc.

Considering



# Previously:

# Partial Oracle

- Oracle returns partial verdict
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- No more composite states
- Simple states kept
- Transitions between simple states kept
- ~~Final states kept~~
- etc.

Considering

*Partial*  
Oracle Data



Oracle  
Function



*Partial*  
Verdict

$M_{OUT}$

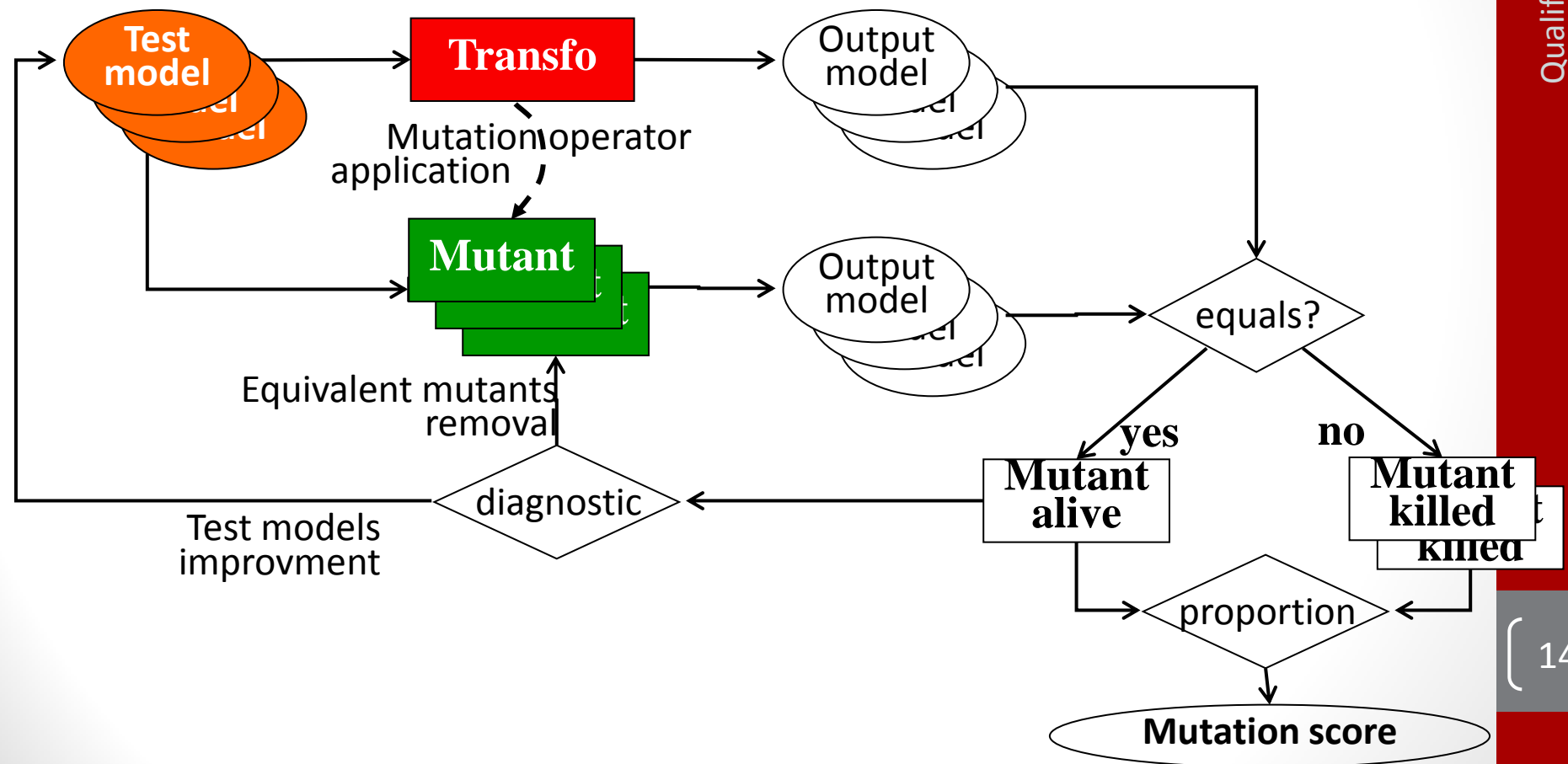


# Problem: Qualifying Oracles

- We define partial oracles
- How do we evaluate their quality?
- Recently formalized by Staats et al. (ICSE'11): Oracle's Power
  - Oracle o1 is more powerful than o2,
    - if o2 detects a fault then so does o1.
    - As a consequence, o1 detects as many faults as o2.
- Evaluate the capacity of the oracles to detect faults
  - with mutation analysis:
    - Faults are voluntary injected in the SUT to measure how the test data and the oracles detect them

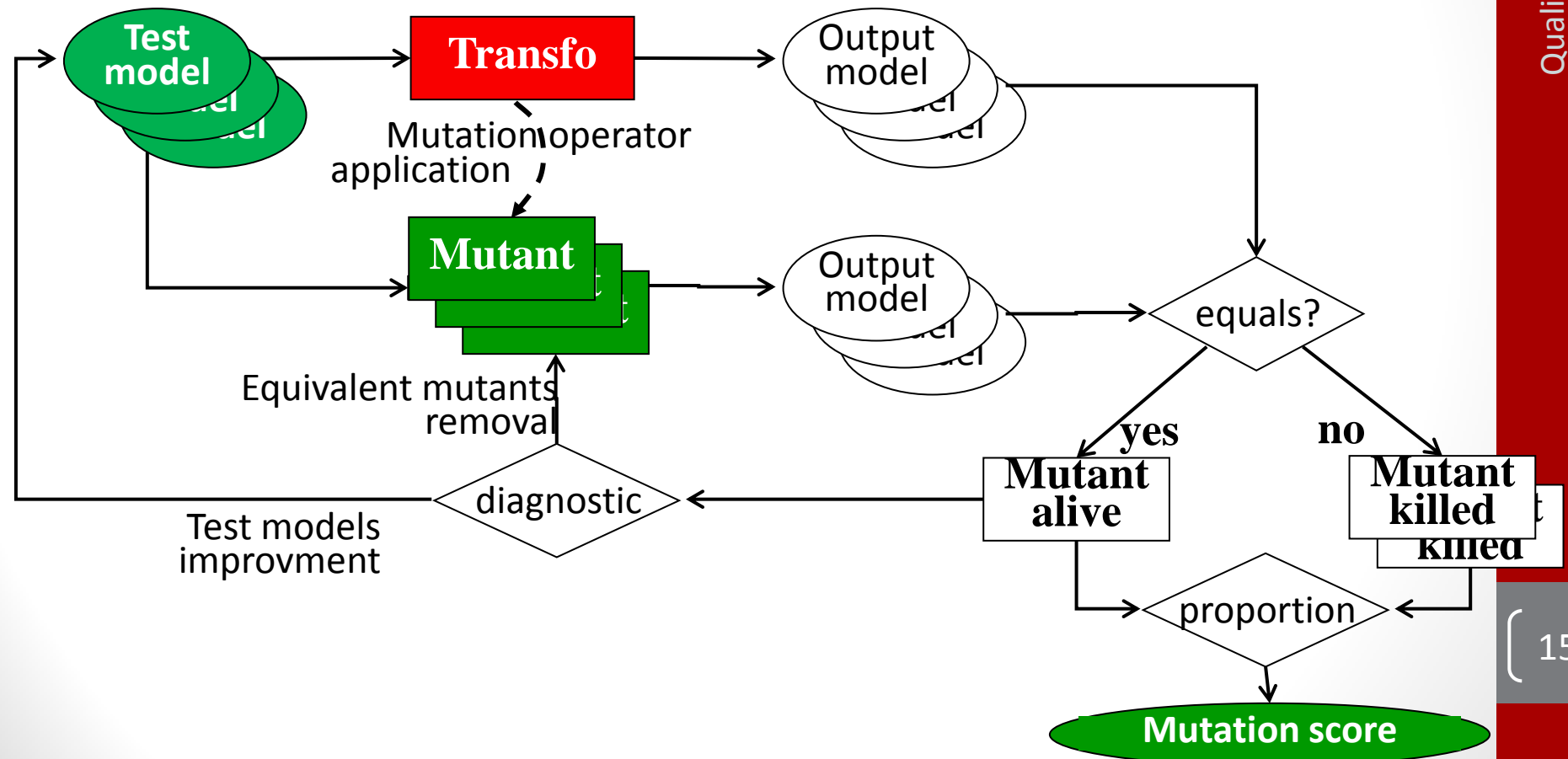
# Mutation Analysis

- Qualified the test model set.



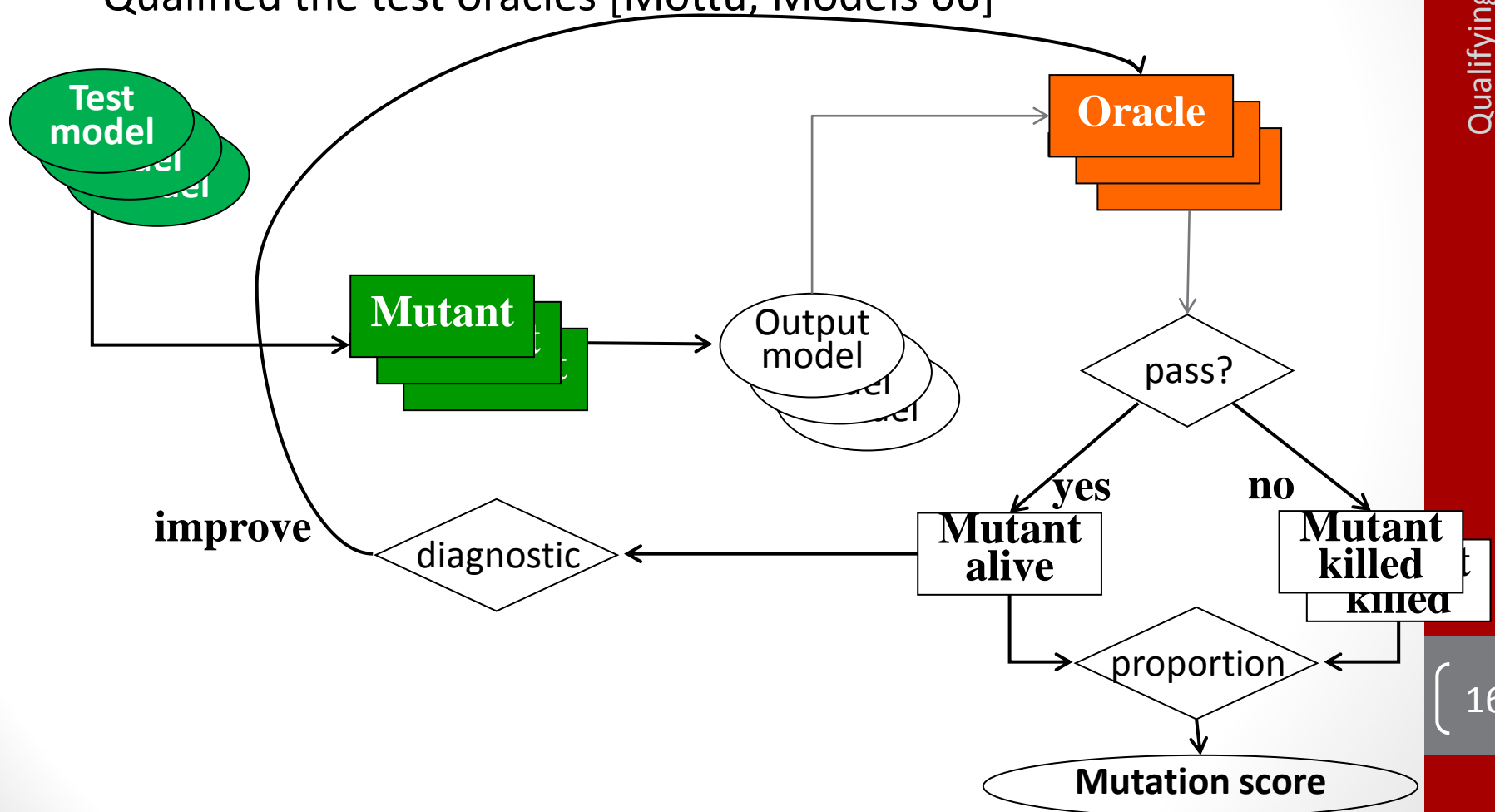
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# Mutation Analysis

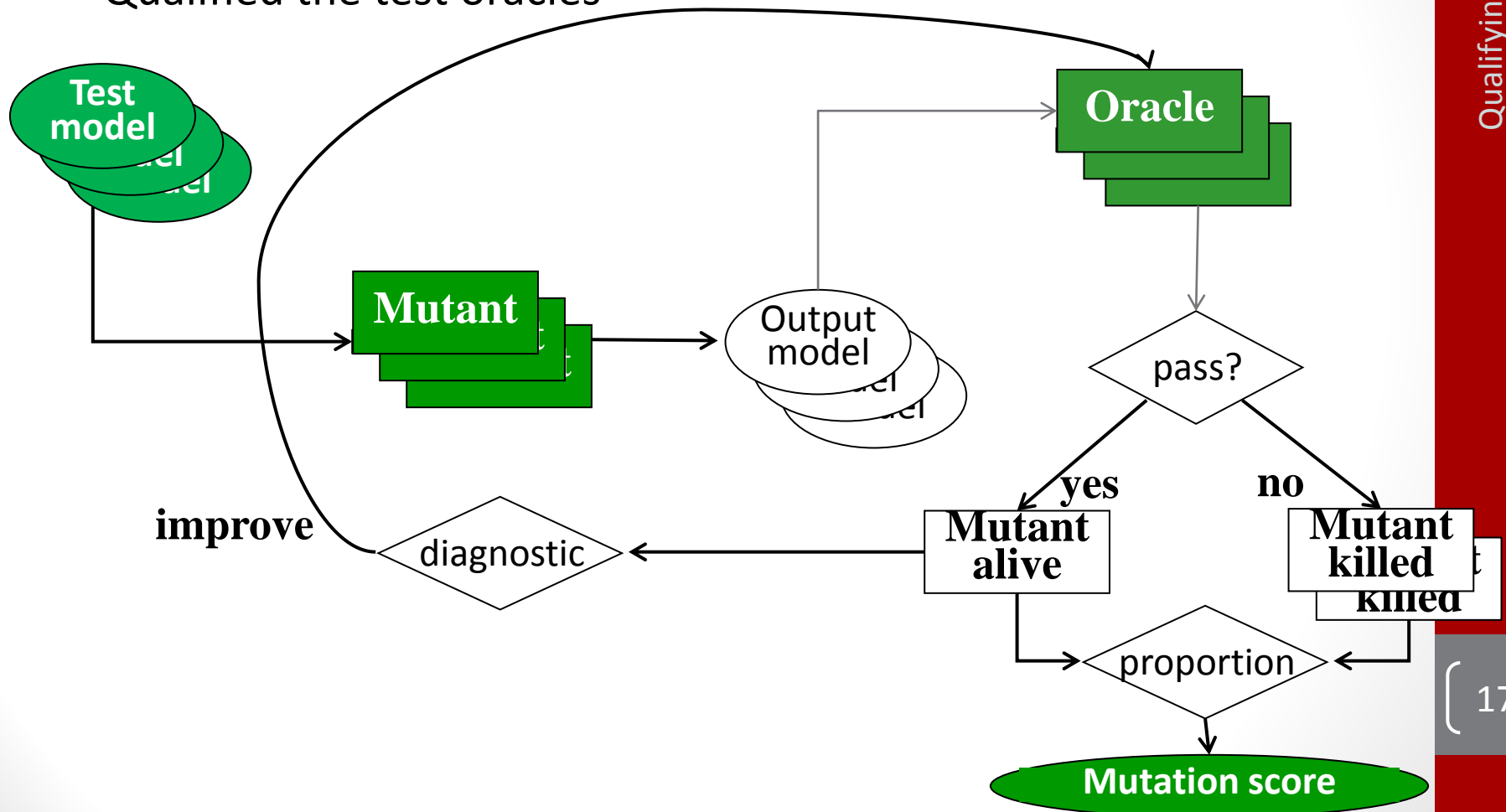
- Qualified the test model set
- Qualified the test oracles [Mottu, Models'06]





# Mutation Analysis

- Qualified the test model set
- Qualified the test oracles

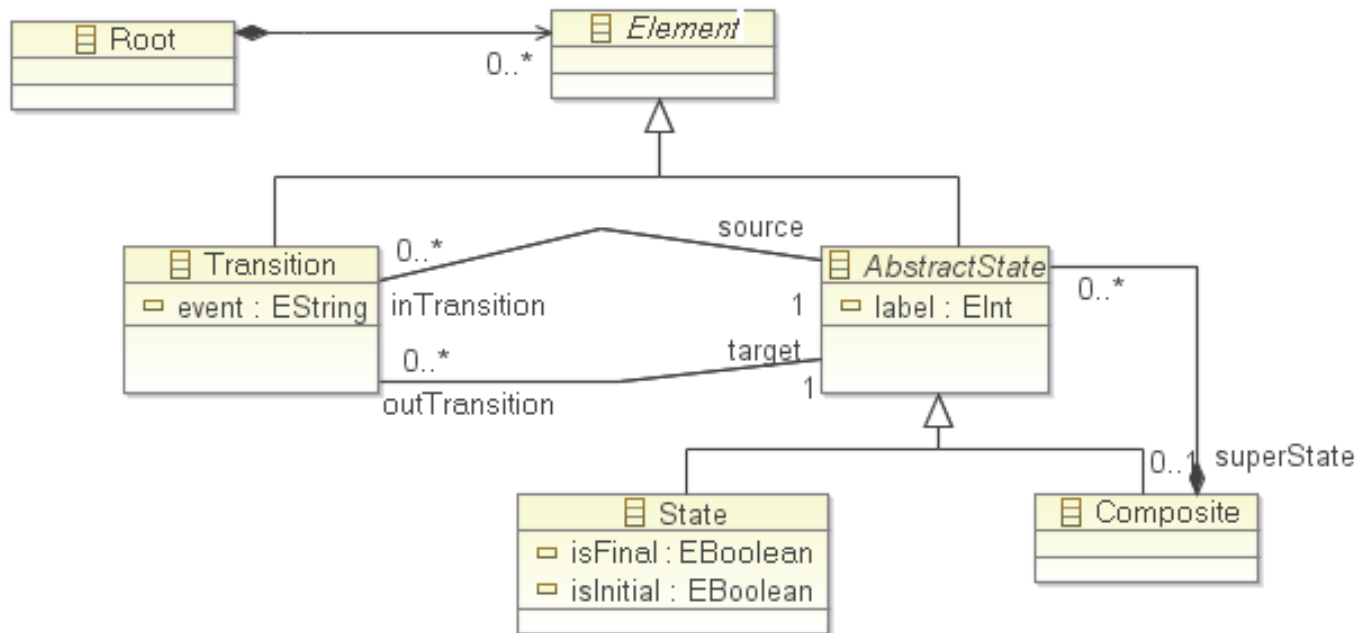


# Mutation Analysis Drawbacks

- Difficult to practically use it to qualify oracles
  - Costly
  - Dependent from the Transformation Language
    - We have designed language independent mutation operators,
    - but they have to be implemented in each language.
- (Test model and) Oracles improvement difficult
  - Require static analysis of the live mutants

# Contribution: Meta-model Coverage to Qualify Oracles

- Qualifying oracles according to output meta-model coverage.
  - Individual oracles have different MM coverage.
  - Set of oracles may not cover entirely the MM.

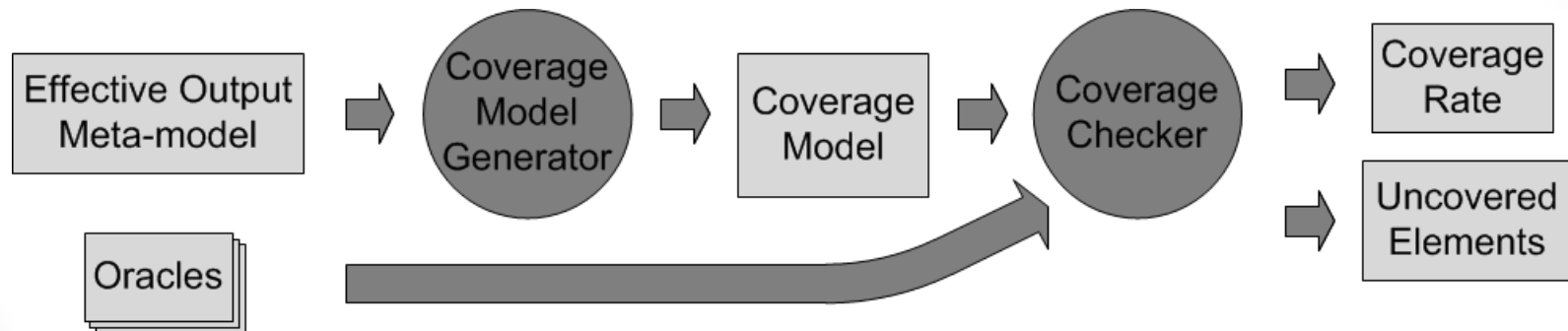


- High coverage => high fault detection power => high quality ?

# Contribution:

## Meta-model Coverage to Qualify Oracles

- Coverage criteria adapted from [Fleurey, Sosym09]
  - All classes
  - Association end multiplicities
  - Class attribute
- We propose a process and we have developed a prototype
  - measuring the MM coverage of test oracles,
  - identifying the MM uncovered Elements.



# Contribution: Experiment

- Objectives
  - Be able to measure the coverage of the output meta-model by a test oracle.
  - Compare the coverage of the output meta-model with the mutation score.
  - Validate that the coverage of the output meta-model can be used as an indicator of the quality of a set of oracles.

# Experiment details

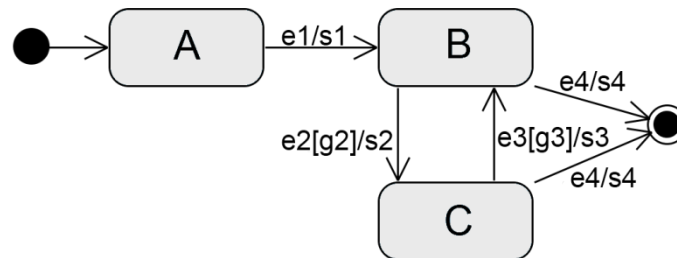
- Two Case Studies
  - FSM2FFSM in Kermeta
    - Flattening Finite State Machine
  - UML2CSP in ATL
    - UML Activity Diagram to CSP
- 22 + 35 Test Models
- Protocol :  
different MM coverage compared based on the mutation analysis
  - 83 + 137 Mutants
- Available on: <https://sites.google.com/site/qualifyingtestoraclesmt/>

# Experiment details

- Two Sets of Oracles considering two oracle functions
  - Contracts
    - Small contracts to control single properties
    - Combined to incrementally increase coverage
  - Comparison of expected output models:
    - Several subsets with different coverage

# Experiment details

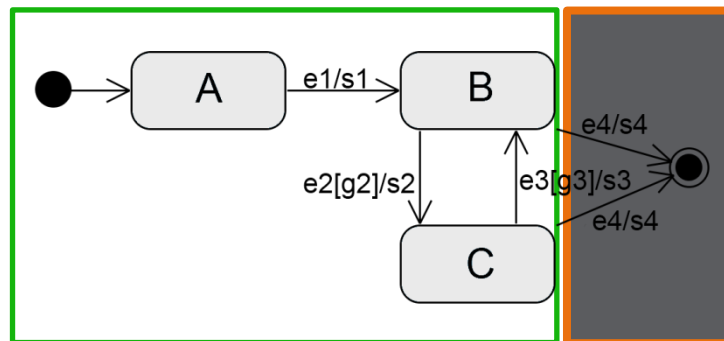
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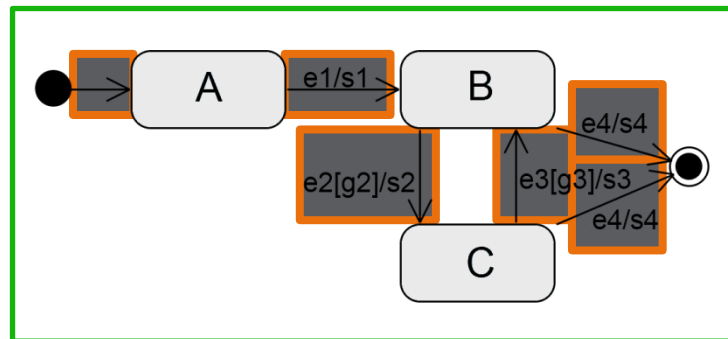
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      - Complete output models:
      - Partial output models :
        - Without finalstate



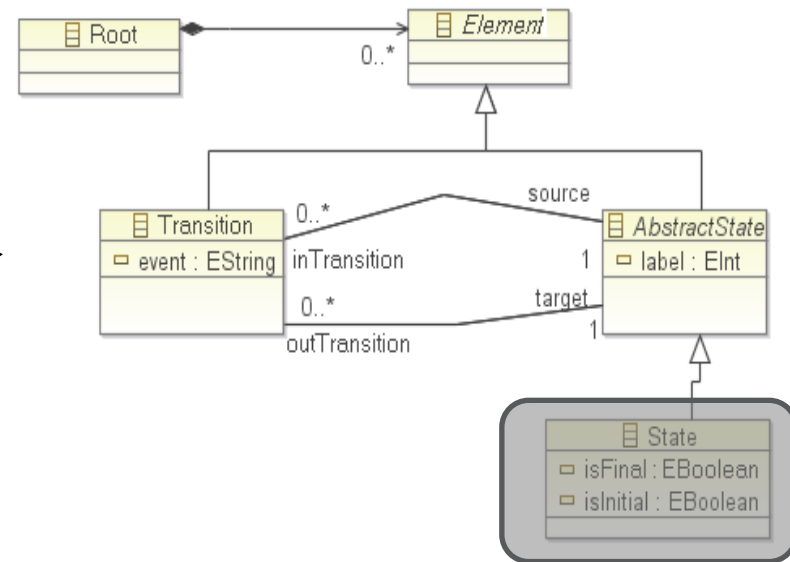
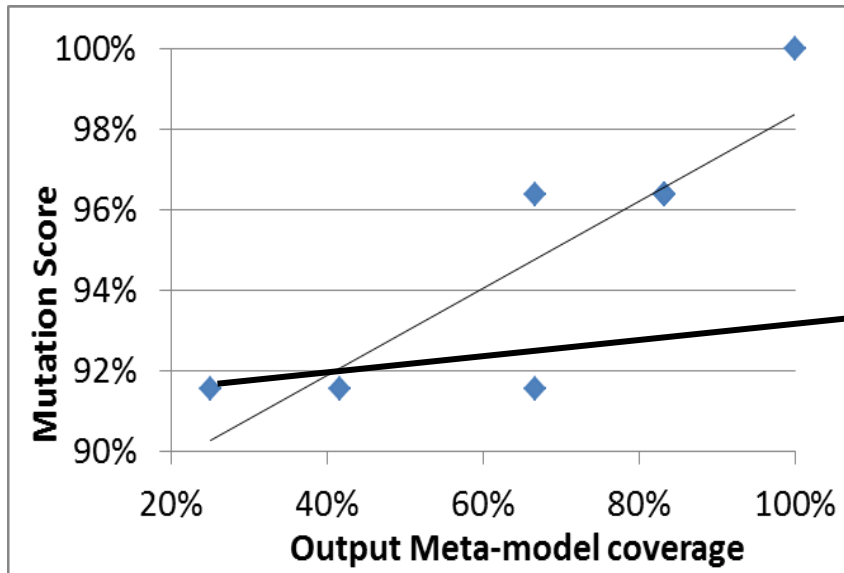
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      - Partial output models:
        - Without finalstate
        - Without transition, etc.



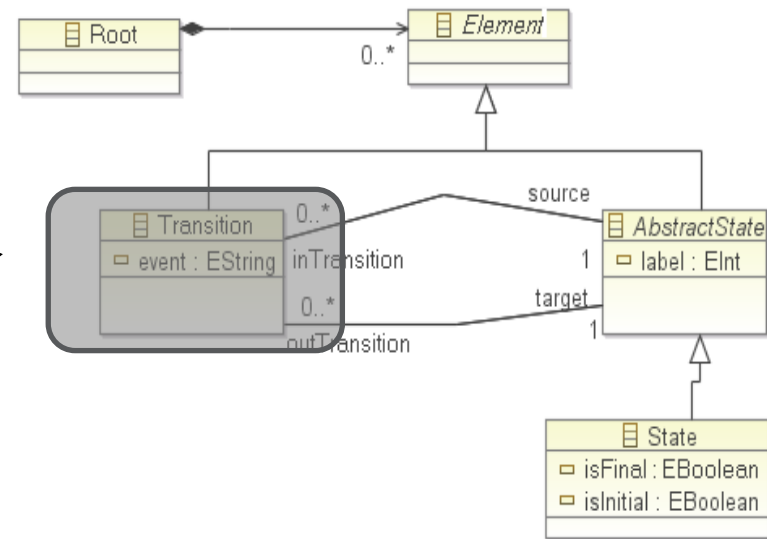
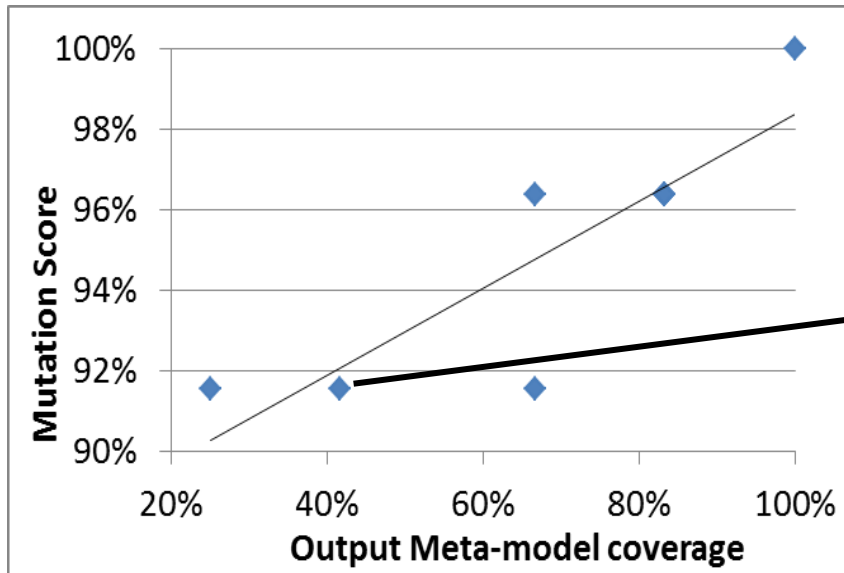
# Results: FSM2FFSM

- Oracles Using Expected Output Models



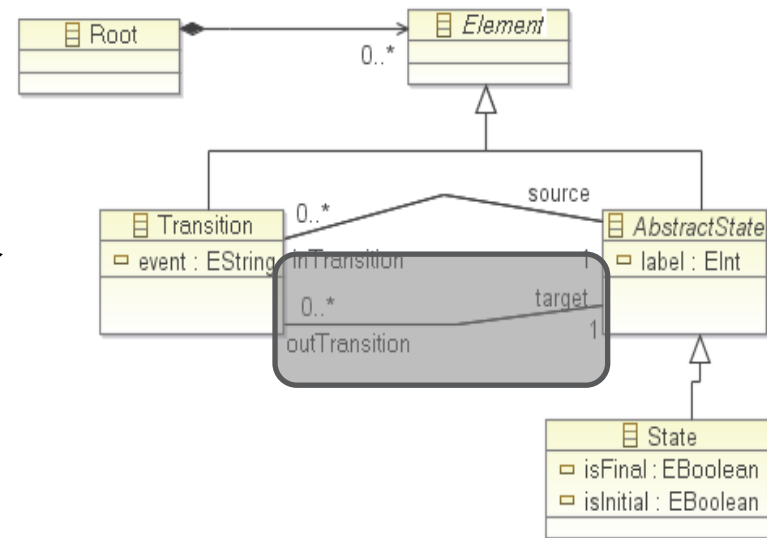
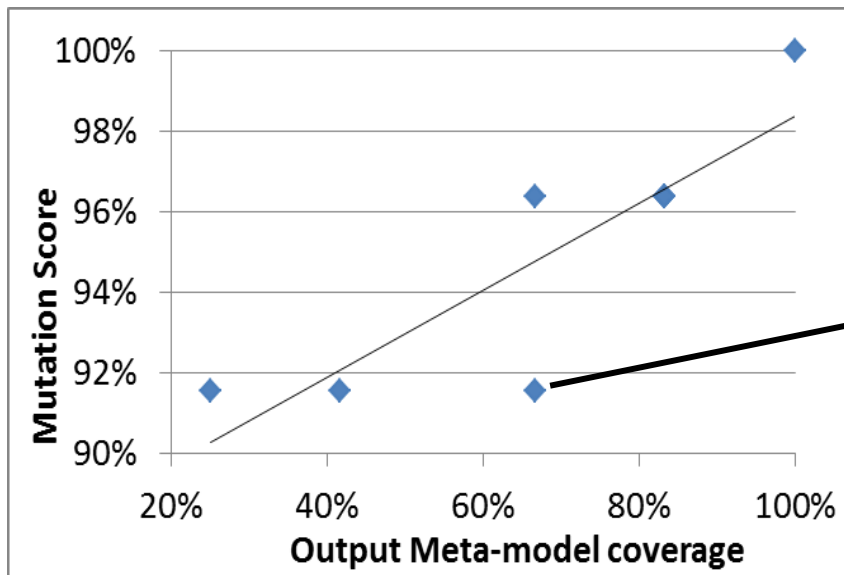
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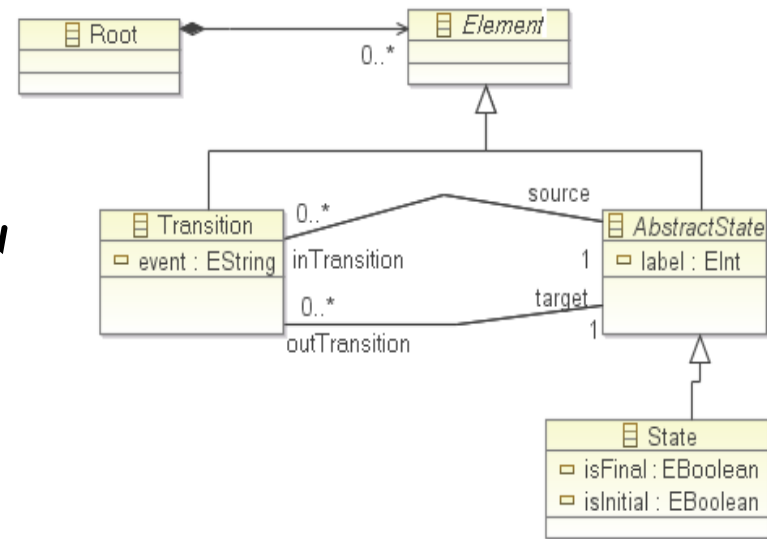
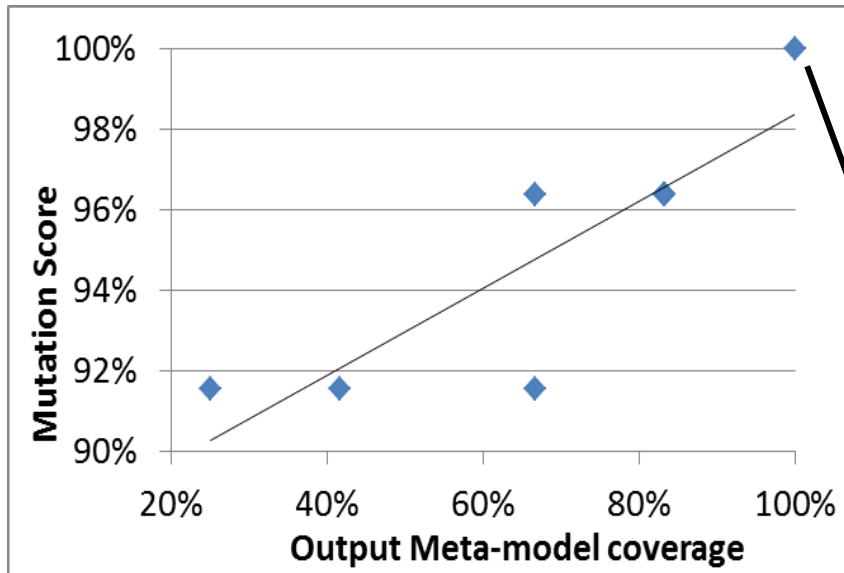
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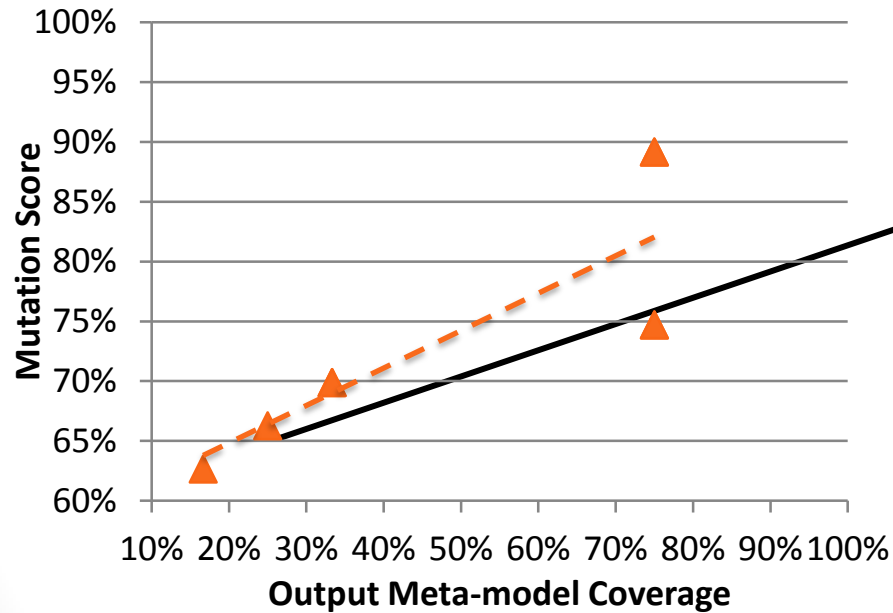
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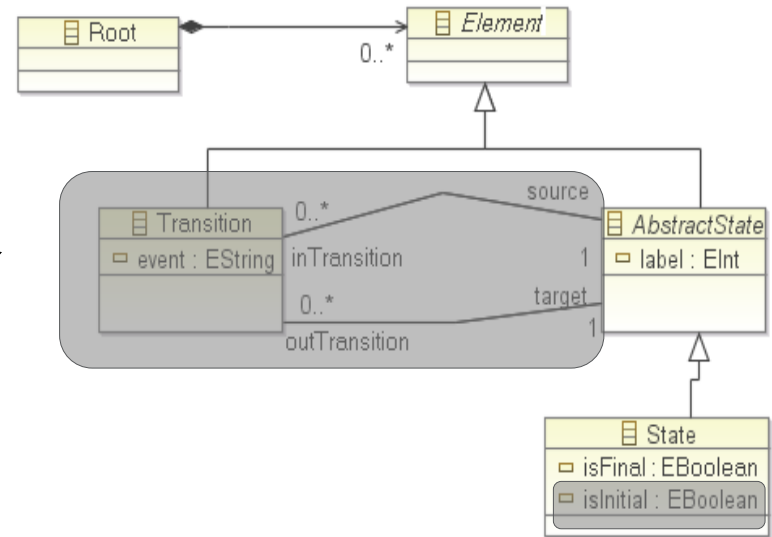


# Results: FSM2FFSM

- Oracles Using Individual Contracts

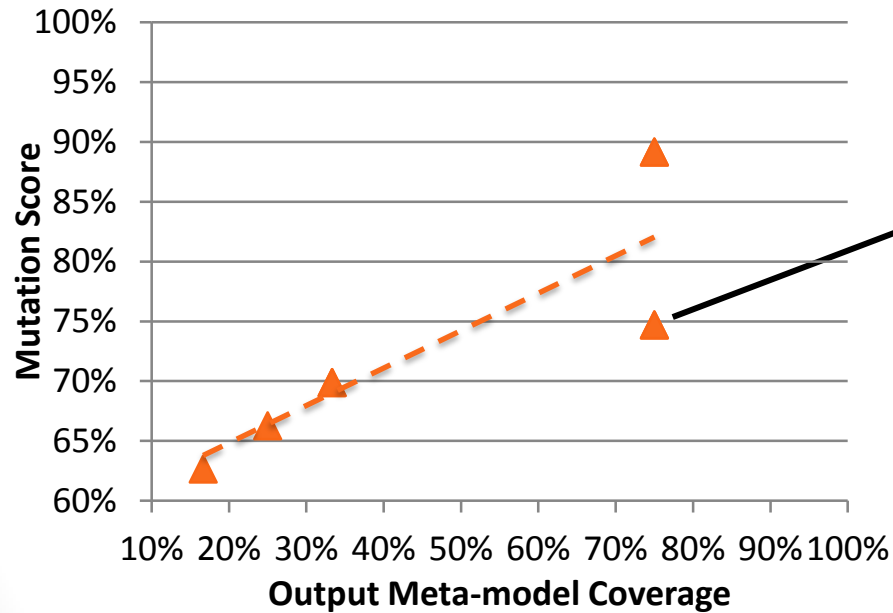


- Contract 2

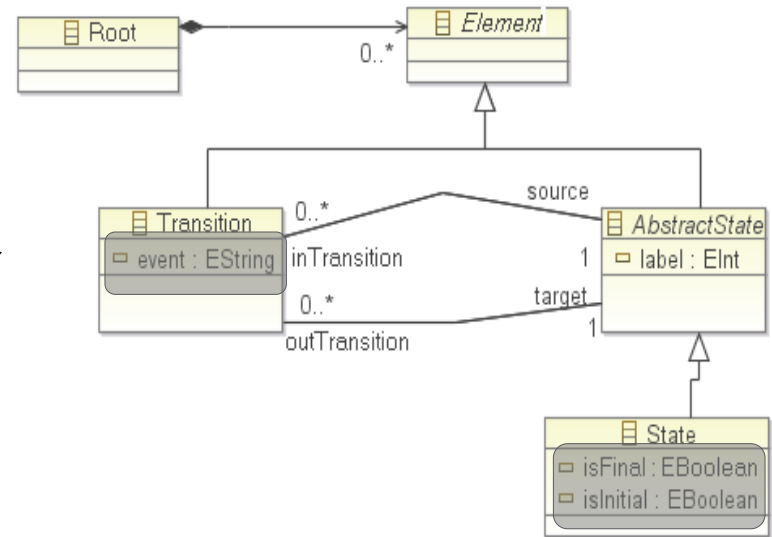


# Results: FSM2FFSM

- Oracles Using Individual Contracts



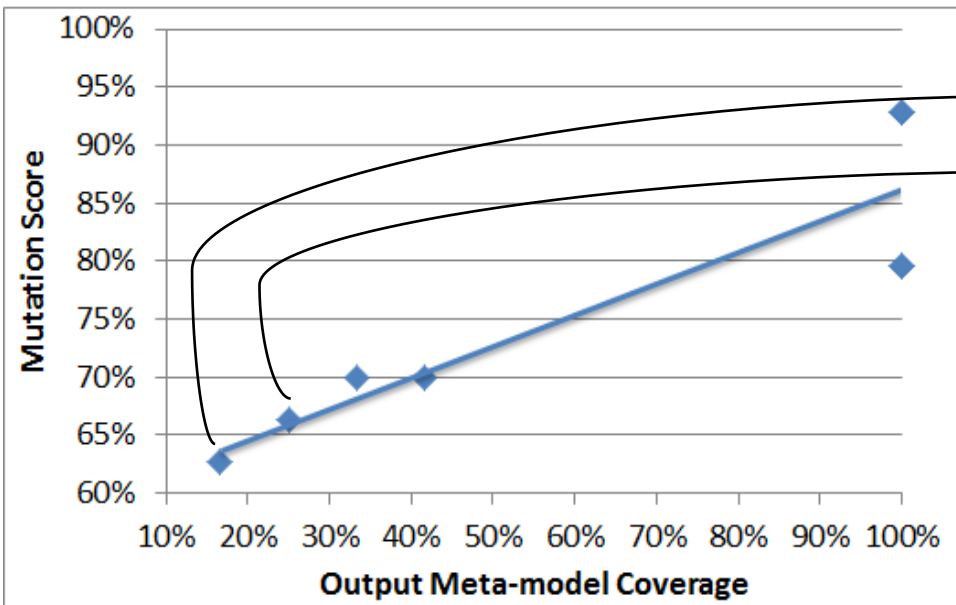
- Contract 4





# Results: FSM2FFSM

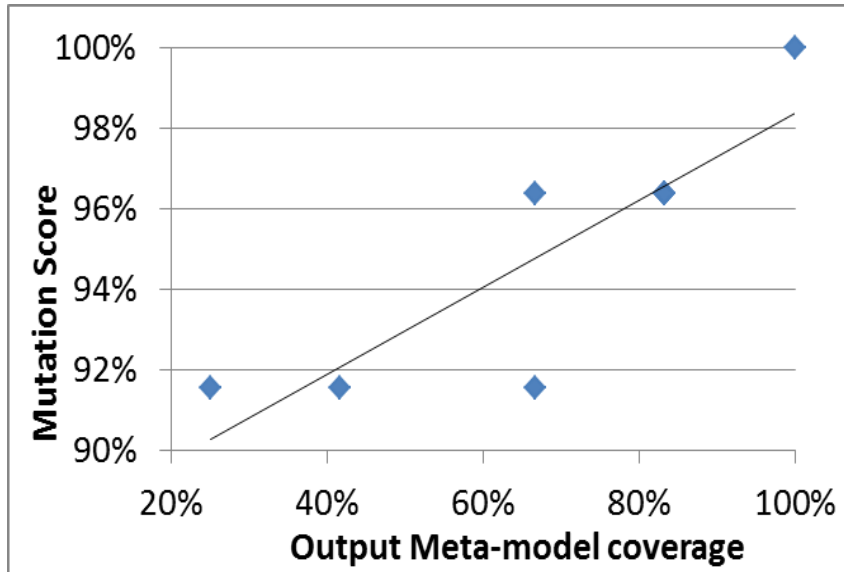
- Oracles Using Incremental Contracts



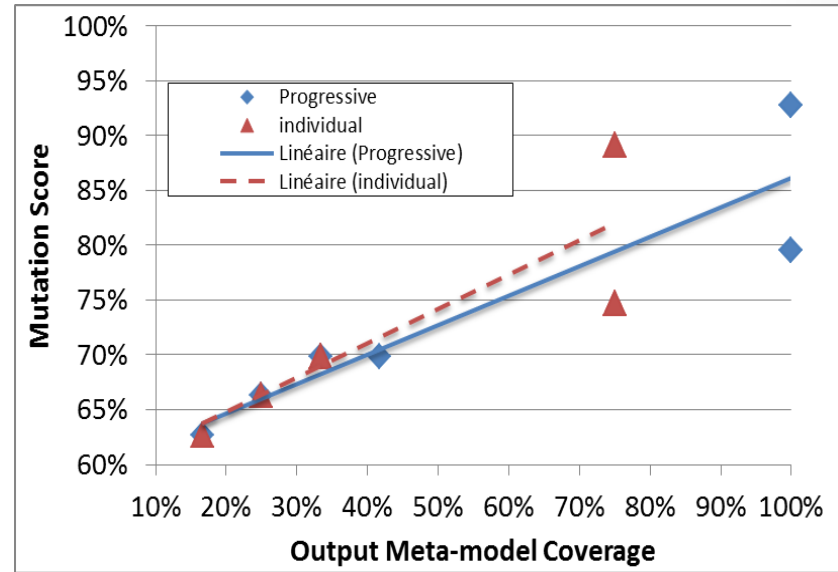
- Contract 1
- Contract 1 & Contract 2
- etc.

# Results: FSM2FFSM

- Synthesis:



Oracles Using Expected Output Models



Oracles Using Contracts

# Benefits

- Lighter than Mutation Analysis
- Higher Coverage => More Faults Detected

# Limits

- 100% Coverage  $\neq$  Sound Oracles
- Less Precise than Mutation Analysis

# Perspectives: Oracles' Improvement

- Uncovered MM Elements List
- Improve Coverage to Improve Quality
- Reasons for Coverage Rate < 100%
  - Elements Not Handled By Transformation
    - Update Effective Output Meta-model
  - Partial Oracles
    - Update Oracles
  - Missing Test Models

# Conclusion

- We can measure the coverage of the output meta-model by a test oracle.
- Coverage of the output meta-model can be used to quality of a set of oracles.



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