Testing Model Transformations in Model Driven Engineering

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(currently visiting CSU)

Outline

- What about model transformation testing?
- Triskell's contributions
  - Coverage criteria
  - Model synthesis
- Related work
- Challenges

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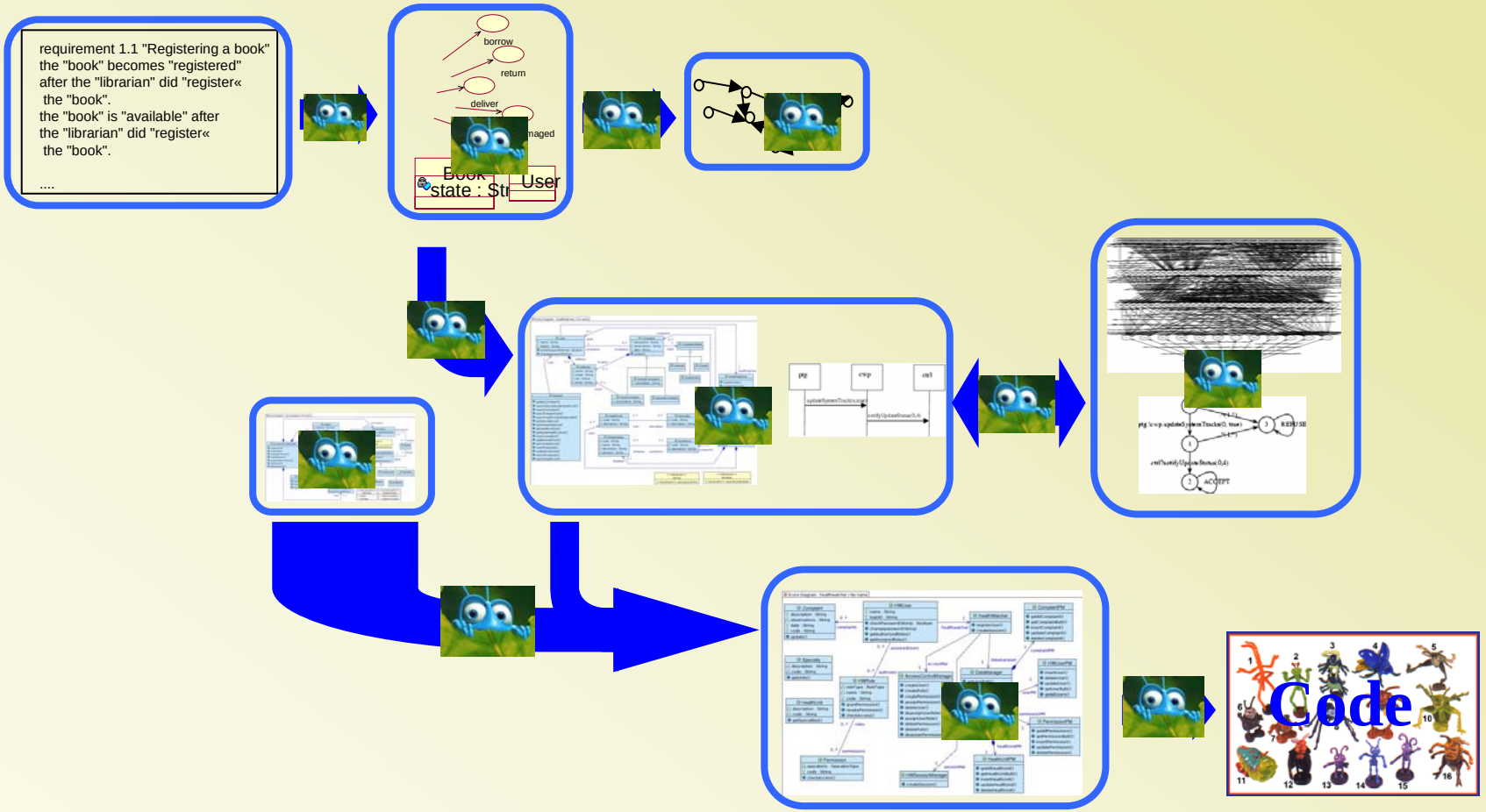
Model Transformation Testing: Motivation



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Model Transformation Testing: Motivation

- A transformation is meant to be reused
  - But also has to be adapted from one project to another
- A transformation is meant to hide the complexity
  - we woud like to trust the transformation as we trust a compiler

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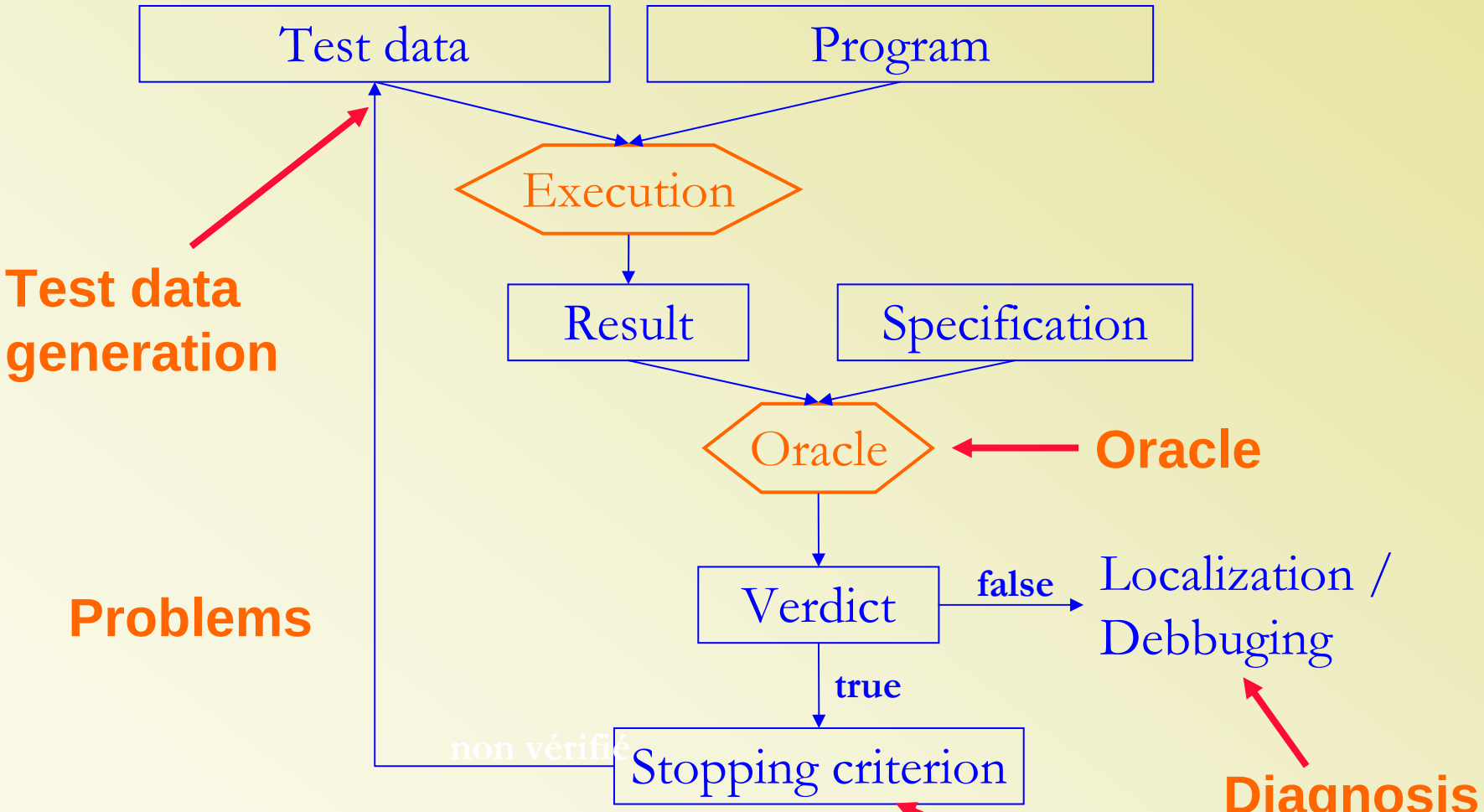
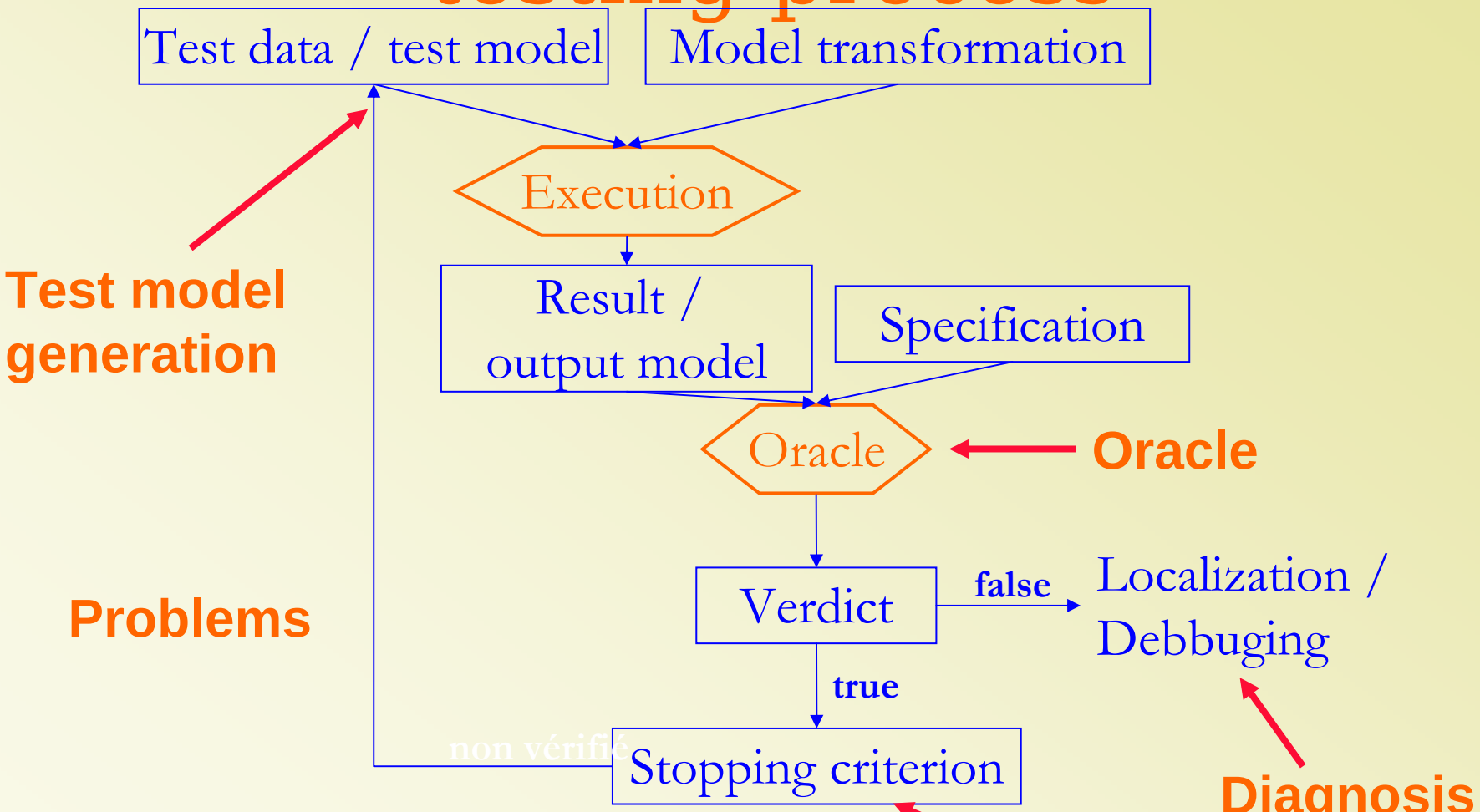
Dynamic testing process



Dynamic transformtation testing process



Dynamic transformtation testing process

- Specific issues
- Complex data
  - Models are manipulated as sets of objects
- Complex constraints
- Lack of specific tools

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Model Transformation Testing

- Currently in Triskell
  - Coverage criteria
  - Automatic synthesis of test models (in coll. With Mc Gill)
  - Specific fault models

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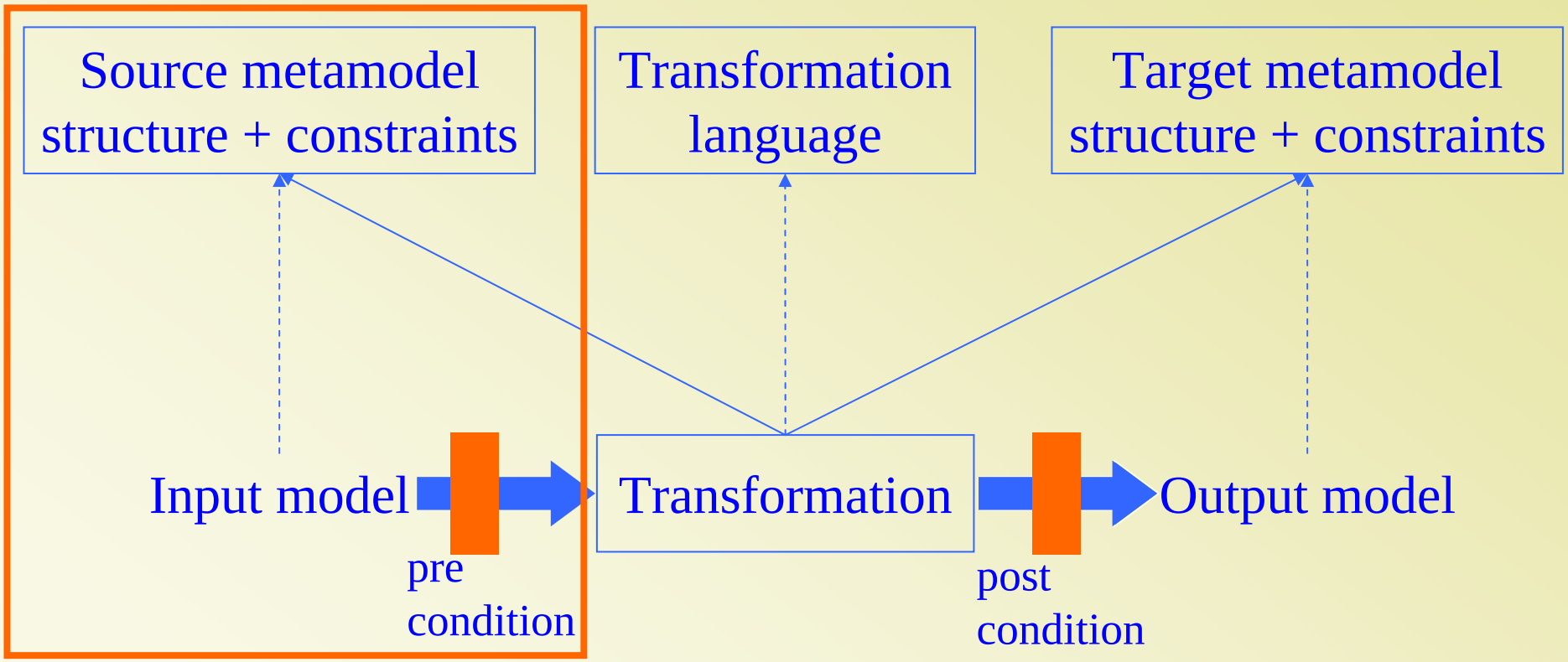
Model transformation



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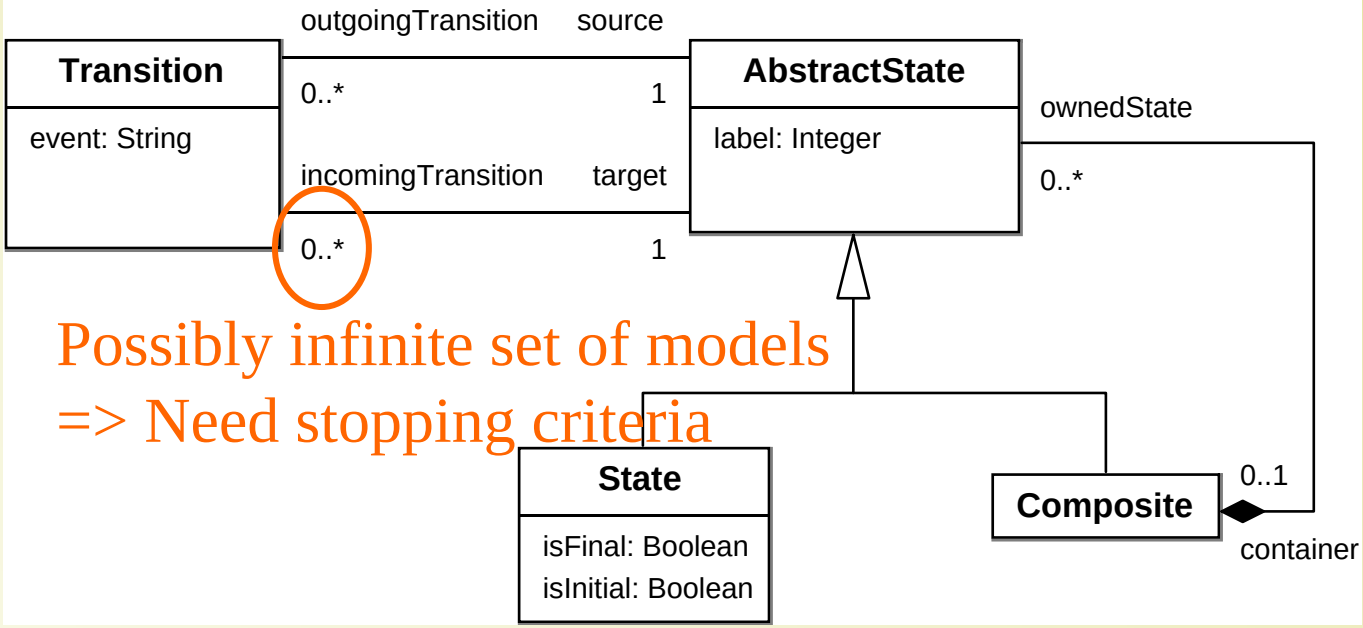
Test data generation: criteria

- Several model transformation languages
  - Different features
  - Different paradigms
  - Different domains
- We did not want to choose
- We define black-box criteria
  - Independent of the model transformation language

Test data generation: criteria

- Define test criteria based on the input metamodel
  - Intuition: a set of models is adequate for testing if every class of the input metamodel is instantiated at least once and if the properties have relevant values
- A model for testing is called a test model

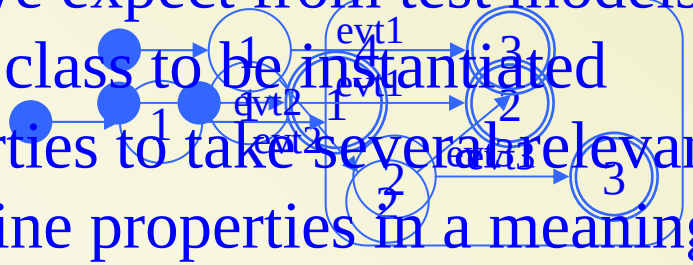
Test data generation: Example



Possibly infinite set of models
=> Need stopping criteria

What we expect from test models

- Every class to be instantiated
- Properties to take several relevant values
- Combine properties in a meaningful way



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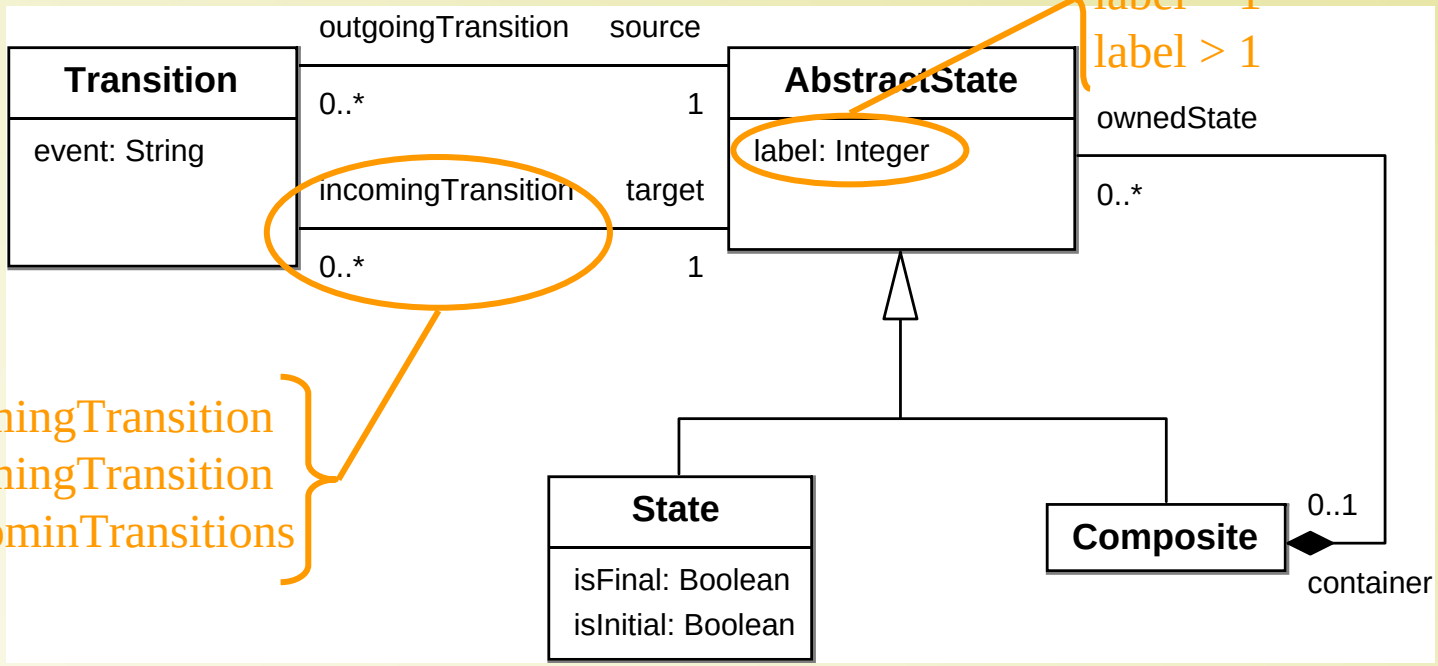
Relevant values for properties



Adapt category partition testing to define ranges of relevant values for properties of the metamodel

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Relevant values for properties

- Define partitions for each property in the input metamodel
- A partition defines a set of ranges on a domain
  - choose one value in each range for the property
- Example
  - partition for AbstractState::label={[0],[1],[2..MaxInt]}
  - A set of test models will need to have, at least three states with three different values for label

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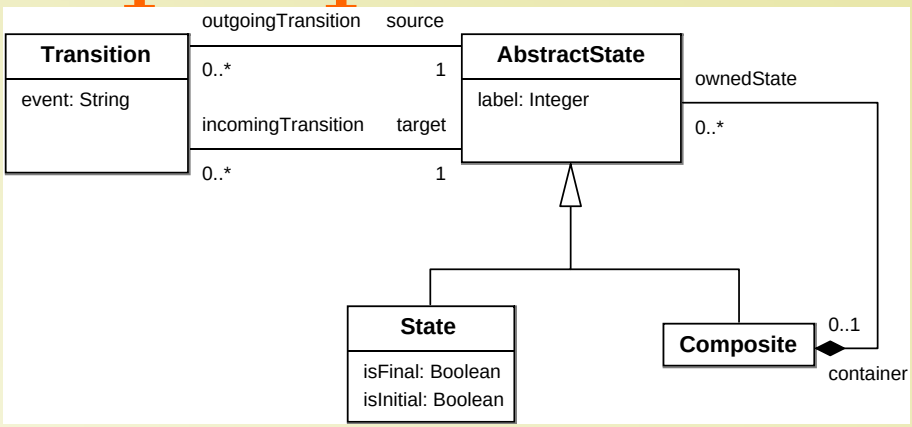
Relevant values for properties



Transition::**event**	**{''}, {'evt1'}, {'.+'}**
Transition::**#source**	**{1}**
Transition::#**target**	**{1}**
AbstractState::**label**	**{0}, {1}, {2..MaxInt}**
AbstractState::#**container**	**{0}, {1}**
AbstractState::#**incomingTransition**	**{0}, {1}, {2..MaxInt}**
AbstractState::#**outgoingTransition**	**{0}, {1}, {2..MaxInt}**
State:**isInitial**	**{true}, {false}**
State::**isFinal**	**{true}, {false}**
Composite::**#ownedState**	**{0}, {1}, {2..MaxInt}**

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Relevant object structures

Transition::**event**	**{''}, {'evt1'}, {'.+'}**
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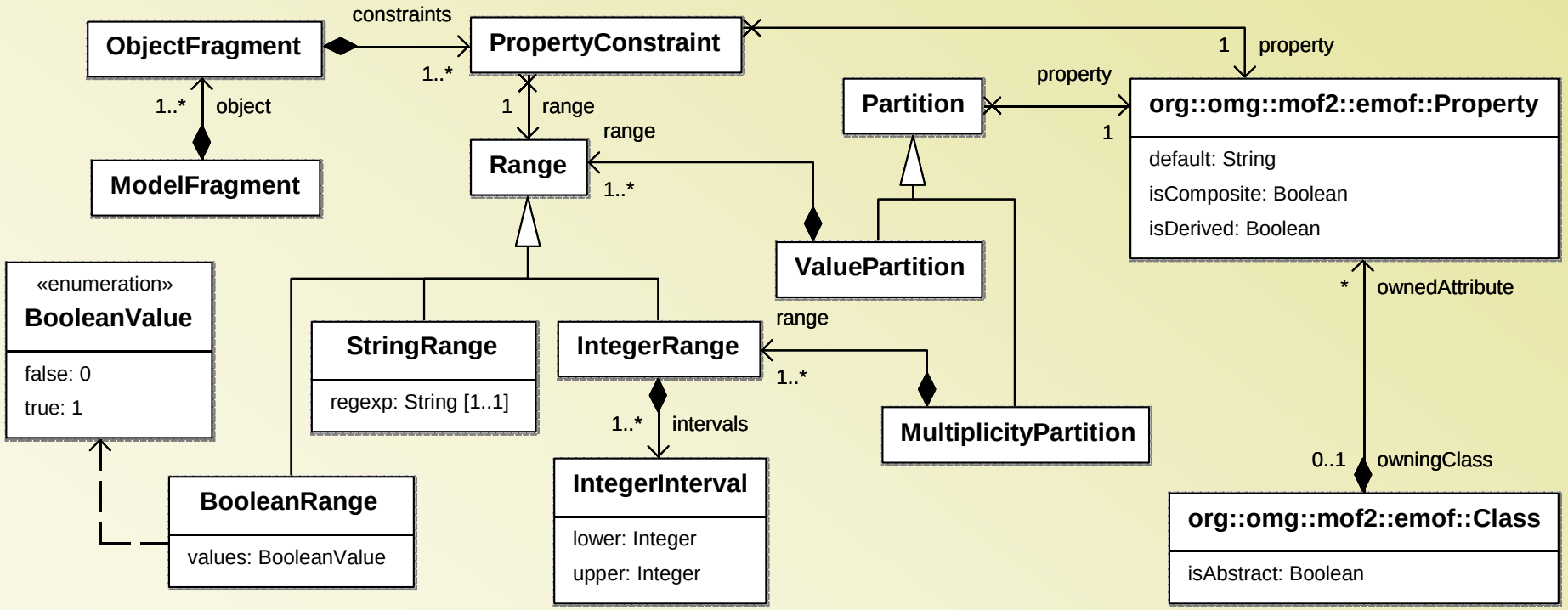
We would like to constrain the models to have a State with one outgoing transition **and** more than one incoming transitions

Relevant object structures



Relevant object structures

- Criteria define structures that must be covered by test models
- These criteria combine partitions
- One criterion = set of constraints
  - one criterion declares the set of ranges that should be covered by a set of test models
- Example
  - Range coverage: Each range of each partition for all properties of the meta-model must be used in at least one model.

Test criteria

- Six test criteria (different combinations of ranges)
  - AllRanges
  - AllPartitions
  - + 4 class criteria
    - object fragments constrain each property of the object
- Do not consider constraints on the metamodel
  - Might generate insatisfiable fragments

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Evaluating a set of models

- A prototype tool: MMCC
  - Framework for partitions and fragments definitions
- Computes a set of model fragments according to
  - Input metamodel
  - Test criterion
- Checks the coverage of a set of test models
  - With respect to the set of model fragments

Automatic synthesis of test models

- Automatic synthesis useful to
  - Limit the effort for test generation
  - Evaluate the test criteria
- Challenges:
  - Combine different sources of knowldege
  - Expressed in different formalisms
  - Complex constraints

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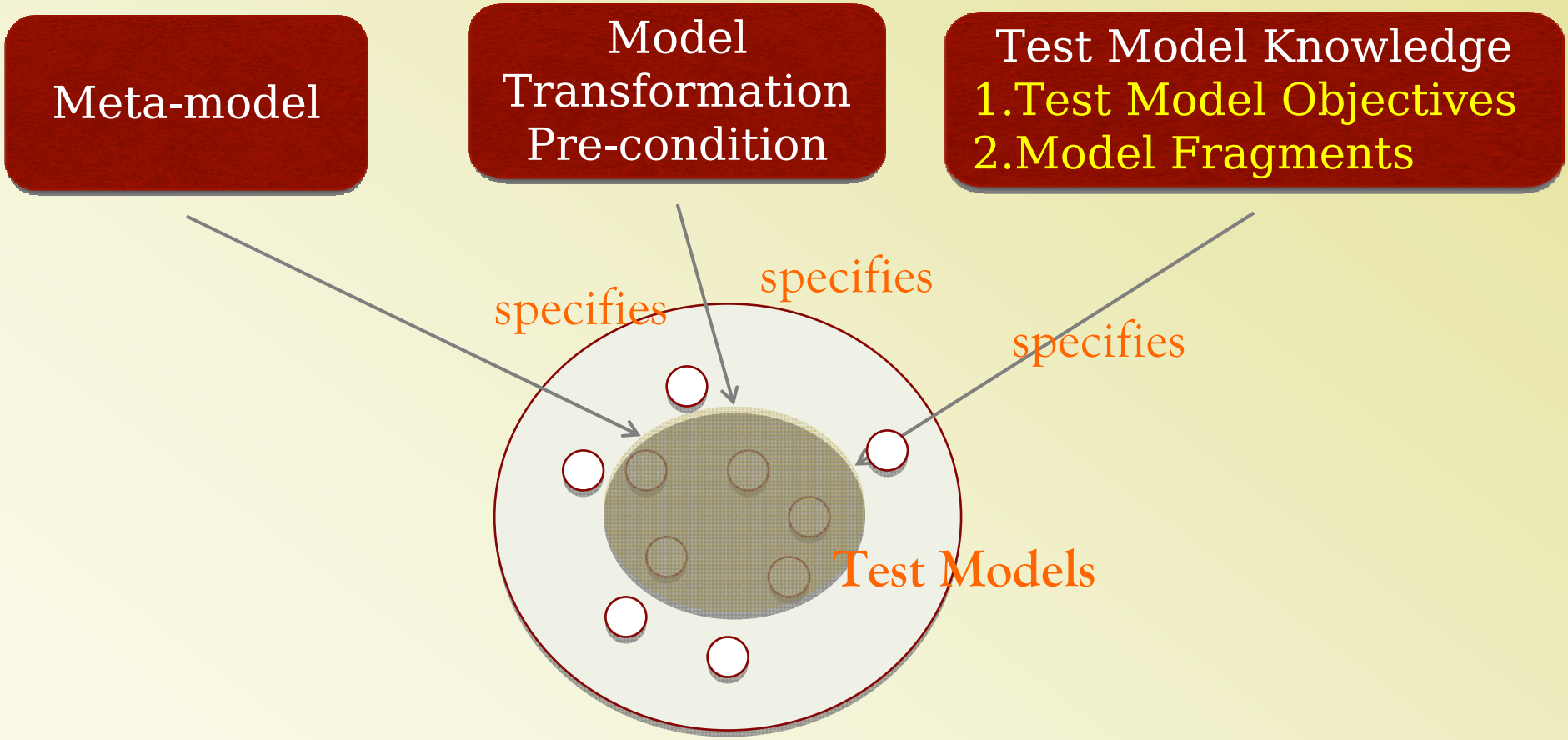
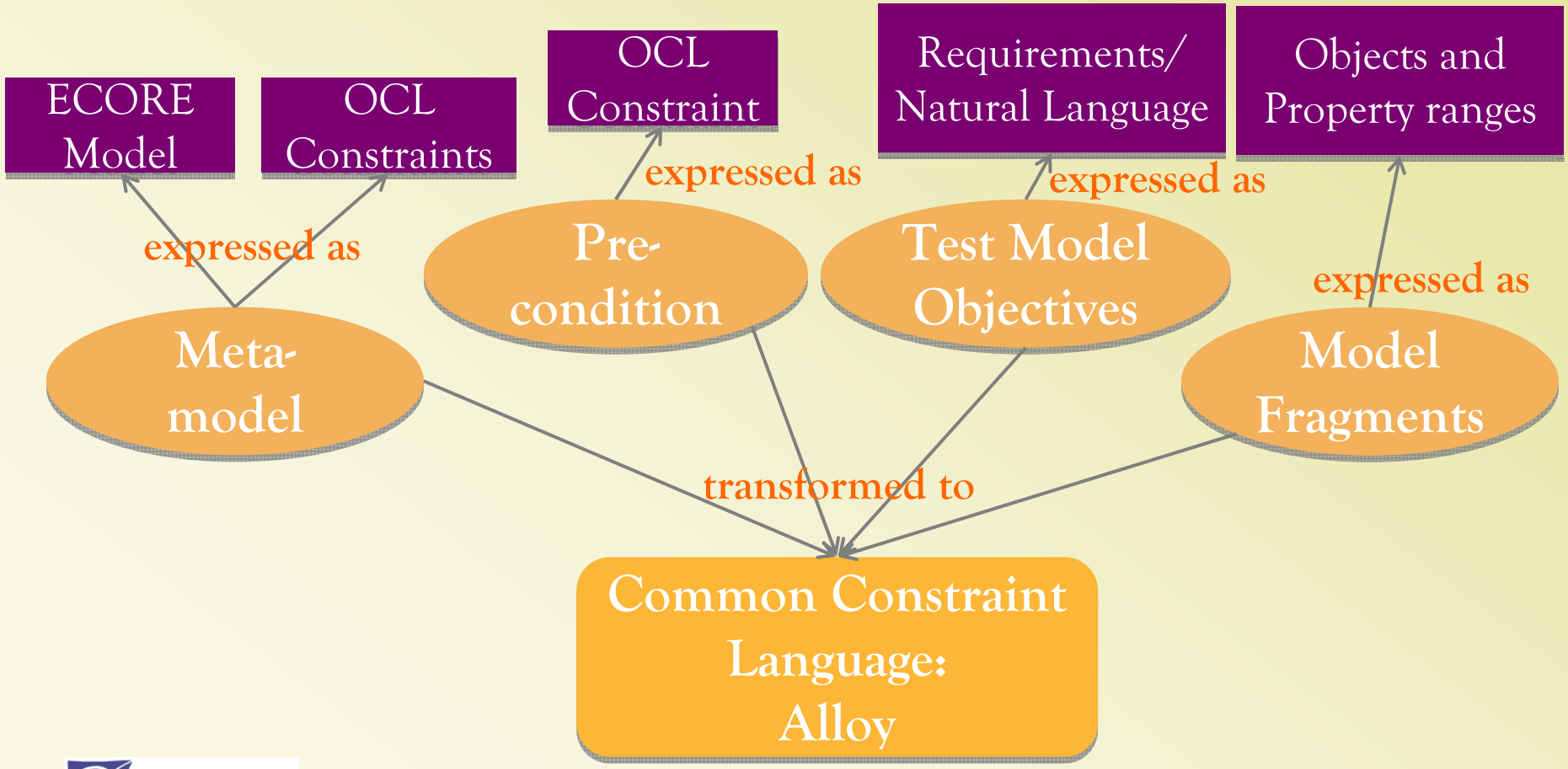
Automatic synthesis of test models



The Solution(1):
Combining Knowledge to Common Constraint Language



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Model synthesis

The *run* command:

Integer scope

run test_requirement1 for 1 ClassModel,5 int, exactly 5 Class,
exactly 20 Attribute, exactly 4 PrimitiveDataType, exactly 5 Association

Exact number of objects

1. Specify a scope
2. Specify an exact number of objects

Output: Alloy model instance that satisfies meta-model + pre-condition + test_requirement1 and has the specified size

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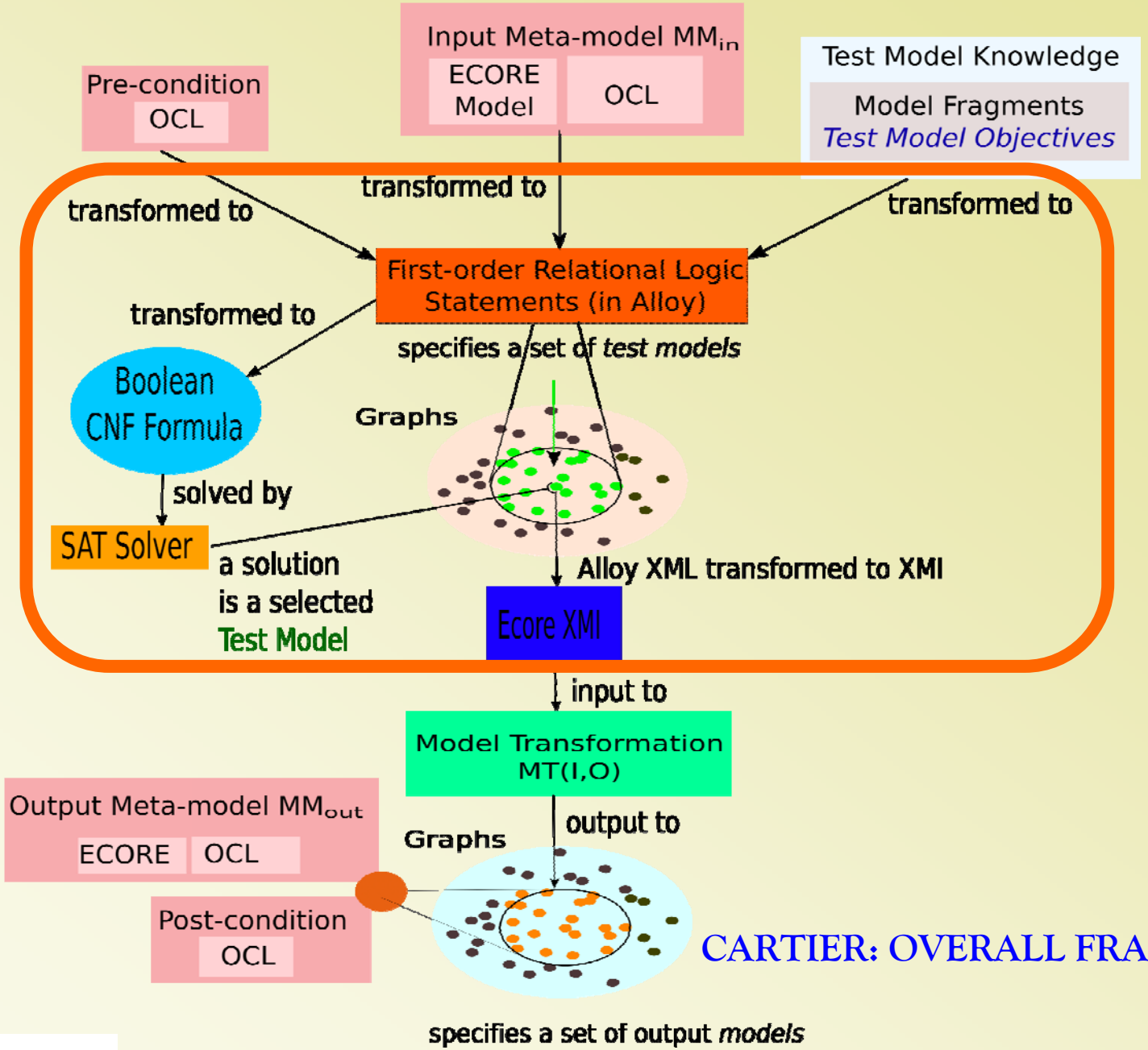

CARTIER: OVERALL FRAMEWORK

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Perspectives on model synthesis

- Strenghten the tool
  - Automate what can be
- Experiments
- Design experiments to test model transformations
- We want to numerically estimate via *mutation analysis* the efficiency of test models

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Mutation Analysis

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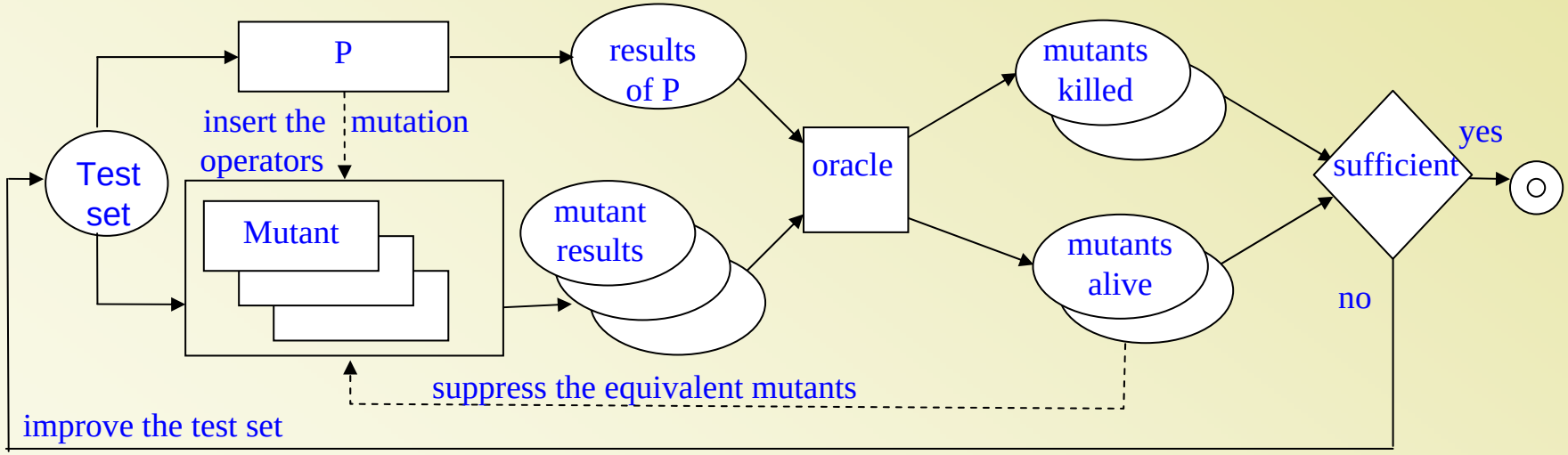
Mutation Analysis

- Evaluate the set of models
  - Producing a Mutation Score

Mutant	1	2	3	4	5	6	7	8	proportion
Killed	X	X		X	X			X	5/8



Mutation Analysis

- Analysis based on fault models
- Faults are based on syntax of programming languages
  - Most common errors
  - For procedural languages, OO languages…

Mutation analysis for model transformation

- What errors occur in a model transformation?
- Implementation language independency
  - Too many different languages
- Lack data on common errors

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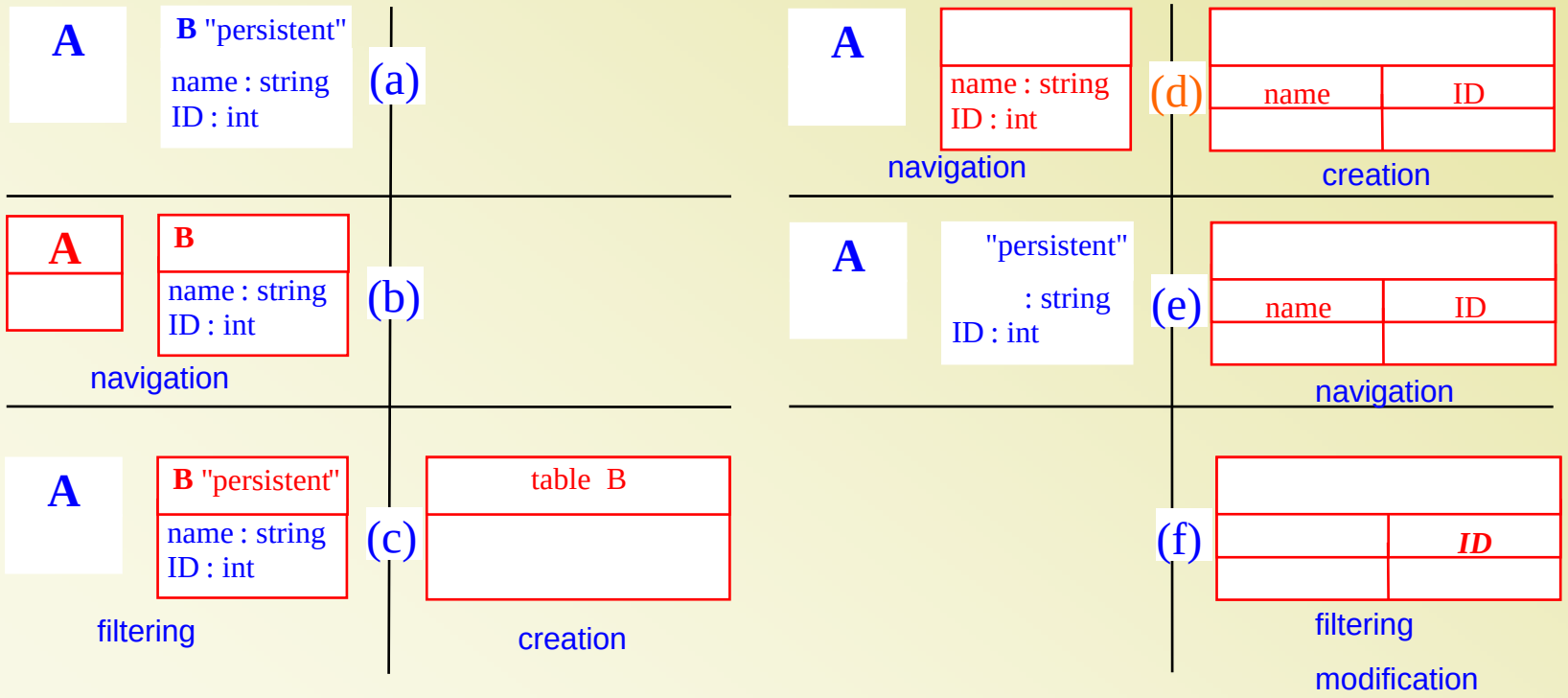
Abstract transformation operations

- Navigation, filtering, creation, modification
  - Example of one transformation



Mutation operators

- Navigation
  - Relation to the same class
  - Relation to another class
  - Relation sequence modification with deletion
  - Relation sequence modification with addition
- Filtering
  - Perturbation in the condition
  - Delete a predicate
  - Add a predicate
- Creation
  - Replace an object by a compatible one
  - Miss association creation
  - Add association creation

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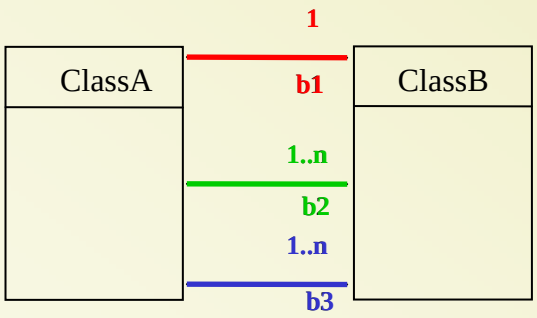
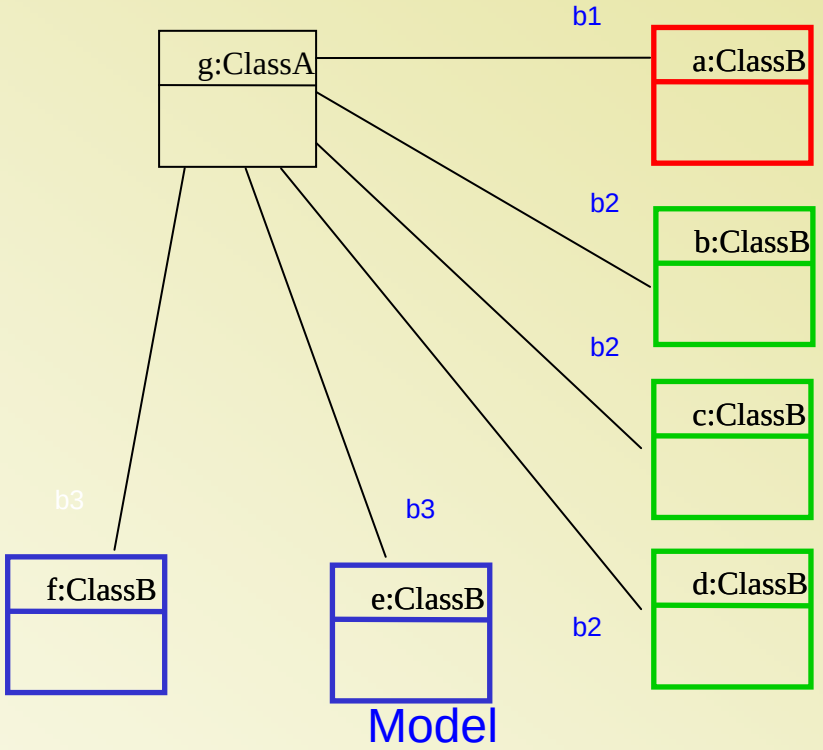
One specific operator example

- Navigation
  - Relation to the Same Class Change - RSCC



Metamodel



Model

Mutation Analysis

- The proposed operator have been adapted to the Kermeta language
- Experiments:
  - To compare mutation operators
  - To evaluate the coverage criteria
  - To evaluate different knowledge for test generation

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Perspectives in Triskell

- Experiment!
  - We have spent a lot of time defining ideas and building the tools
- White-box techniques for specific languages
  - Specific adequacy criteria
  - Fault localization
- Oracle function definition
- Application with CNES

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Model Transformation testing in broad

Testing the transformation engine

- A. Darabos, A. Pataricza, and D. Varro. *Towards Testing the Implementation of Graph Transformations*
  - Define fault models for pattern matching
- J. Steel and M. Lawley. *Model-Based Test Driven Development of the Tefkat Model-Transformation Engine*
  - Partition based test generation

Test data generation

- Templates to describe 'patterns' for test models
  - J.M. Küster and M. Abd-El-Razik. *Validation of Model Transformations - First Experiences using a White Box Approach*
  - Automatic instantiation of patterns with different combinations of values
  - Related to the notion of test model objective

Test data generation

- K. Ehrig, J.M. Küster, G. Taentzer, and J. Winkelmann. *Generating Instance Models from Meta Models*
- Consider only the structural definition of a metamodel
  - Additional constraints have to be checked a posteriori

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Oracle

- Model comparison
  - Kolovos, D.S., R.F. Paige, and F.a.C. Polack. *Model Comparison: A Foundation for Model Composition and Model Transformation Testing.*
  - Y. Lin, J. Zhang, and J. Gray, *A Testing Framework for Model Transformations*, in *Model-driven Software Development*
- Major issue: producing the expected model
  - Complex, tedious and error-prone
  - Difficult to maintain
  - Except if another version of the transformation or an precise specification is available

Oracle

- Execute the output model
  - In case the output model is executable it can be tested
  - T. Dinh-Trong, N. Kawane, S. Ghosh, R. France, and A. Andrews. *A Tool-Supported Approach to Testing UML Design Models*
- Issue for fault localization
  - If a fault is detected in the output model it has to be located in the model, then back in its source in the transformation

Oracle

- No standard technique to write and evaluate contracts for a model transformation
  - is OCL well adapted?
  - A. Solberg, R. Reddy, D. Simmonds, R. France, and S. Ghosh, *Developing Service Oriented Systems Using an Aspect-Oriented Model Driven Framework*
- Different levels of complexity
  - contracts on the output model
  - contracts that relate input and output model elements
  - design-by-contract for the transformation (if implemented using an OO language)

Still a lot to do: testing

- Methodology
  - Adapt to specific transformations / domains
- Systematic criteria
- Test environments
- Debugging support
  - Trace the detected error back to its source
- Experiments

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Still a lot to do: development methods

- Specification of the model transformation
  - To derive contracts
  - To drive the generation of test models
  - To have accurate oracle functions
- Need two definitions of the transformation
  - Check the conformance of one according to the other = testing

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Still a lot to do: tool support

- Tools to support oracle definition and test generation
  - Model comparison
  - Model visualisation
- Model type
  - Save a large number of verifications on input and output

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References

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