Correctness of Constraint-Aware Model Transformations

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Outline

Introduction

Diagram Predicate Framework

Correctness of Model Transformation

Model-Driven Engineering (MDE)

- In model-driven engineering, models are
  - Primary artefacts
  - Used to specify, generate and maintain code
  - Manipulated by model transformations
- Advantage
  - Productivity is greatly improved
  - Consistence between models is assured

Model Transformation

- Model transformation is automatic
    - Platform Independent Model (PIM) → Platform Specific Model (PSM)
    - Model → executable code
    - Model refactoring
- Improves the software development productivity and quality

Model Transformation

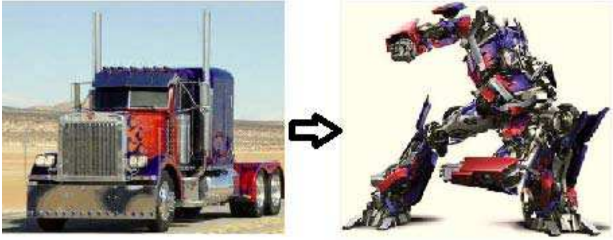
- Model transformations:
    - Source models → Target models
- Model transformation rules:
    - Source metamodel ↔ Target metamodel
- Given a source model and a set of model transformation rules, we use the following transformation process:
    - Find a suitable rule
    - Change on the source model according to the rule
    - Generate a new model which satisfies the target metamodel
    - Repeat the process until there is no suitable rule found

Correctness of Model Transformation

- Software programs need validation before deployment

Correctness of Model Transformation

- Model transformations must also be reliable



Correctness of Model Transformation

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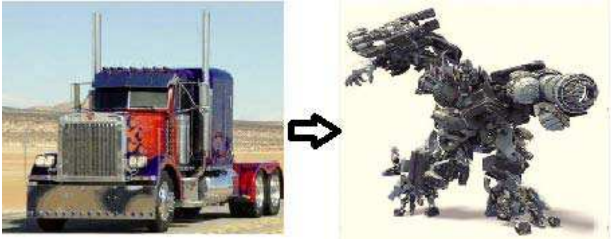

Correctness of Model Transformation

- Model transformation rules are designed manually
- In order to ensure reliability, it is necessary to check the correctness of the model transformation

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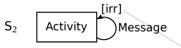
Diagram Predicate Framework (DPF)

- A fully diagrammatic specification framework for MDE
- Aims to be a diagrammatic formalism to define and reason about models and model transformations

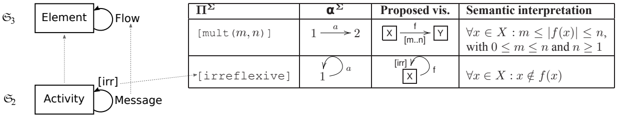
Diagram Predicate Framework (DPF)



Π^{Σ}	α^{Σ}	Proposed vis.	Semantic interpretation
`[mult(`m,n`)]`	$1 \xrightarrow{a} 2$	$\boxed{X} \xrightarrow[\text{[m..n]}]{f} \boxed{Y}$	$\forall x \in X : m \leq \lvert f(x) \rvert \leq n$, with $0 \leq m \leq n$ and $n \geq 1$
`[irreflexive]`	$\begin{tikzcd} 1 \arrow[loop right, "a"] \end{tikzcd}$	$\begin{tikzcd} \boxed{X} \arrow[loop right, "f", "\text{[irr]}"'] \end{tikzcd}$	$\forall x \in X : x \notin f(x)$

- Models are formalized as diagrammatic specifications which consist of an underlying graph structure together with a set of atomic constraints

Diagram Predicate Framework (DPF)



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A modelling language is formalized as a modelling formalism $(\Sigma_2 \triangleright S_2, S_2, \Sigma_3)$

- Specification S_2 represents the metamodel of the language
- Signature Σ_3 contains predicates which are used to add constraints to the metamodel S_2
- Typed signature $\Sigma_2 \triangleright S_2$ contains predicates which are used to add constraints to the specification S_1 that are specified by the modelling formalism

Diagram Predicate Framework (DPF)

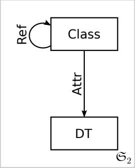
Constraint-Aware Model Transformation

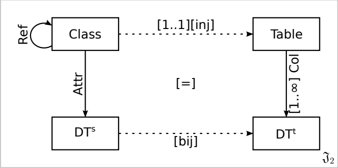
Joined Modelling Formalism

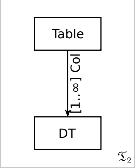
Σ_3

$\Gamma_3 := \Sigma_3 \uplus \Xi_3 \uplus \Theta_3$

Θ_3







$\Sigma_2 \rhd S_2$

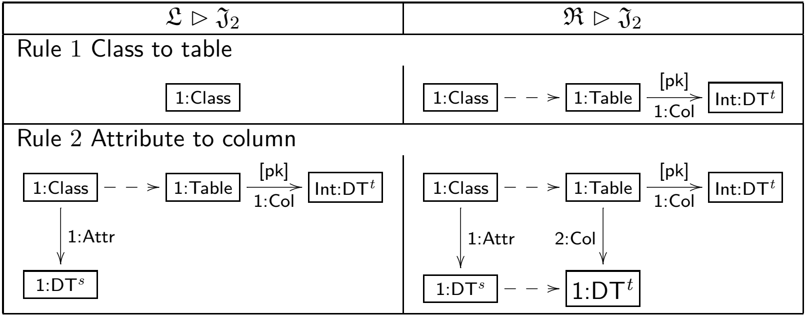
$\Gamma_2 := \Sigma_2 \rhd S_2 \uplus \Theta_2 \rhd T_2$

$\Theta_2 \rhd T_2$

Diagram Predicate Framework (DPF)

Constraint-Aware Model Transformation

Model transformation rules



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Correctness of Model Transformation

Correctness of Model Transformation

A match of a rule:

- It exists a graph homomorphism from the left hand side of the rule to the model

If a match of a rule is found in a model, we say that the rule is applicable to the model.

A model transformation is correct if:

- For any valid source model, a sequence of applicable rules which constructs a valid target model can be found

Correctness of Model Transformation

Rule application strategy

- When several rules are applicable at the same time
- When several matches of a rule are found in the model

Which method to use

For correctness of program:

- Testing: Never completely identify all the defects
- Theorem provers: Need a mathematical formalization of the program and involves human activities
- Model checkers: State explosion problem

Which method to use

Model transformations are automatic

- Run automatic tests of model transformations
- A sequence of applicable rules to constructs a desired target model
- Feedbacks assisting the designers to correct the rules

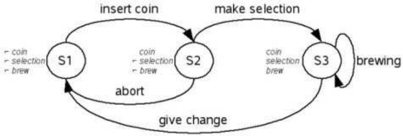
Which method to use

- For any determinstic program, each input only have one execution path
- For a model transformation, several different sequences of applicable rules may exist
- Model checker can check all the possible sequences

Model Checking

Model checking is an automatic way to verify that a model satisfies a given specification

- Model is represented as a Kripke structure



- Specification is formalized in temporal logic, CTL or LTL
- $E[(\neg selection)\,U\,(brew)]$

Verification Process

Given

- Joint modelling formalism (JMF), including the source metamodel (SMM) and the target metamodel (TMM)
- Transformation rules (MTRs)
- Source model (SM)

A kripke structure can be constructed through this procedure

Verification Process

- We define a initial state i representing SM
- For each state $s \in S$ and for every MTR $r : \mathfrak{L} \rhd S_2 \hookrightarrow \mathfrak{R} \rhd S_2$ we check $IsMatch(Model, \mathfrak{L} \rhd S_2)$. If it is true, the rule is applicable
- For each state $s \in S$ and for every applicable MTR $r : \mathfrak{L} \rhd S_2 \hookrightarrow \mathfrak{R} \rhd S_2$, we define a new state $r(s) \in S$ and a transition $t : s \to r(s)$

Verification Process

Correctness property:
In the future there is a state where no more rule is applicable and from this state a valid target model can be derived. In CTL, it is formalized as

$$EF!AnyRuleApplicable(Model, MTRs)\&\&IsInstanceof(getTargetModel(Model), TMM)$$

Future Work

- Find a suitable way to make rule application terminate
- Find way to implement the approach
- Find way to evaluate the approach
  - Efficency of checking
  - Number of states handled by the model checker

Thank you!

Questions?

For more information visit: `http://dpf.hib.no/`