Fully Verifying Transformation Contracts for Declarative ATL

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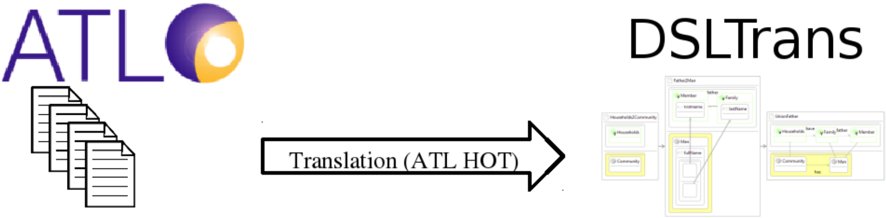
  - Input independence - verification for all input models
  - Examine combinations of transformation rules

Overview

- Translating ATL transformation into DSLTrans language



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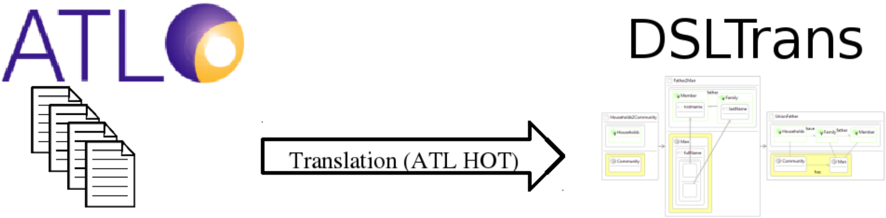

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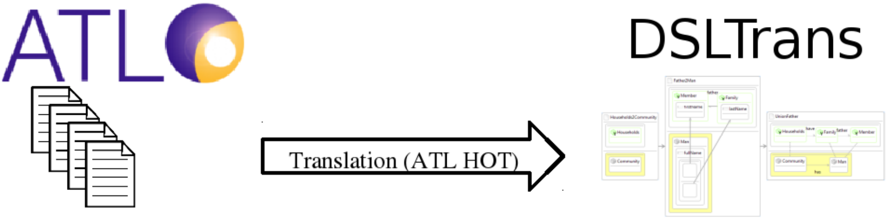

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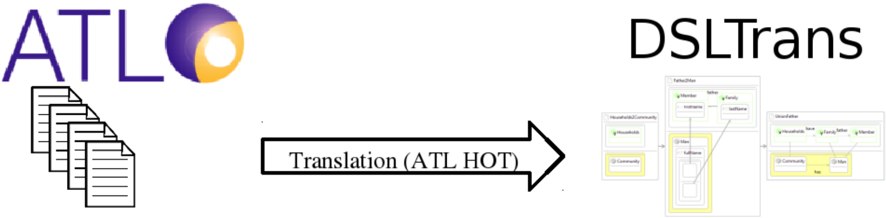
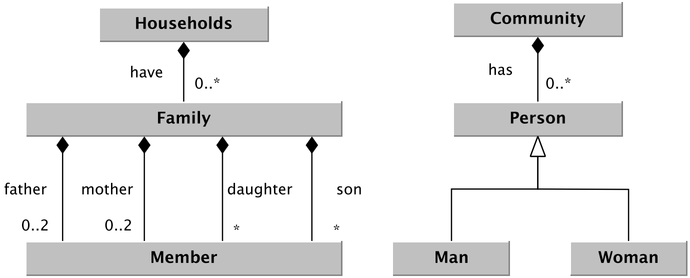


- Performed through a higher-order transformation
  - Specified in ATL

Transformation Metamodels



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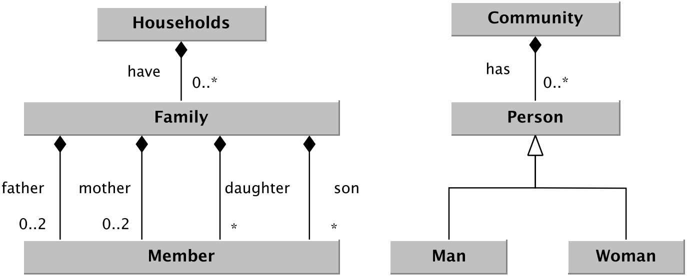

- Transform *Members* to *Men* and *Women*
- NB: Metamodels are not representative of today's society!

ATL Transformation

```
module Families2Persons;
create OUT : Persons from IN : Families;

rule Father2Man { -- R2
 from
  mem : Families!Member, fam : Families!Family
        (fam.father=mem)
 to
  m : Persons!Man (
   fullName <- mem.firstName + fam.lastName --B2
  )}
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ATL Transformation

```
module Families2Persons;
create OUT : Persons from IN : Families;

rule Households2Community { -- R1
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 to
  c : Persons!Community (
   has <- hh.have->collect(f | thisModule.
    resolveTemp(Tuple{mem=f.father,fam=f}, 'm')), --B11
   has <- hh.have->collect(f | thisModule.
    resolveTemp(Tuple{mem=f.mother,fam=f}, 'w')) --B12
 )}

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- Implicit resolution mechanism of ATL
- Through collect operation

DSLTrans Transformation

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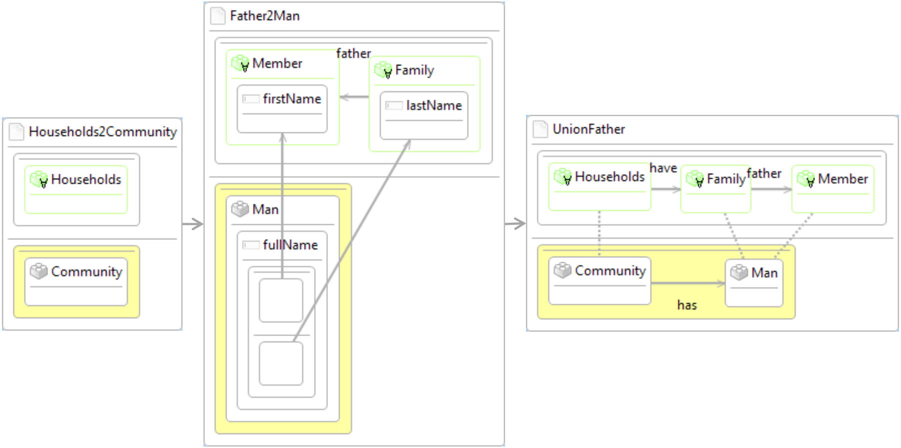
- All DSLTrans computations are terminating and confluent
- Unbounded loops during execution are not allowed



- Rules arranged in layers
- Match graph on top of rules
- Apply graph on bottom
  - Produced when match graph is found

Mapping - Part One

- Higher-order transformation written in ATL
- Creates a DSLTrans transformation from declarative ATL
  - Informal testing: less than 20 seconds
- Available on our website: `http://msdl.cs.mcgill.ca/people/levi/files/MODELS2015`

Mapping - Part Two

TABLE I
FEATURES OF DECLARATIVE ATL CONSIDERED

Matched Rules	✓	Filters	✓
Lazy Rules	✓	OCL Expressions	✓
Several Bindings	✓	Helpers	×
Several *InPatternElements*	✓	Conditions	×
Several *OutPatternElements*	✓	Using Block	×

- Covers declarative ATL
- Transformation can be rewritten to avoid missing features

- Two steps for higher-order transformation

Mapping - Part Three

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- Attributes will also be set in these rules
- Second, DSLTrans rules are produced for any bindings in the ATL rule

Mapping - Part Four

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rule Households2Community { -- R1
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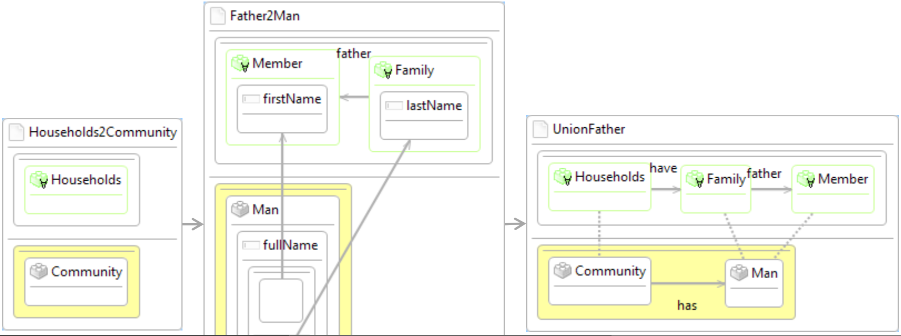
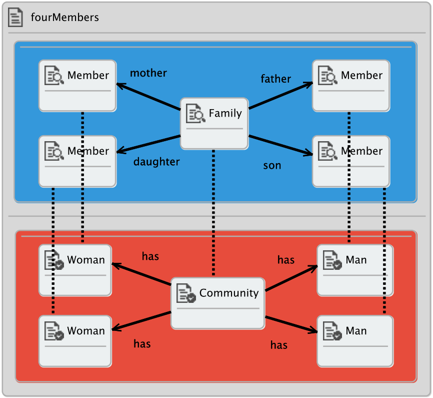
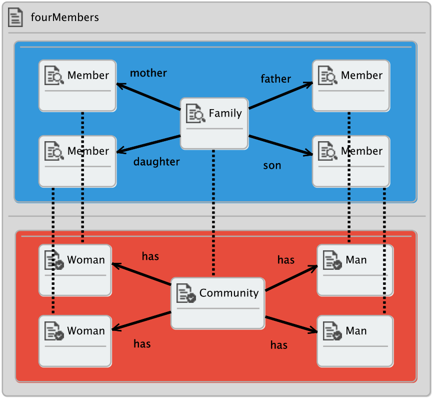


Contracts



fourMembers
Member
mother
father
Member
Family
Member
daughter
son
Member
Woman
has
has
Man
Community
Woman
has
has
Man



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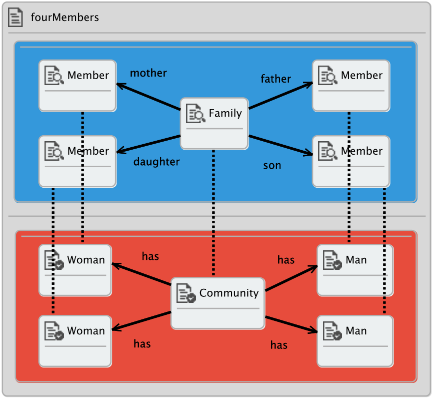

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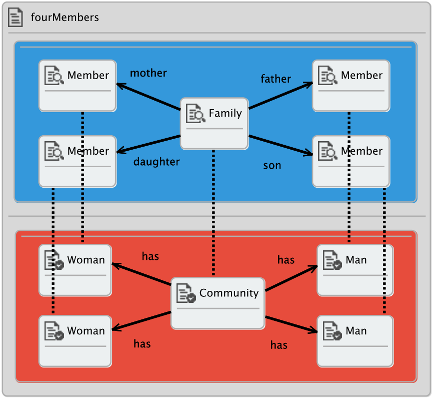

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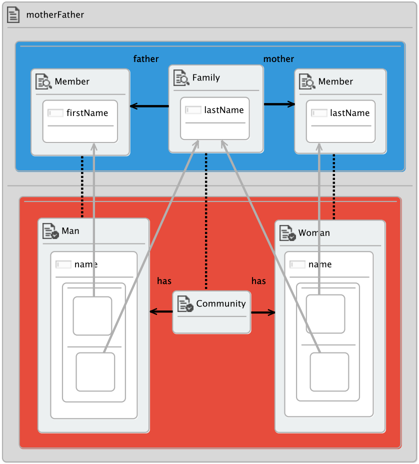
- *A family with a father, mother, son, daughter should always produce two males and two females in the target community*

Contracts



motherFather
father
mother
Member
firstName
Family
lastName
Member
lastName
Man
name
has
has
Community
Woman
name

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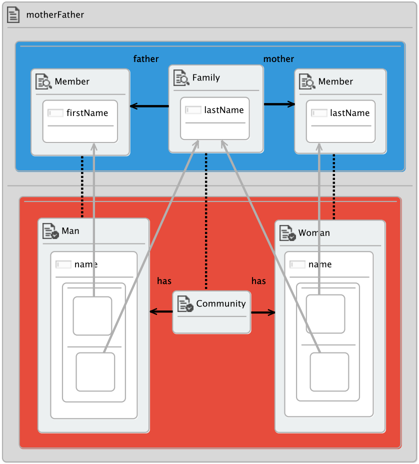

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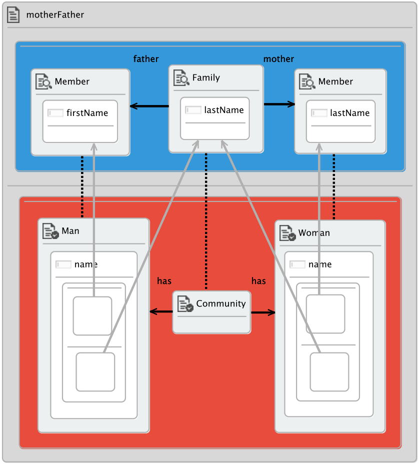
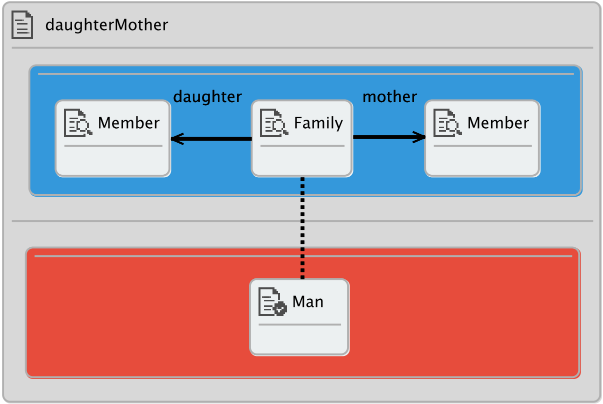


- Reasoning about attributes of elements
- *Is the full name of the produced Person correctly created from the last name of the Family and the first name of the Member?*

Contracts



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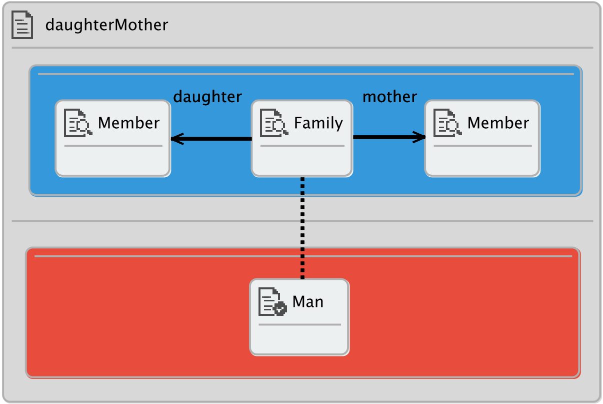

- A contract that will not hold
- *A family with a mother and a daughter will always produce a community with a man*

Contract Proving - Part One

- SyVOLT contract proving tool

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Levi Lucio et al. SyVOLT: Full Model Transformation Verification Using Contracts

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- A contract holds for a transformation if it holds for all generated path conditions

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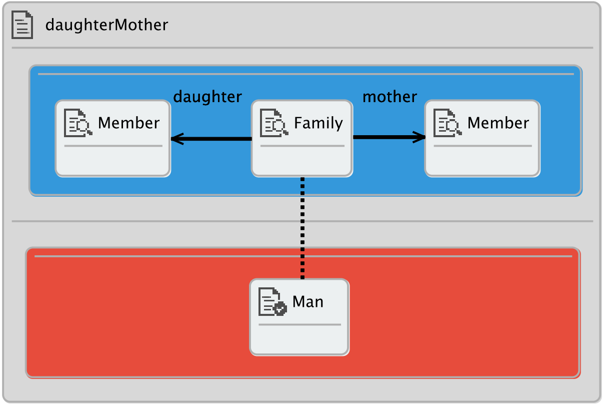

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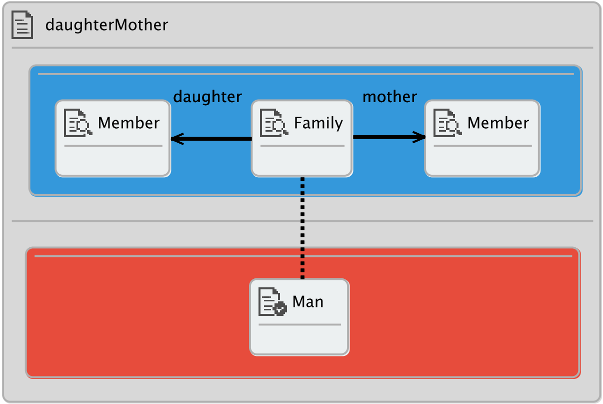

- *A family with a mother and a daughter will always produce a community with a man*
- Fails on path condition: 'HEmpty_HRoot_HMotherRule_HDaughterRule'

Experiments Conducted

- Applicability of the Technique
- Time and Memory Characteristics
- Reducing Contract Proving Time
- Higher-Order Transformation

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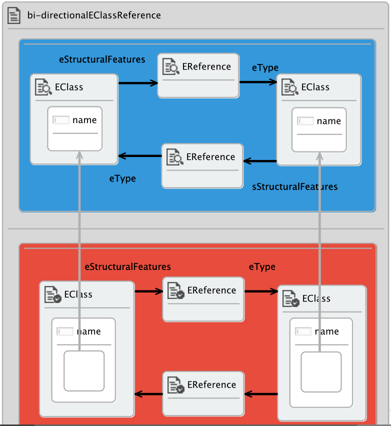

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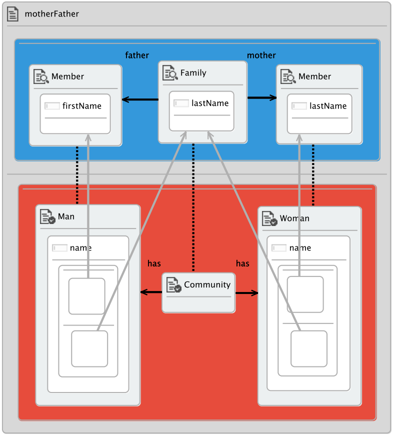

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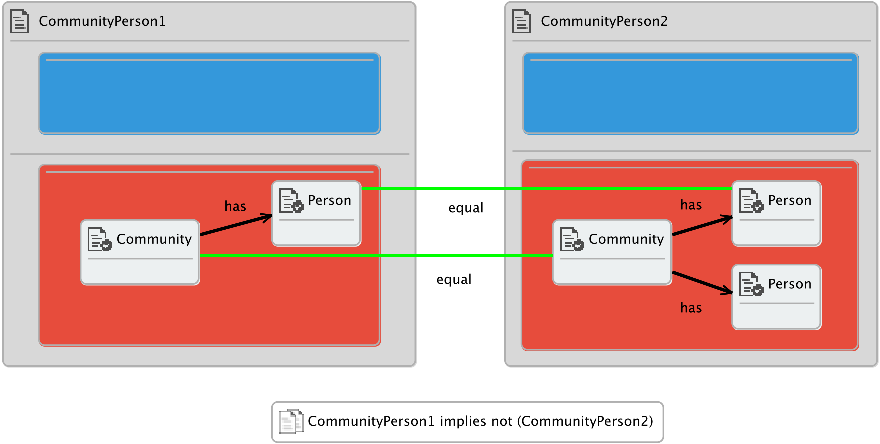

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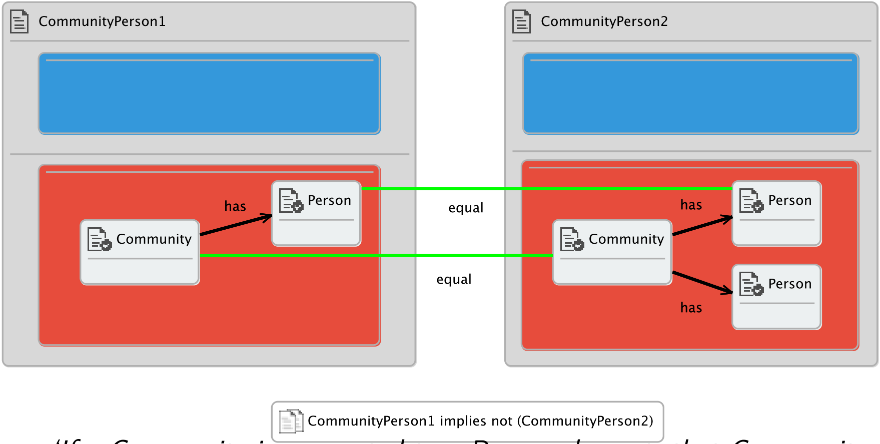

- *'If a Community is connected to a Person element, that Community is connected to one and only one Person element'*
- Selim, Gehan. Formal Verification of Graph-Based Model Transformations. PhD Diss. Queen's University, 2015.

Time and Memory Characteristics

	ATL/ DSLTrans Rules	Path Conds. Gen.	Time (s)	Contracts Proved	Time (s)	Memory (MB)
Families-to-Person	5 / 9	52	1.54	4	31.45	45
ER-Copier	5 / 9	70	0.48	1	1.70	43
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  - Recursively create rule dependency tree
- Manually performed - slicing has since been automated

Higher-Order Transformation

- Question: Is a transformation produced by a HOT equivalent to a hand-built one?

G. M. Selim, L. Lúcio, J. R. Cordy, J. Dingel, and B. J. Oakes. Specification and verification of graph-based model transformation properties. In Graph Transformation, pages 113–129. Springer, 2014.

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Industrial (from [18])	5 / 7	3	0.07	9	0.16	43
Industrial (from HOT)	5 / 9	3	0.17	9	0.26	48

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Higher-Order Transformation

- Question: Is a transformation produced by a HOT equivalent to a hand-built one?

	ATL/ DSLTrans Rules	Path Conds. Gen.	Time (s)	Contracts Proved	Time (s)	Memory (MB)
Industrial (from [18])	5 / 7	3	0.07	9	0.16	43
Industrial (from HOT)	5 / 9	3	0.17	9	0.26	48

- Note that number of rules/transformation shape not optimized
- But HOT produces roughly equivalent result

G. M. Selim, L. Lúcio, J. R. Cordy, J. Dingel, and B. J. Oakes. Specification and verification of graph-based model transformation properties. In Graph Transformation, pages 113–129. Springer, 2014.

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- Thank you for your time!

Fully Verifying Transformation Contracts for Declarative ATL

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http://msdl.cs.mcgill.ca/people/levi/files/MODELS2015

Multiplicity Contract

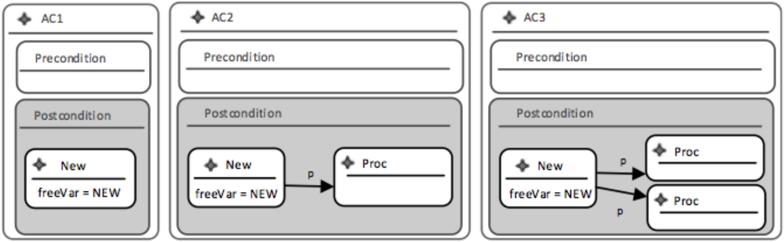

Figure C.1: *AtomicContracts AC1, AC2,* and *AC3* that are used to express *MM1* (Table 6.4) as $AC1 \Longrightarrow_{tc} (AC2 \wedge_{tc} \neg_{tc} AC3)$.

"Multiplicity Invariants ensure that the transformation does not produce an output that violates the multiplicities in the Kiltera metamodel"

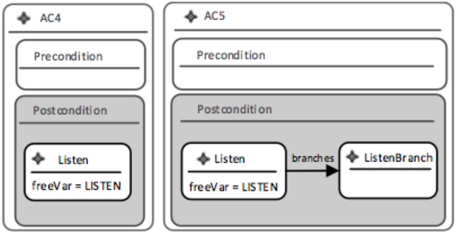

Figure C.5: *AtomicContracts AC4* and *AC5* that are used to express *MM5* (Table 6.4) as $AC4 \Longrightarrow_{tc} AC5$.

"Syntactic Invariants ensure that the generated Kiltera output model is well-formed with respect to Kiltera's syntax."

Pattern Contracts

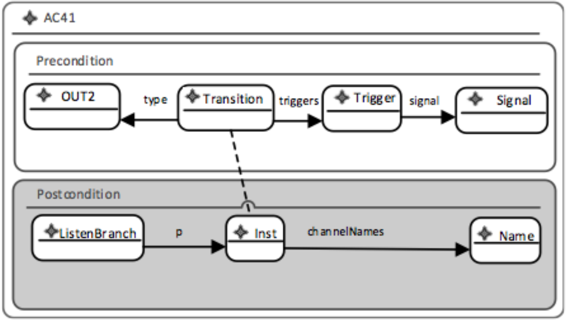

Figure C.16: *AtomicContract AC41* that is used to express *PP2* (Table 6.4).

"Pattern contracts require that if a certain pattern of elements exists in the input model, then a corresponding pattern of elements exists in the output model"