# SyVOLT: Full Model Transformation Verification Using Contracts

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# Motivation and Overview

- Model transformations are at the heart of model-driven engineering
- Want to verify correctness for transformation specifications
  - Verify visual pre- / post-condition contracts
  - Identify those combinations of rules where contracts hold or not
- Objective: Contract verification for all input models
  - Input independence

# DSLTrans Transformation

- Visual language for model transformations
- Graph-based, rule-based
- Rules are grouped in sequential layers
- Out-place so no rewriting performed
  - Suited for 'translation' transformations
- All its computations are terminating and confluent
  - Unbounded loops during execution are not allowed

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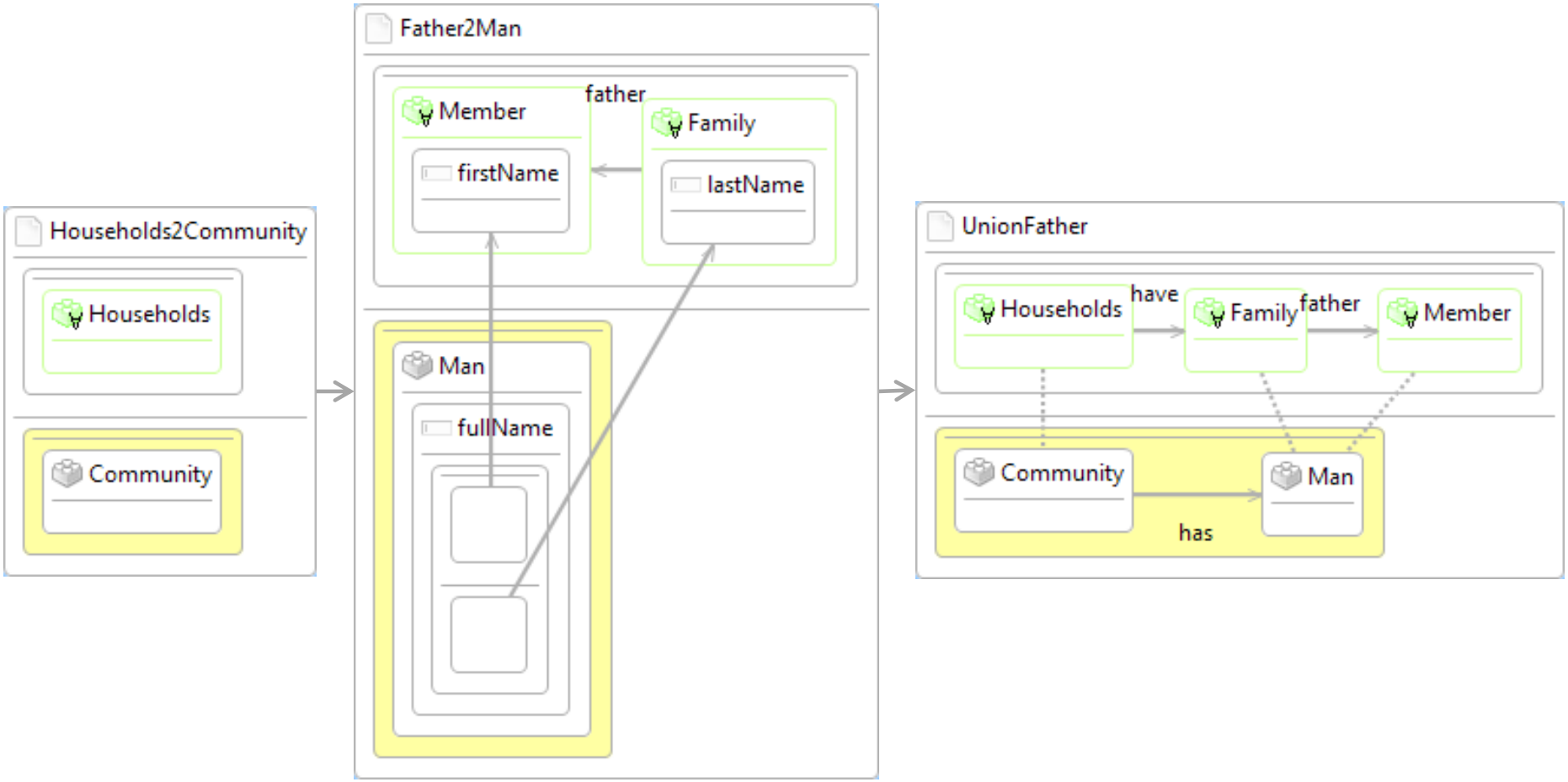
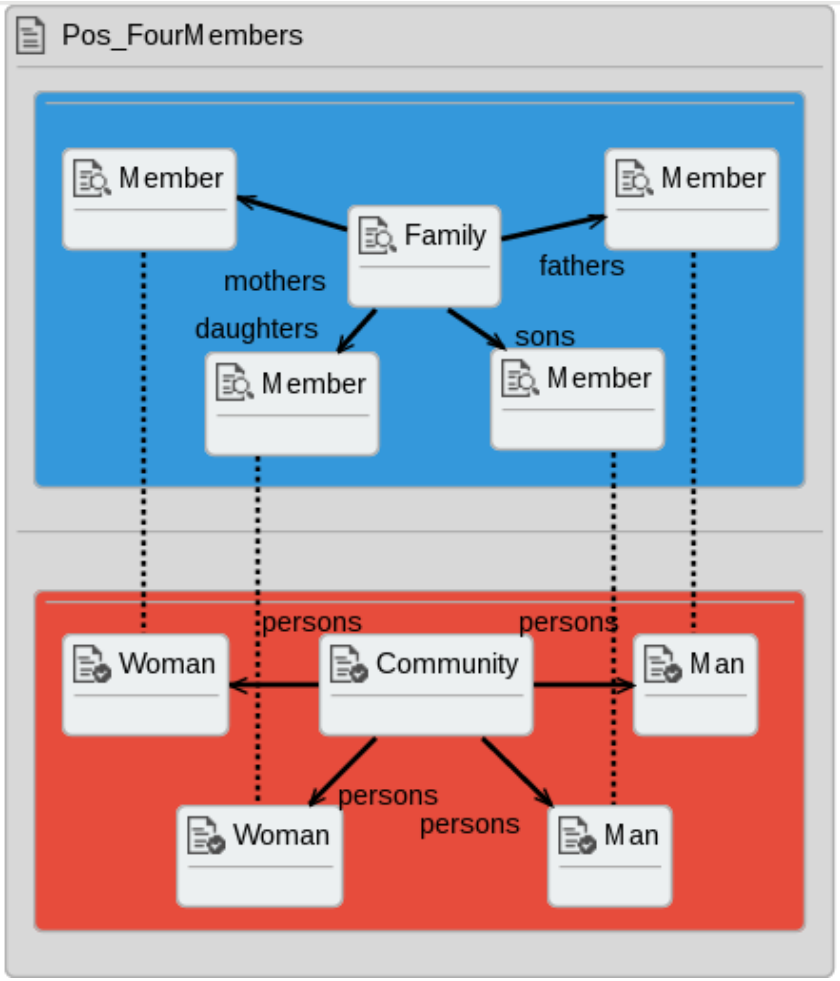
Selim, Gehan et al. "Model transformations for migrating legacy deployment models in the automotive industry." Software and Systems Modeling 14, no. 1 (2013): 365-381.

# DSLTrans




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

# Pre- / Post- Visual Contracts




- If blue graph is found in input model, then red graph is found in output model
- Objective: Prove for all input models/transformation executions - input independence
- *A family with a father, mother, son, daughter should always produce two males and two females in the target community*

# SyVOLT Tool

- All possible executions of the transformation are symbolically constructed
  - Built as sets of rules called path conditions
    - No rules execute, only rule 1 executes, rule 1 and rule 2 both execute
  - Rule dependencies/combinations resolved
- Final finite set of path conditions represents all possible transformation executions
- A contract holds for a transformation if it holds for all generated path conditions
- Otherwise, counter-example path conditions are produced
- Proving process completes within seconds

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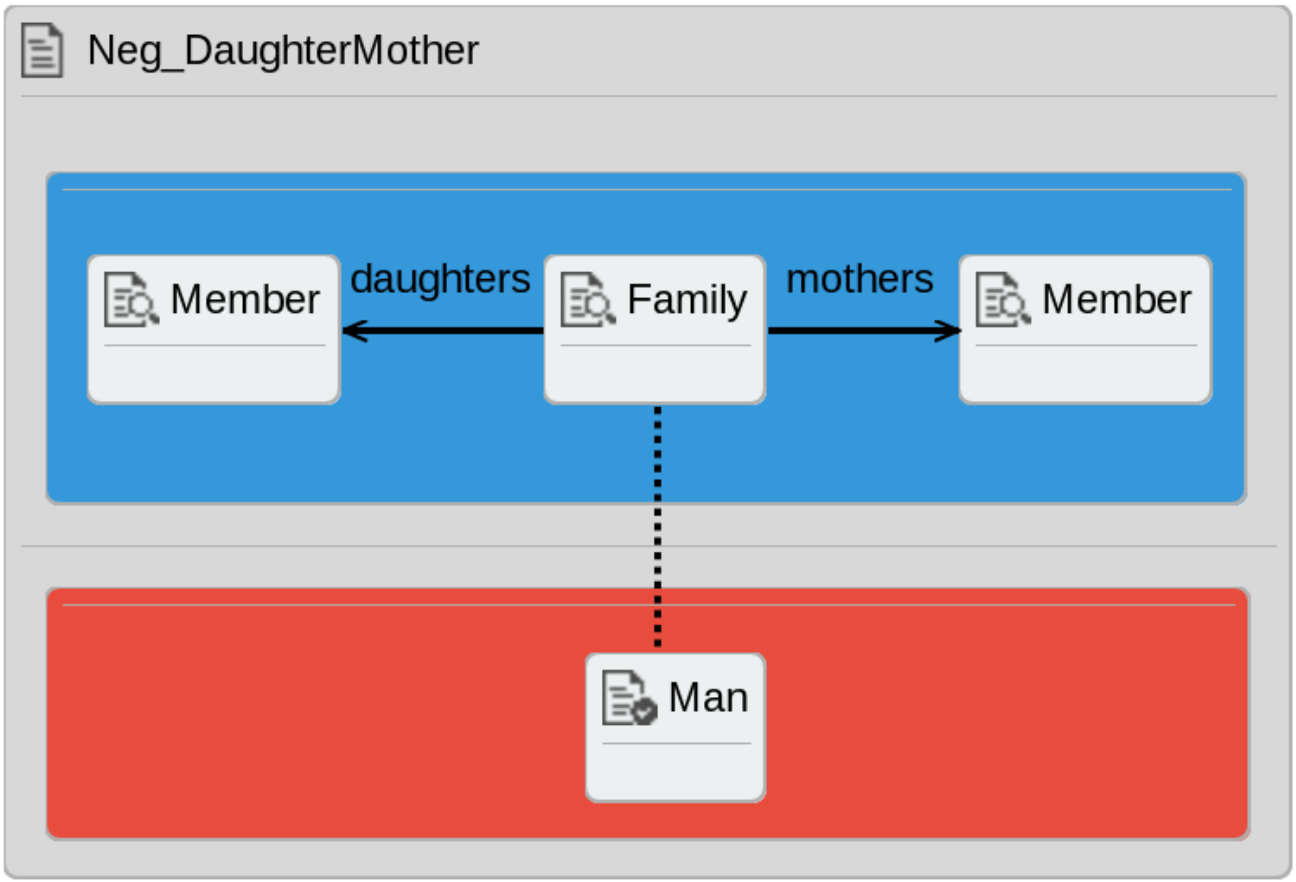
L. Lúcio, B. Oakes, and H. Vangheluwe. A technique for symbolically verifying properties of graph-based model transformations. Technical report, Technical Report SOCS-TR-2014.1, McGill U, 2014.

# Contract Proving Example




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

# Contract Expressibility

- Next few slides will discuss concepts expressible with our contract language.
  - Pattern contracts
  - Element attributes
  - Propositional logic and pivots
  - Syntactic invariants
  - Multiplicity invariants
- Prover reports rule reachability as well

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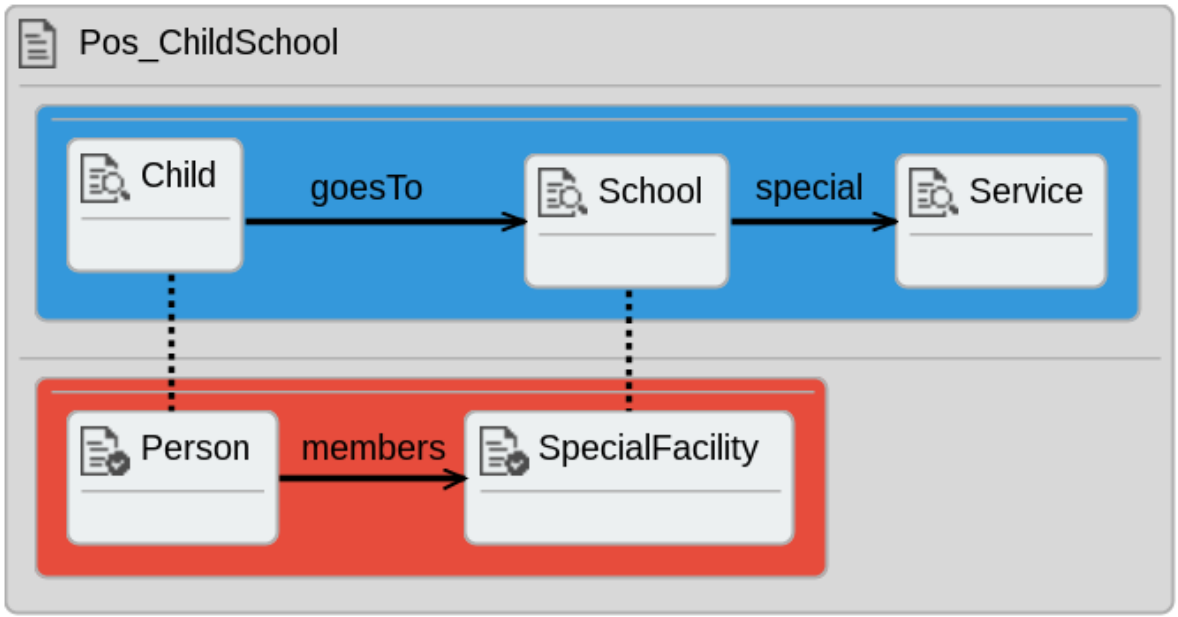
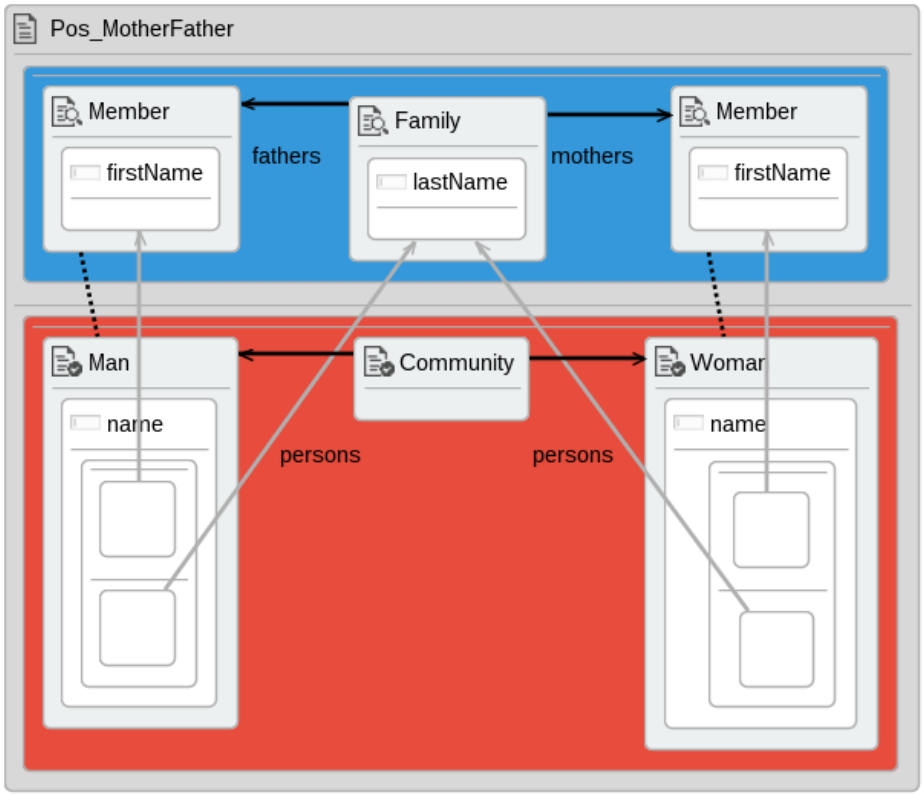
Selim, G.M.: Formal Verification of Graph-Based Model Transformations. Ph.D. thesis, Queen's University. 2015.

# Pattern Contracts



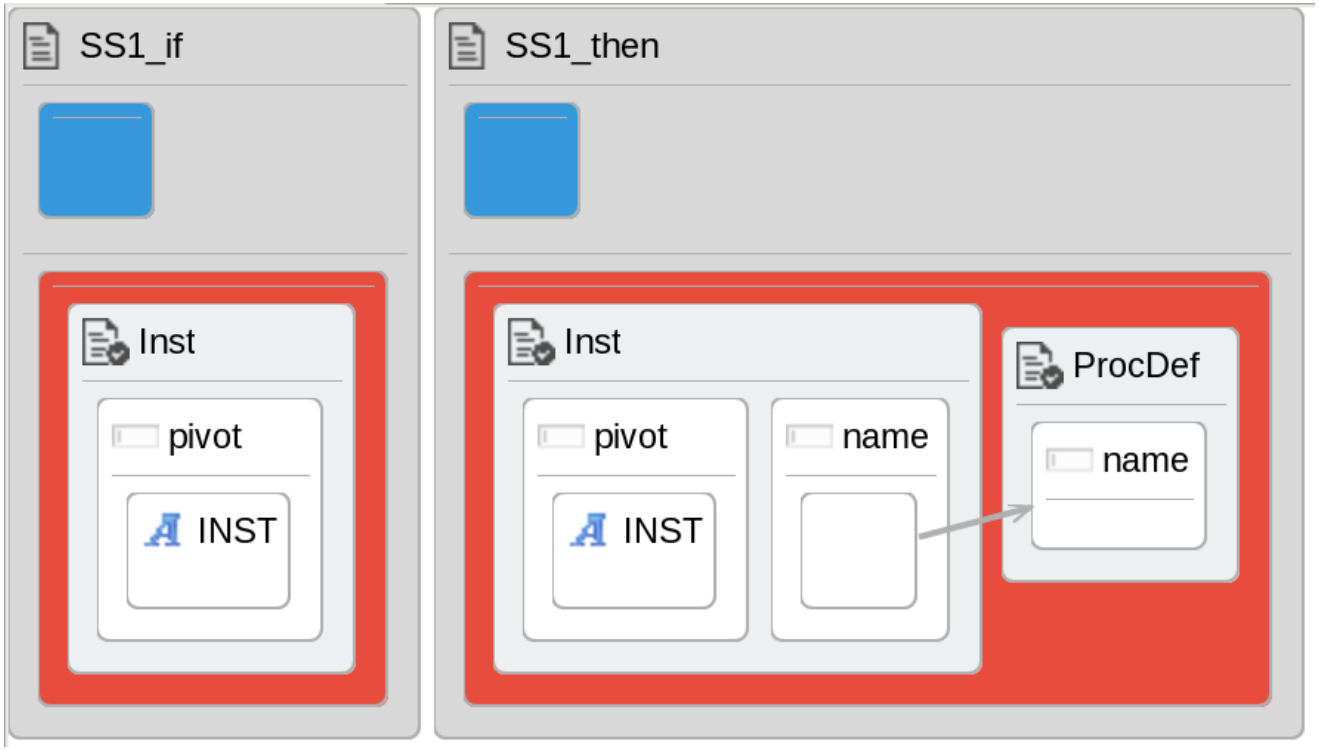

- Relates elements in input model to elements in output model
- *If a Child goesTo a School that has a special Service, then a SpecialFacility has the associated Person as a member*
- Intention is to allow verification of rule interaction
  - Three rules in example

# Element Attributes



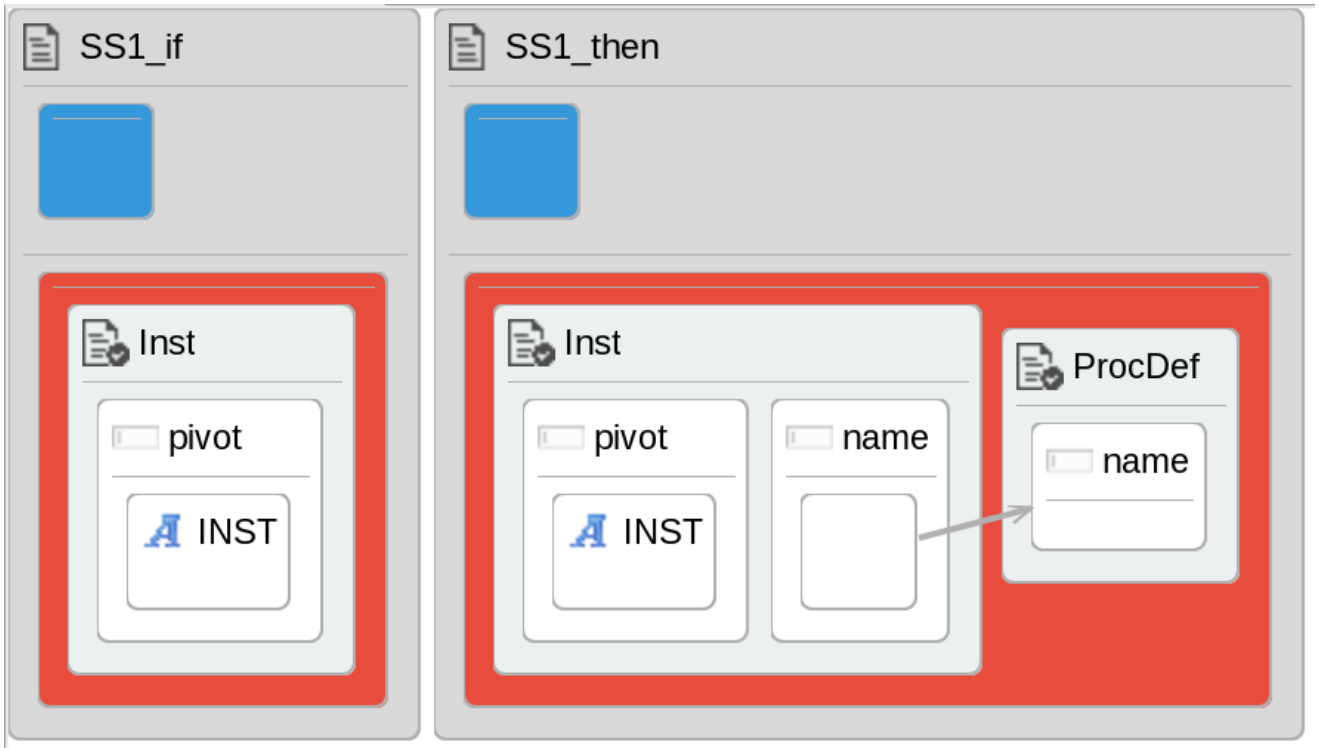

- Reasoning about (String) attributes of elements
- *Is the full name of the produced Person correctly created from the last name of the Family and the first name of the Member?*

# Propositional Logic and Pivots



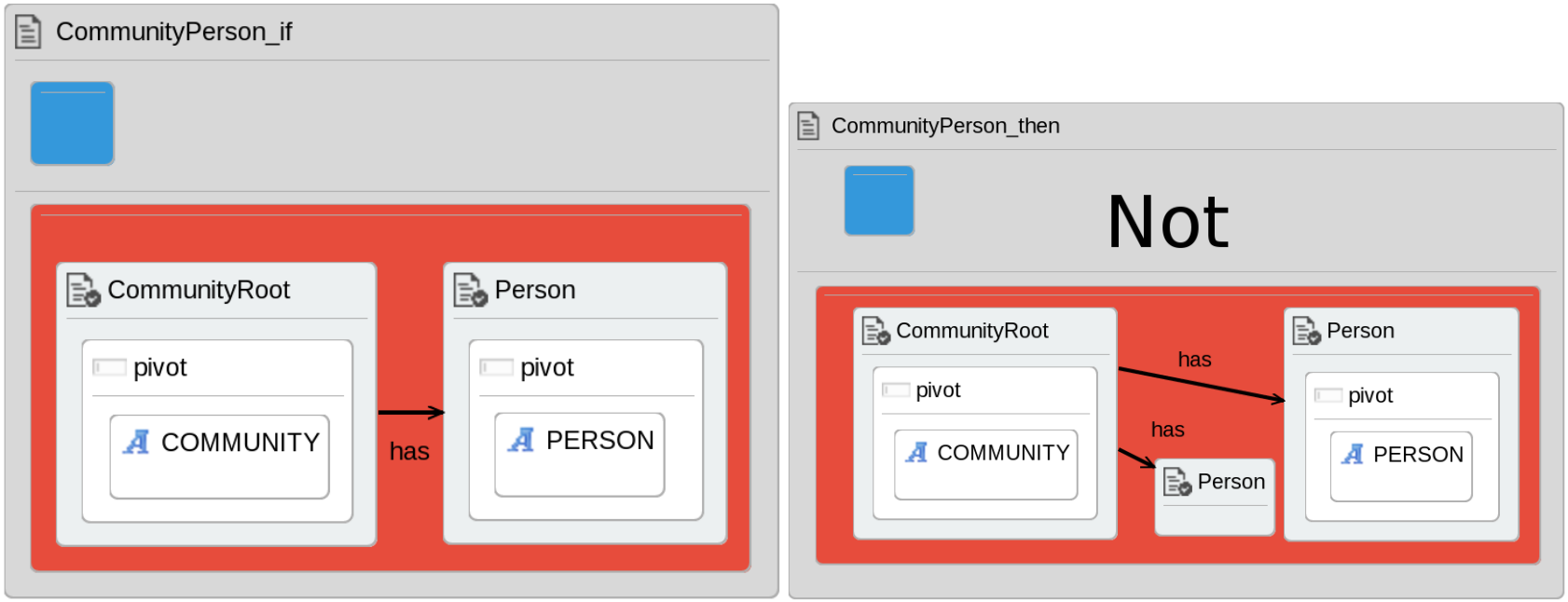

- Contracts can be combined with AND, OR, NOT, IF-THEN
- Pivots ensure that same element is bound in both contracts
- *If there is an Inst element, then that Inst element has the same name as a ProcDef element*

# Syntactic Invariants




- Check if path condition has well-formed input or output syntax
- *If there is an Inst element, then that Inst element has the same name as a ProcDef element*

# Multiplicity Invariants




- *Only one Person is in the Community in the output model*
- Abstraction of our approach loses multiplicity information
  - Multiple applications of a rule are not represented
- Contract only fails if *two Persons are always created in output*

# Contract Limitations

- DSLTrans transformation language only manipulates Strings
  - Could pack data and operations into Strings
- Limitations from symbolic execution technique
  - Loses multiplicity information
    - Cannot count elements created
    - Difficult to express *for each A element, there exists unique B element*

# Contract Limitations

- No query language implemented
  - Cannot create sets of elements
  - Cannot match pattern with inheritance and report subtype names
  - No indirect links/navigation
- Difficult to reason about negative contracts
- Cannot validate instance data
  - 'Do all names start with G'
  - 'Is gender == male or age $< 18$'

# Current Work - mbeddr

- Verify contracts on the mbeddr to C transformation
- mbeddr takes components of embedded system expressed in MPS and generates C code
- Transformation must be verified in order to ensure that resulting C code is valid

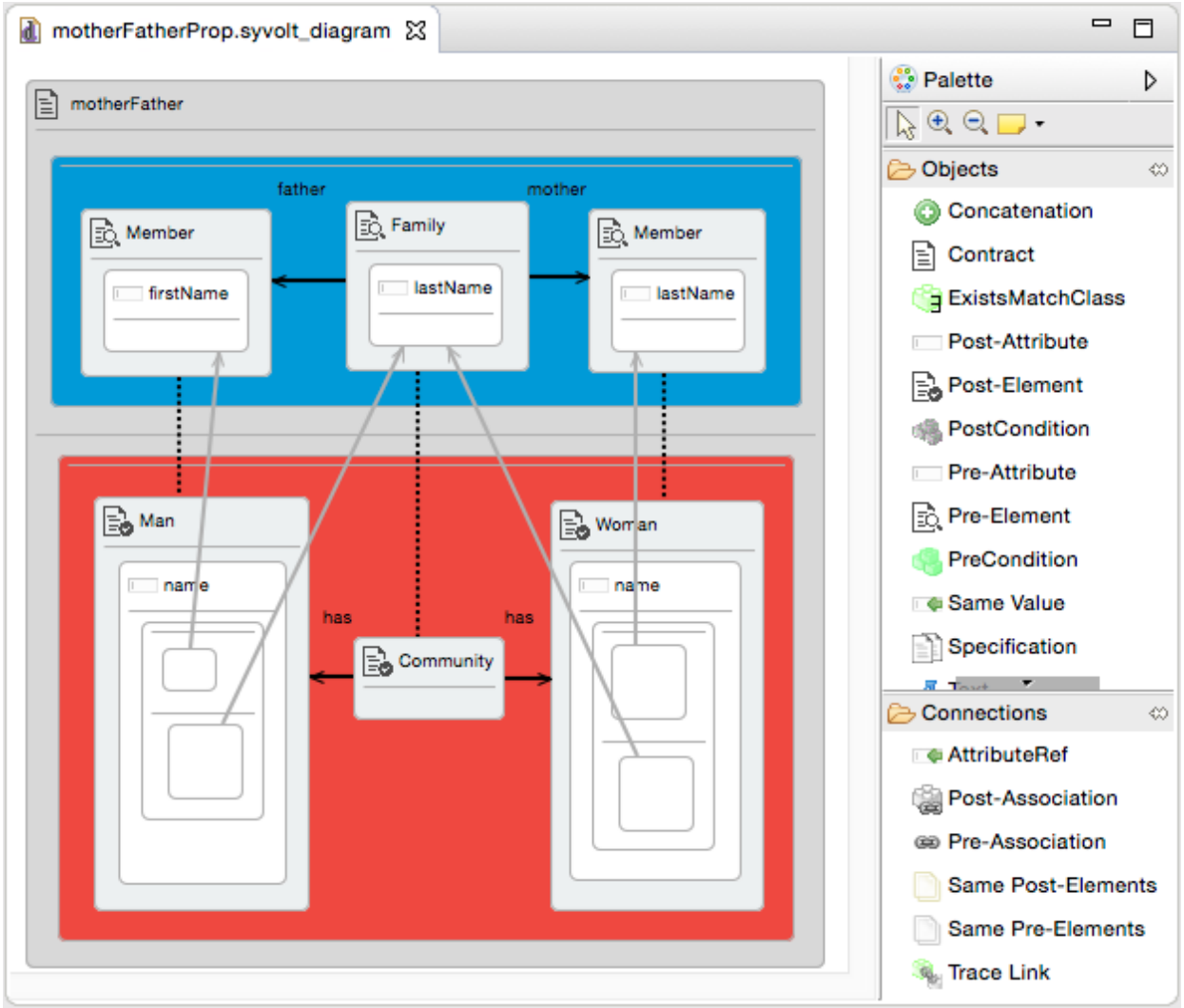
# Challenges

- Scalability
- What are appropriate contracts for this transformation?

# Literature

- Fully Verifying Transformation Contracts for Declarative ATL
  Bentley James Oakes, Javier Troya, Levi Lucio, and Manuel Wimmer
  Proceedings of MODELS 2015
    - Extended to journal article: Full Contract Verification for ATL using Symbolic Execution, SoSyM (to appear)
- Finding and Fixing Bugs in Model Transformations with Formal Verification: An Experience Report
  Gehan M. K. Selim, James R. Cordy, Juergen Dingel, Levi Lucio and Bentley James Oakes
  Proceedings of AMT 2015

# Eclipse Plugin




- Eclipse GMF plugin for building DSLTrans transformations and contracts.

# Conclusion

- Verification of visual contracts on DSLTrans transformations
- Approach is complete for all transformation executions
- Can extend contract language expressiveness
- Eclipse plugin to build transformation and contracts
- Current work: Verification of mbeddr transformation

- Thank you for your time!

**SyVOLT: Full Model Transformation Verification Using Contracts**