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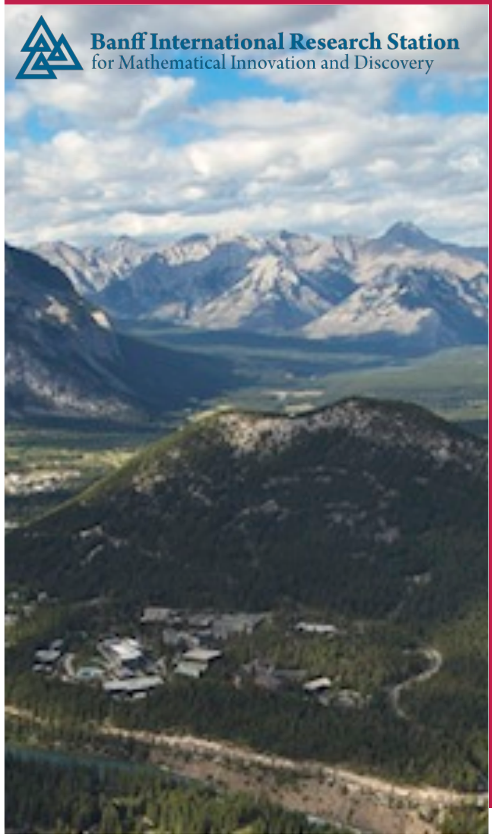

"The Implications of Optimality Results for Incremental Model Synchronization for TGGs"

Bi-directional transformations (BX) –
Theory and Applications Across Disciplines (13w5115)
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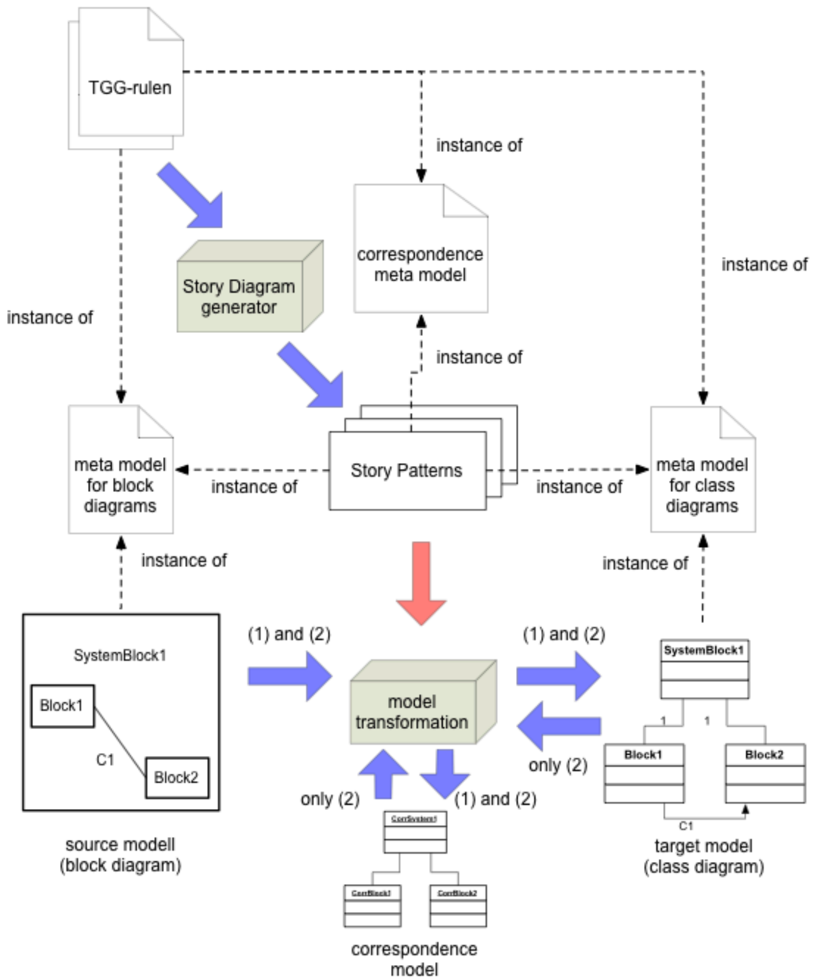
Holger Giese, Stephan Hildebrandt
System Analysis & Modeling Group,
Hasso Plattner Institute for Software Systems Engineering
University of Potsdam, Germany
holger.giese@hpi.uni-potsdam.de

Outline

1. **Introduction**
2. **Optimality Result**
3. **Open Issues & Implications**

1. Introduction: Triple Graph Grammars



Problem:

- Describe full model transformations where source and target can have different meta-models

Solution:

- TGGs: describe **relation** between source and target by means of a grammar that generates all valid pairs (here even triples incl. correspondence)
- Derive operational rules in form of Story Pattern for
  - forward direction,
  - backward direction, and
  - consistency

1. Introduction:
Theoretical Results on TGGs

- MDELab is a toolset for our Triple Graph Grammar dialect (and Story Diagrams) covering also testing and analysis [1]

Consistency, Completeness of TGG:

- Well-formedness rules which guarantee consistency and completeness for our TGG dialect [2] ➔ apply to model synchronization as well

Testing of TGGs:

- Automated test generation for our TGG dialect offering a complete coverage of the TGG specifications [3,4] ➔ apply to model synchronization as well

Verification of TGGs (and related GTS):

- Automatic checking behavior preservation for our TGG dialect [5]
  ➔ apply to model synchronization as well
- Automatic checking of structural constraints for transformation rules [6]
  ➔ apply to TGGs and model synchronization as well

1. Introduction:
Practical Results on TGGs

Applications:

- Industrial Case Study on the Integration of SysML and AUTOSAR with Triple Graph Grammars via model synchronization [7,8]
- Application of model synchronization for Runtime Models [9]

Efficiency:

- Improved performance for Story Diagrams using runtime information [12]
- **Optimal performance for incremental model synchronization for our TGG dialect for practically relevant models [13,14] based on the results for Story Diagrams [12]**

Why is it relevant, what is the result, and why does it work?

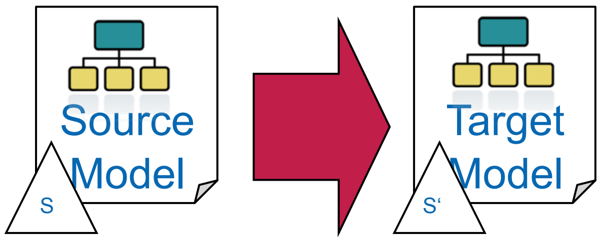
2. Optimality Result: Motivation

Why does performance matter at all?

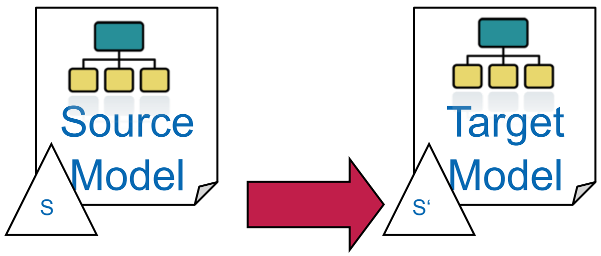
- Reducing the effort also means to minimize the unnecessary changes; **optimal means no unnecessary changes at all!**
- We may have multiple model synchronizations linked together additional steps such as consistency checks, and/or rollbacks and thus the overall performance matters (model management)
- Short execution times make conflicts very unlikely (if models are handled by the same tool or a shared repository)
- Besides case tools we apply model synchronizations also for runtime models where the overhead should be minimal

2. Optimality Result:
Synchronization Problem

- Model Synchronization

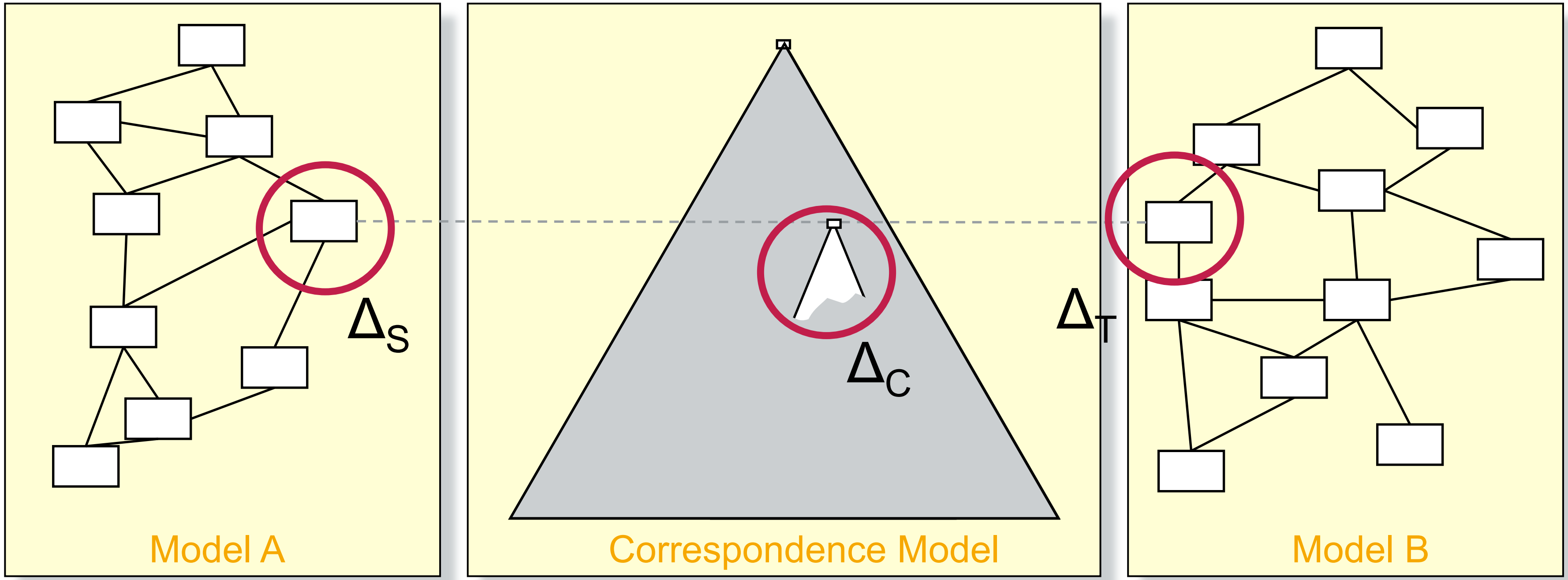


- Incremental Model Synchronization



Remark: concurrent updates are not considered!

2. Optimality Result:
Synchronization Problem



- forward: Δ_S implies to compute $\Delta_C + \Delta_T$
- backward: Δ_T implies to compute $\Delta_C + \Delta_S$ (can be handled analogous to the forward case)

Remark: $O(\Delta_S + \Delta_C + \Delta_T)$ is thus a lower complexity bound

2. Optimality Result:
Restrictions of our TGG dialect

[14]

The rules of our TGG dialect allow only to link finite many elements in the source and target model to each other via one correspondence elements at once. Consequently,

- $O(\Delta_C) = O(\Delta_S + \Delta_C + \Delta_T)$
- $O(\Delta_C)$ is also a lower bound for the synchronization problem

Implications for BX:

- Do similar restrictions apply for other techniques (GT or other domains)?

2. Optimality Result: Practically Relevant Models

[14]

Study of available data concerning model transformations reveals:

- P1 The models contain at most one “unbounded” link (link in O(n)-O(1)).
- P2 Source and target models are weakly connected graphs.
- P3 Expressions in the rules can be evaluated in constant time.
- P4 TGG transform all elements of the source and target models*

Implications for BX:

- Do similar limitations for practical cases also apply in other domains (SE is already considered)?

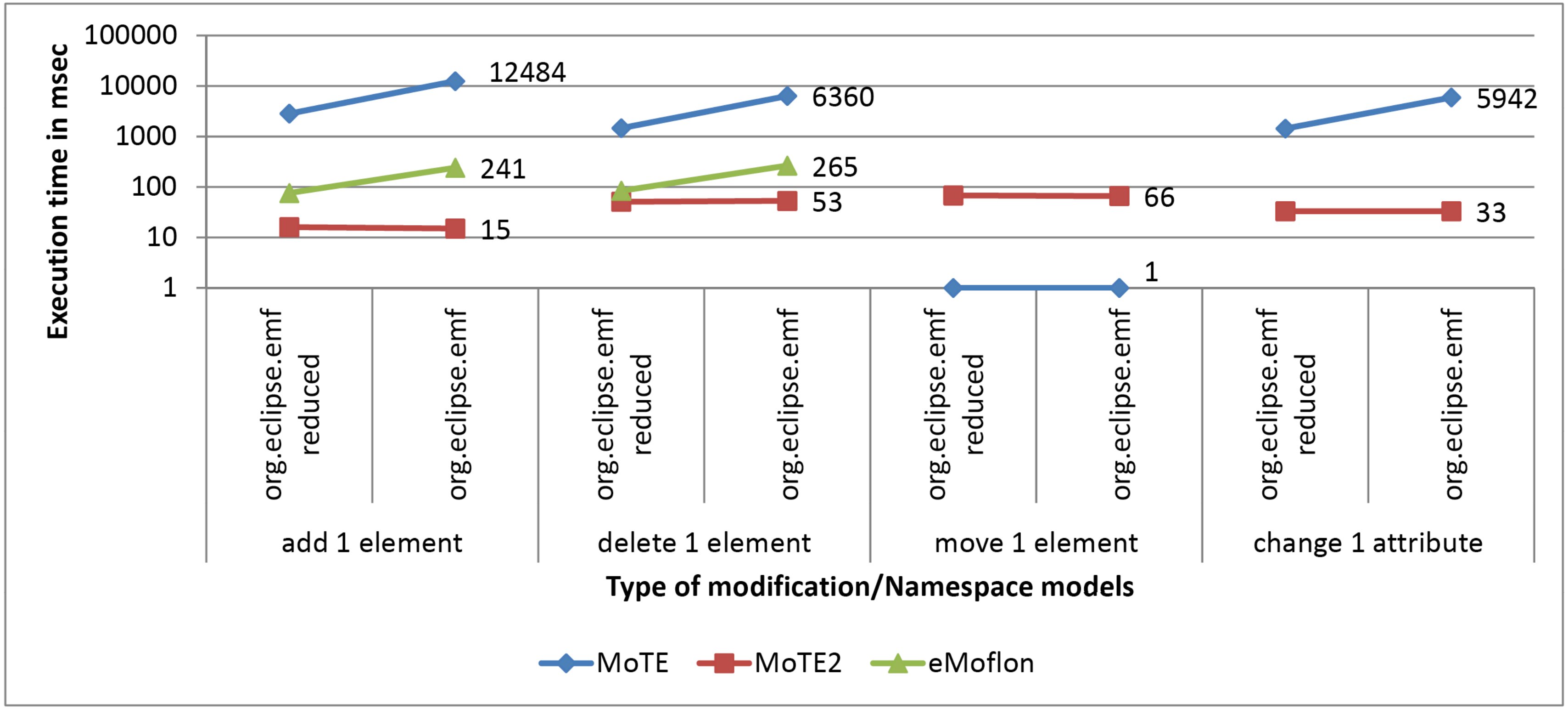
2. Optimality Result: Optimal Model Synchronization

[14]

- synchronization algorithm with repair ➔ The overall synchronization requires $O(\Delta_C)$ rule checks and applications
- dynamic pattern matching strategy ➔ Finding all matches for a single rule starting from a given correspondence is in $O(\Delta_C)$ steps, if it conceptually has to traverse the unbounded link (by using the untransformed elements set) or $O(1)$ otherwise.
- As for one correspondence only for each rule all matches have to be searched (still $O(\Delta_C)$), the combined execution of the checks and applications for the synchronization scheme requires also only $O(\Delta_C)$ steps.

Result: if P1-P4 hold, complexity is $\mathbf{O(\Delta_C)}$ and thus **optimal!**

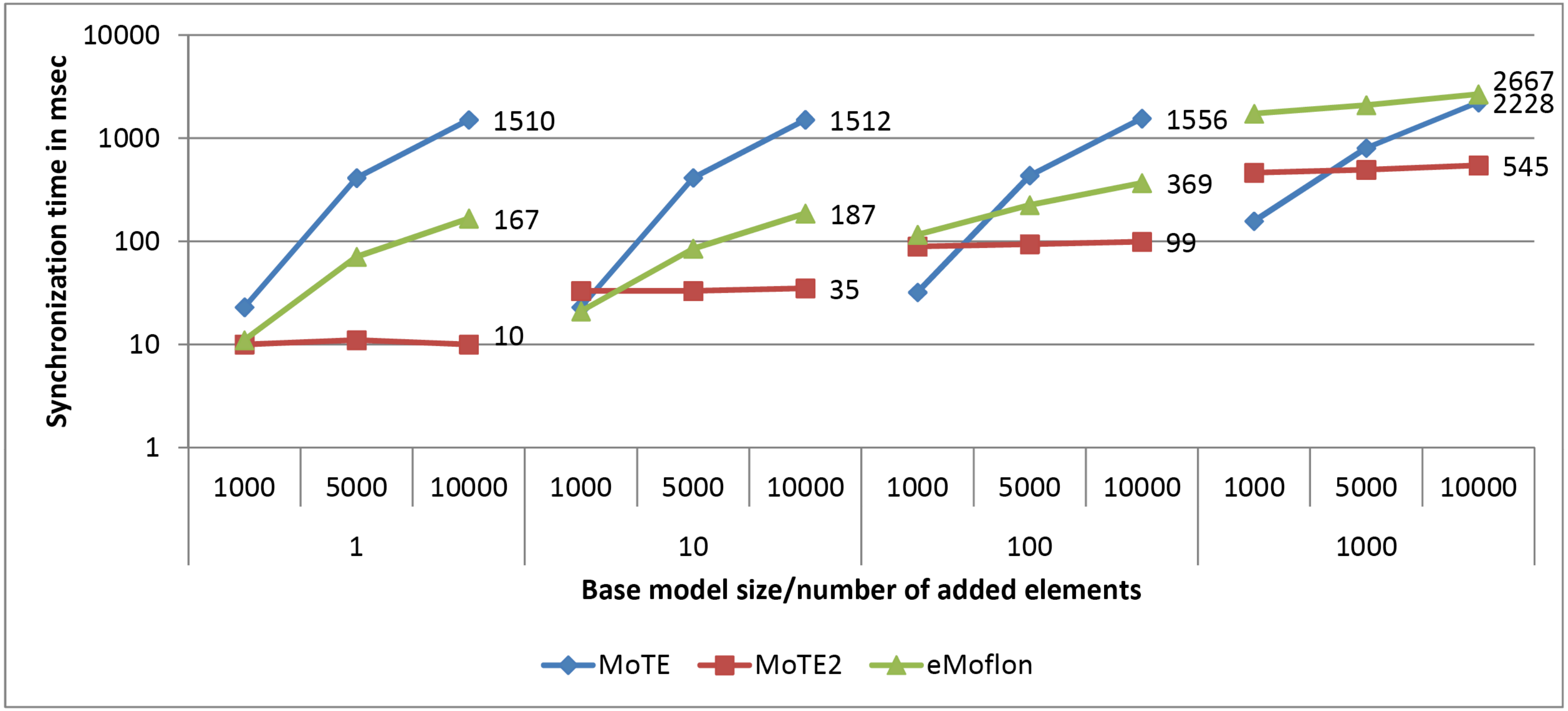
2. Optimality Result: Results for the Implementation



- UML2RDBMS standard benchmark
- org.eclipse.emf reduced: 3227 classes and 2295 associations
- org.eclipse.emf: 6455 classes and 6761 associations

➔ no increase with growing model size!

2. Optimality Result:
Results for the Implementation



- UML2RDBMS standard benchmark
- generated test data …

➔ linear increase with growing delta size!

2. Optimality Result:
Results for the Implementation

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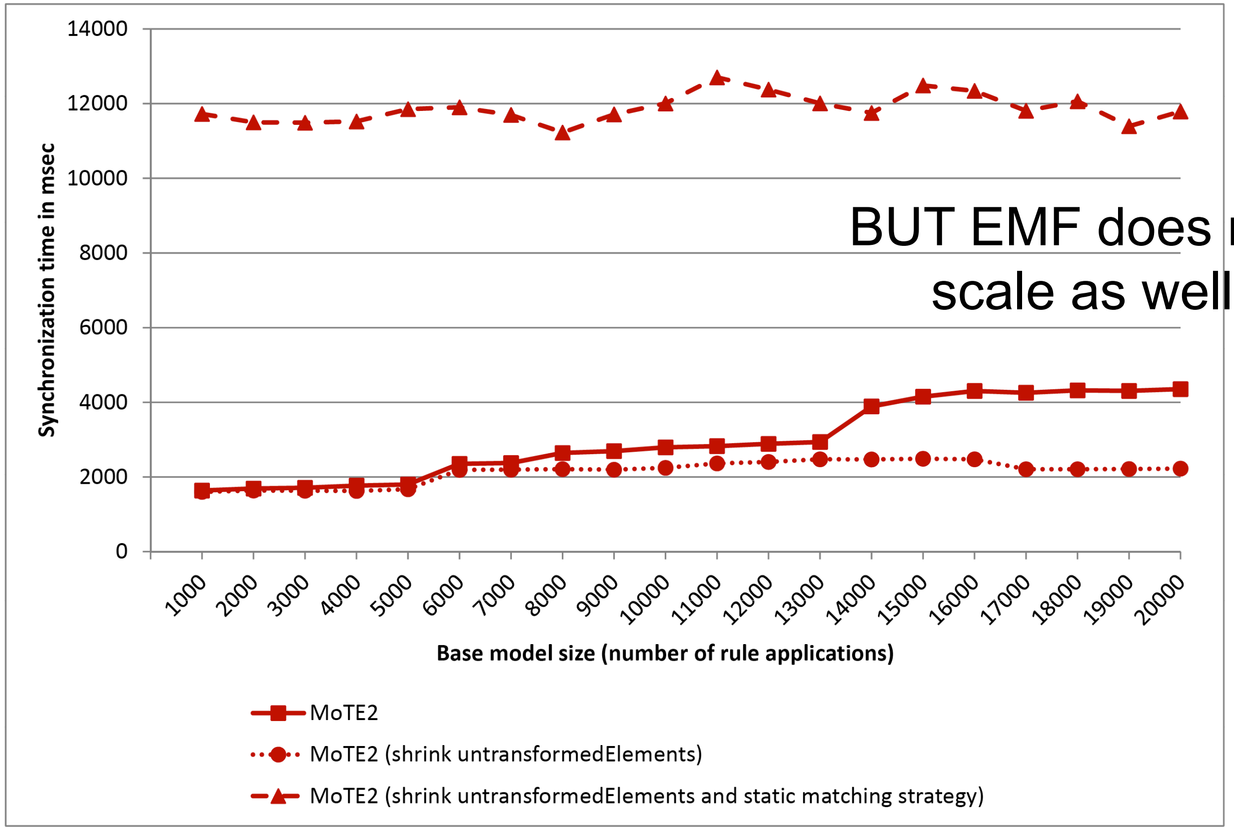

BUT EMF does not scale as well …

- SDL2UML example with adding 1000 elements
- UML model is about six times the number of rule applications

➔ some minimal increase with growing model size due to EMF!

3. Open Issues & Implications

[14]

Open Issues (for TGGs):

- Which not yet supported TGG concepts can be added without loosing the optimality result? Priorities ✓, … ?

Implications (for TGGs):

- Multiple model synchronization with TGGs that link multiple models would still be highly efficient (remark: interpreter vs. compiler!)

Implications (for BX):

Observation: The restrictions for practical problems matter!

➔ **Maybe it is more promising to look for solutions for relevant classes of practical problems rather then the general case?**

➔ Maybe we can decompose relevant problems into some relevant classes and compose our solution from solutions for each class?

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