

Compositional development framework for bidirectional model transformations based on *structural recursion* on graphs

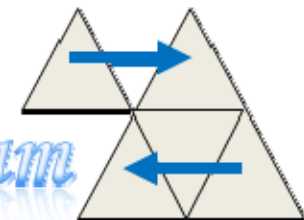
Soichiro Hidaka*
National Institute of Informatics

BIRS-BX 2013
December 4, 2013

*Joint work with BiGteam@NII (K.Asada, Z. Hu, K. Inaba, H. Kato, K. Matsuda, K. Nakano,). Other collaborators appear explicitly in the slides.



GRoundTram

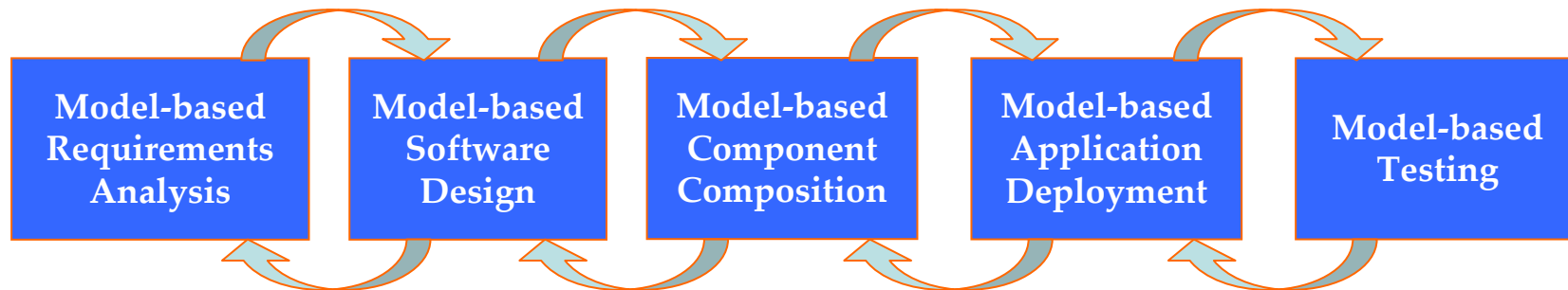
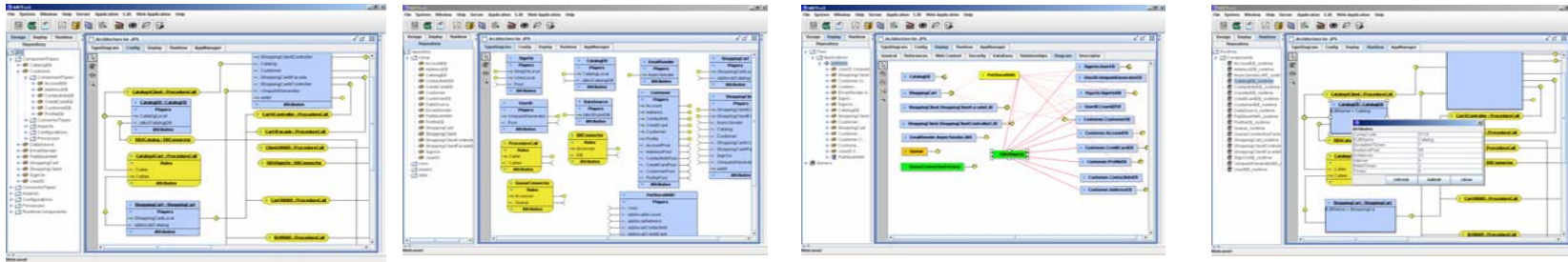


Bidirectional *Graph* Transformation

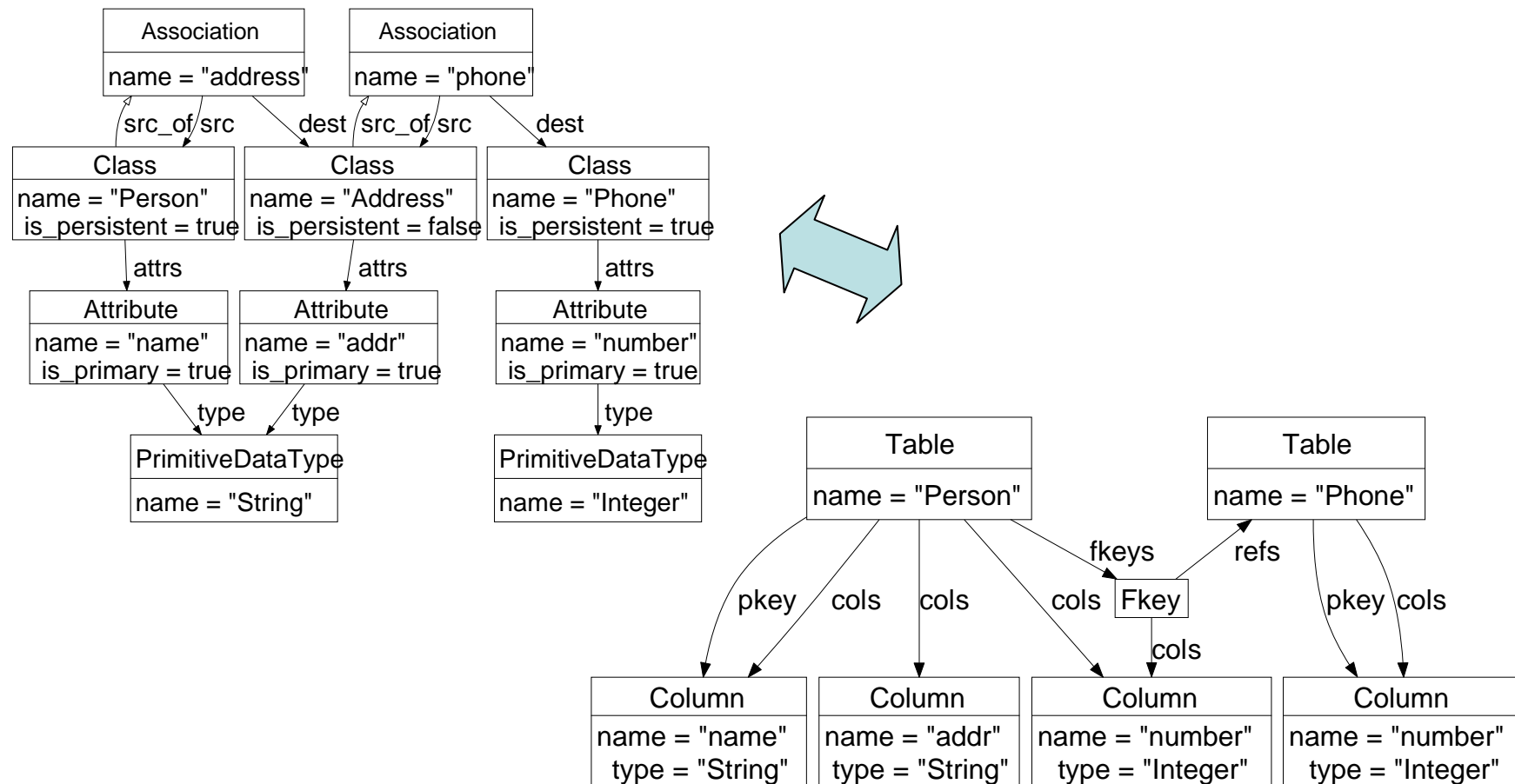
BX on Graphs

Models: Graphs

Bidirectional Model Transformation: Bidirectional Graph Transformation

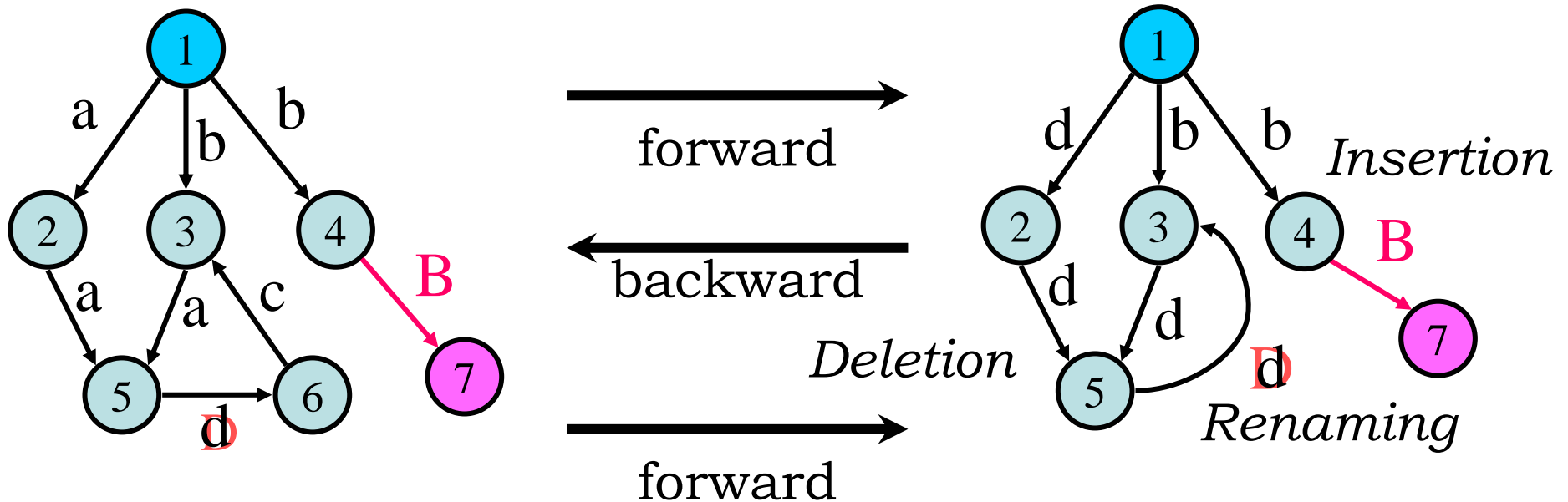


Can We Design a Language for BiG?

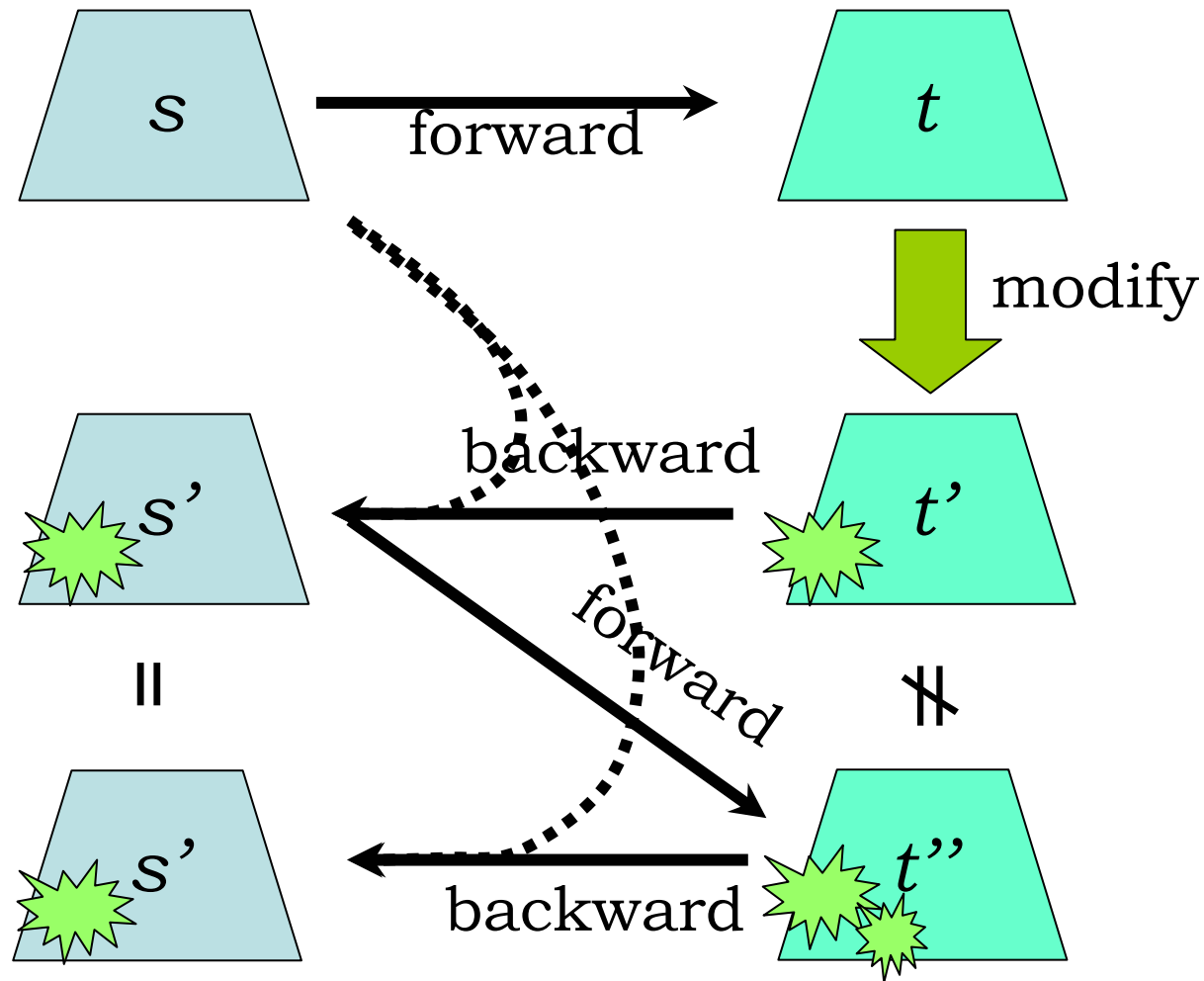


Example of BX on Graphs

- Replace 'a' by 'd' and removes 'c'



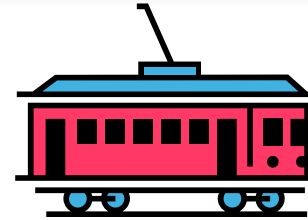
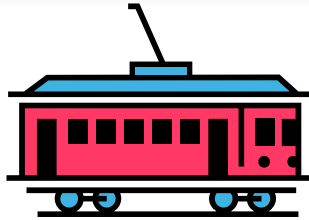
WPutGet (Weak PutGet)



Towards a General Solution ...

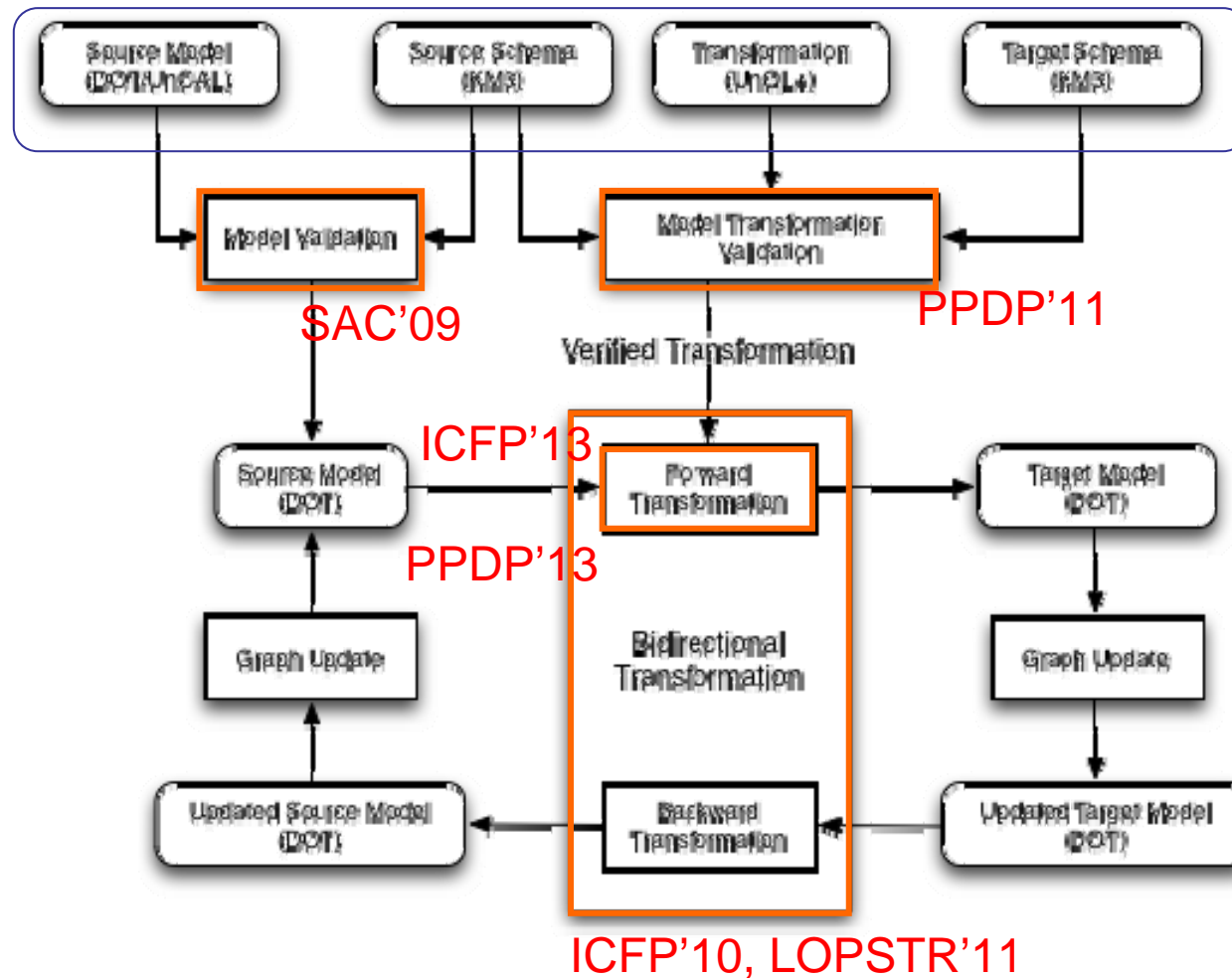
- How to deal with termination of graph transformation?
→ Structural Recursion and its bulk semantics
- How to deal with equality of two graphs?
→ Bisimulation (graphs as regular trees)
- How to correctly reflect changes on the view to the source?
→ Traceability based on Bulk Semantics

GRoundTram: A General Functional Framework



- It is **compositional (functional)**
 - Based on the existing graph query language UnQL
- It is **well-behaved**
 - Built upon bidirectional UnCAL: a graph algebra with clear bidirectional semantics
- It is an **integrated development environment**
 - Graph editor, graph validation, graph transformation checking, visualizations of bidirectional behavior

Overview of GRoundTram

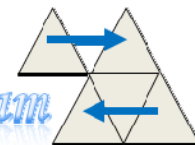


User Input

[ASE] S. Hidaka, Z. Hu, K. Inaba, H. Kato and K. Nakano, *GRoundTram: An Integrated Framework for Developing Well-Behaved Bidirectional Model Transformations* (short paper), ASE 2011



GRoundTram

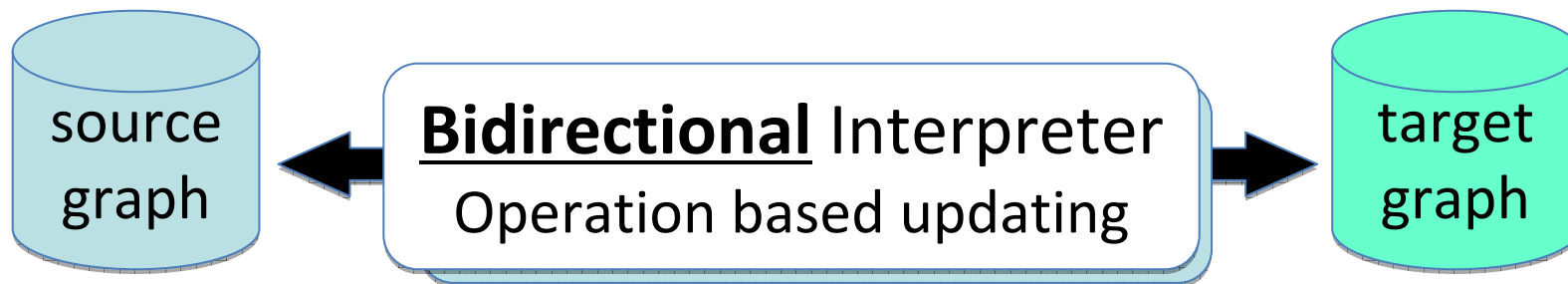


Our Approach: Bidirectionalization

UnCAL graph algebra
structural recursion
[Buneman et al., VLDBJ00]

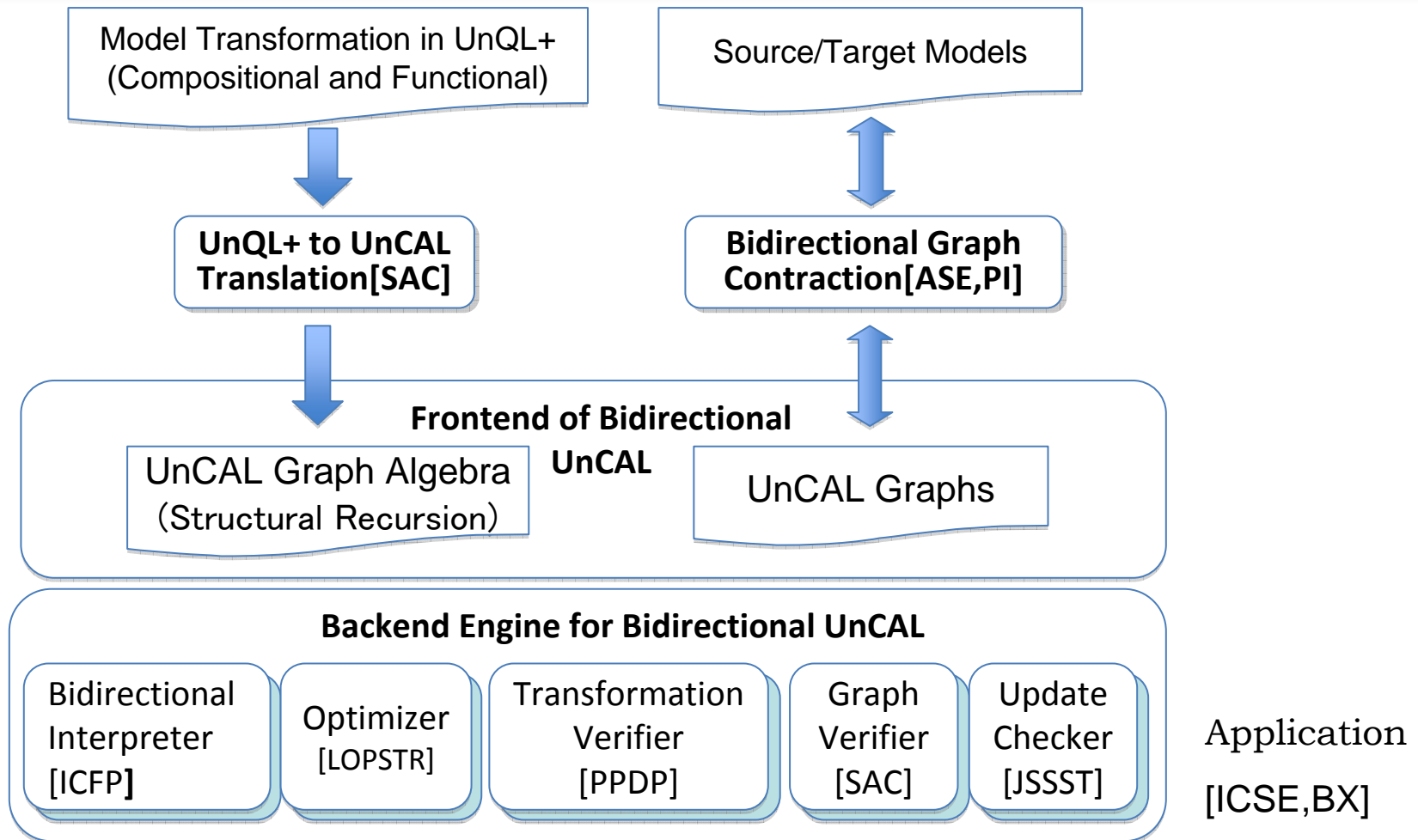
Bidirectionalization

- adding *trace* information
- narrowing



[ICFP'10] S. Hidaka, Z. Hu, K. Inaba, H. Kato, K. Matsuda, K. Nakano, Bidirectionalizing Graph Transformations, 15th ACM SIGPLAN International Conference on Functional Programming, pp.205-216 Sep 2010

Architecture of GRoundTram



UnCAL : Graph Query Language

UnCAL (Unstructured CALculus)

[Buneman et al. VLDB J. 2000]

features:

1. Regular tree transformation
2. Structural Recursion
3. Termination and finiteness-preserving

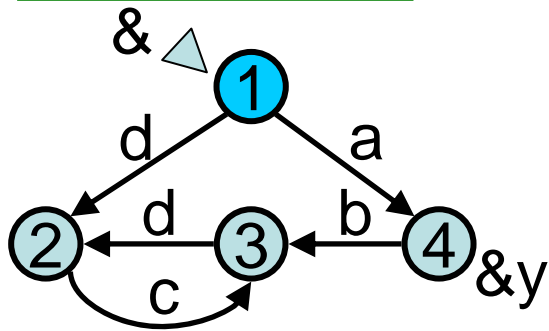
UnCAL-1. Regular Tree Transformation

- $\{\text{finite graphs}\}/\text{bisimilarity} \simeq \{\text{regular trees}\}$
 - Graph transformations as regular tree transformations
- All UnCAL queries are well-defined w.r.t. bisimilarity

$$g_1 \sim g_2 \Rightarrow f(g_1) \sim f(g_2)$$

Graph Model

Graph Model



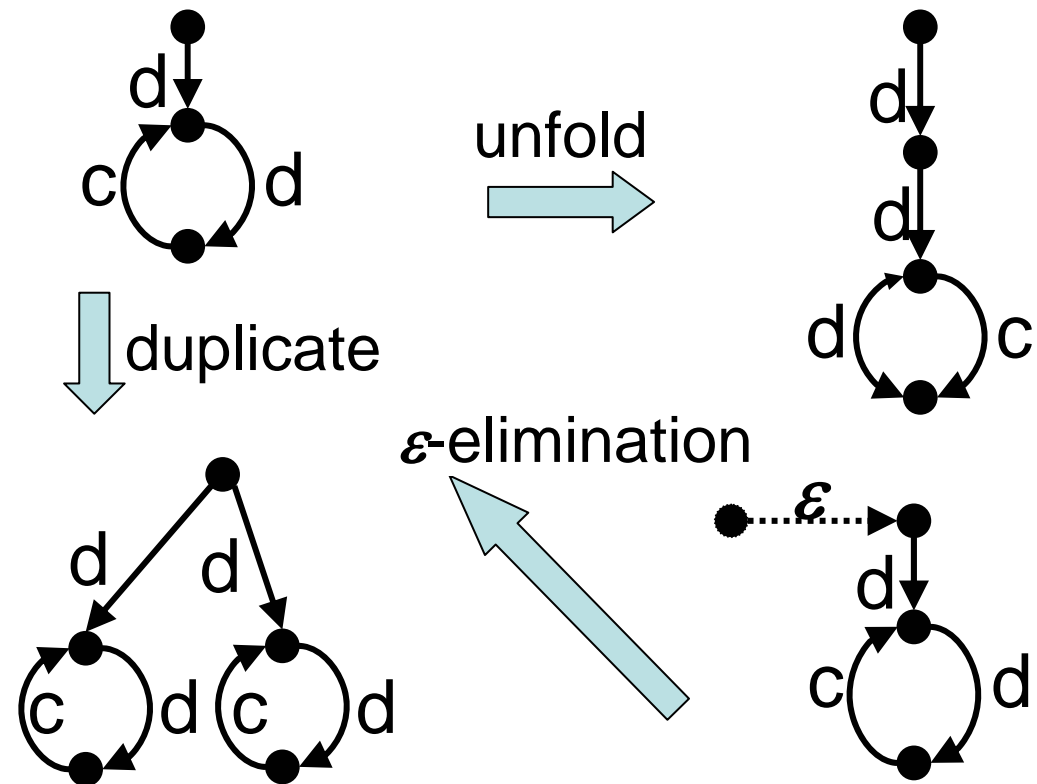
$G=(V,B,I)$ where

$$\left\{ \begin{array}{l} V=\{1,2,3,4\}, \\ B=\{1 \mapsto \{E(d,2), E(a,4)\}, \\ \quad 2 \mapsto \{E(c,3)\}, \\ \quad 3 \mapsto \{E(d,2)\}, \\ \quad 4 \mapsto \{E(b,3), O(\&y)\}\}, \\ I = \{(\& \mapsto 1)\} \end{array} \right.$$

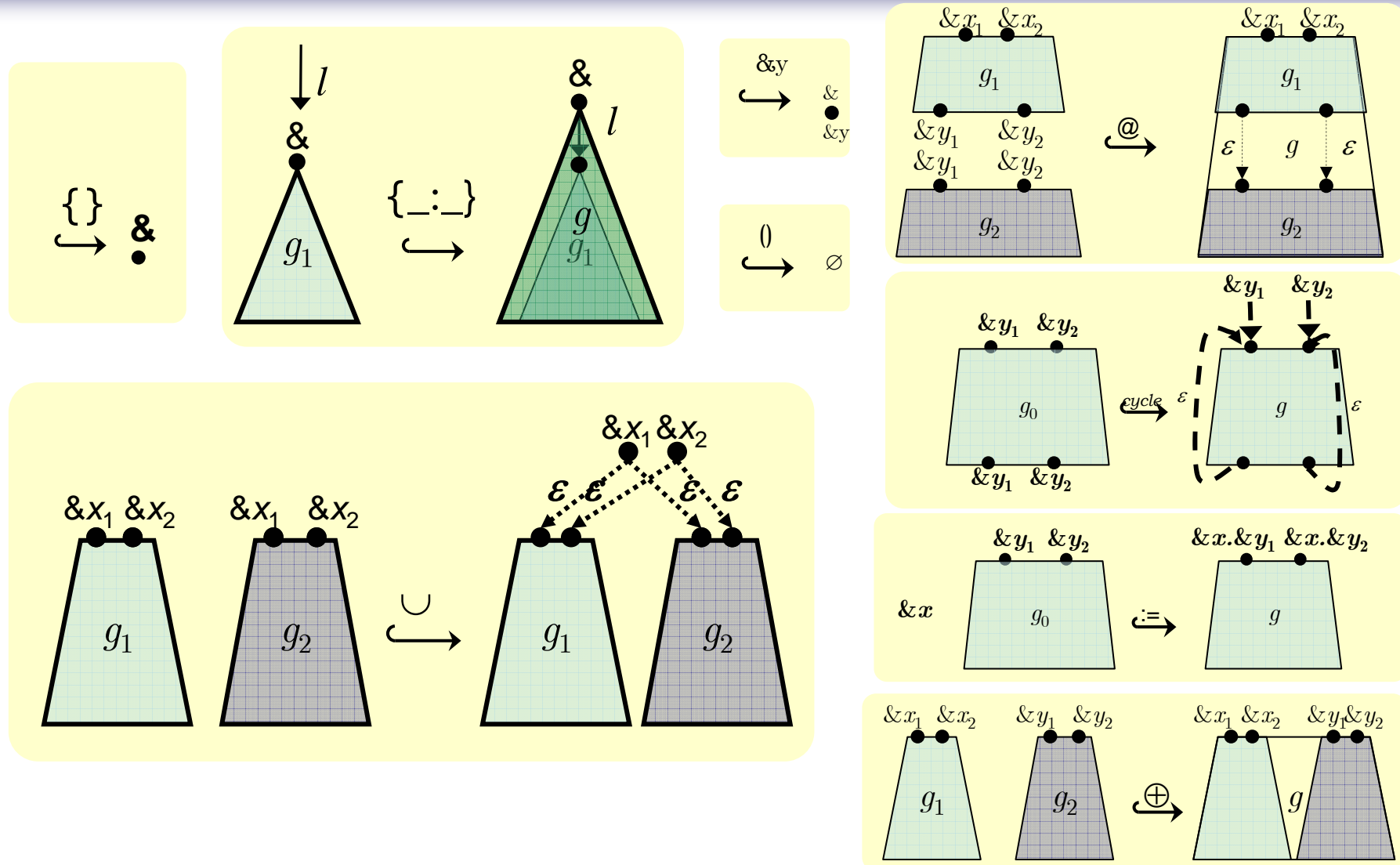
Graph Equivalence

bisimulation

= strong bisim. + ϵ -elimination



Graph Constructors



UnCAL-2: Structural Recursion

- Functional style programming /

For example:

For $f = \mathbf{srec}(e)$

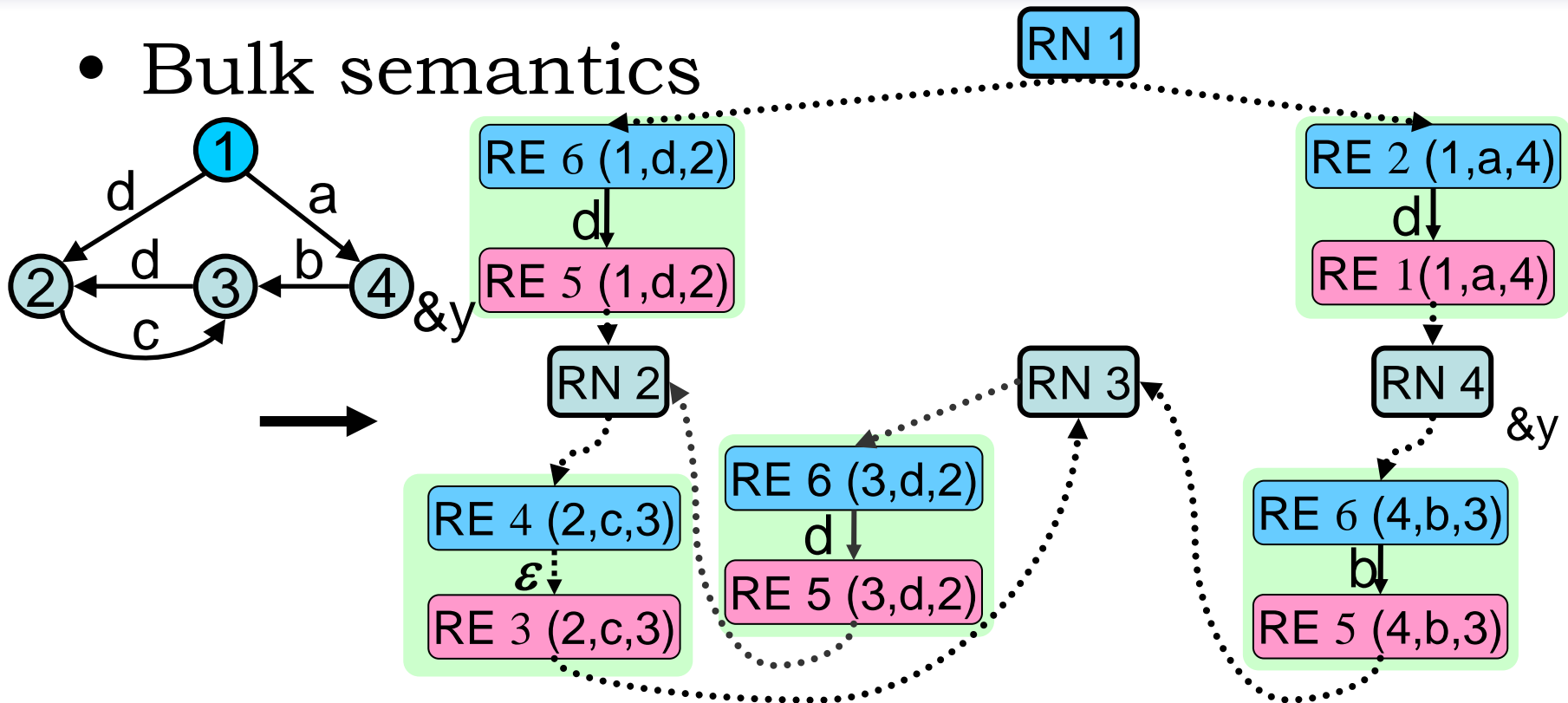
$$f \ \{\} \quad = \ \{\}$$

$$f \ (\{L:G\}) \quad = \ e(L,G)@ \ f \ G$$

$$f \ (G_1 \cup G_2) \quad = \ (f \ G_1) \cup (f \ G_2)$$

UnCAL-3: Termination and Finiteness-Preserving

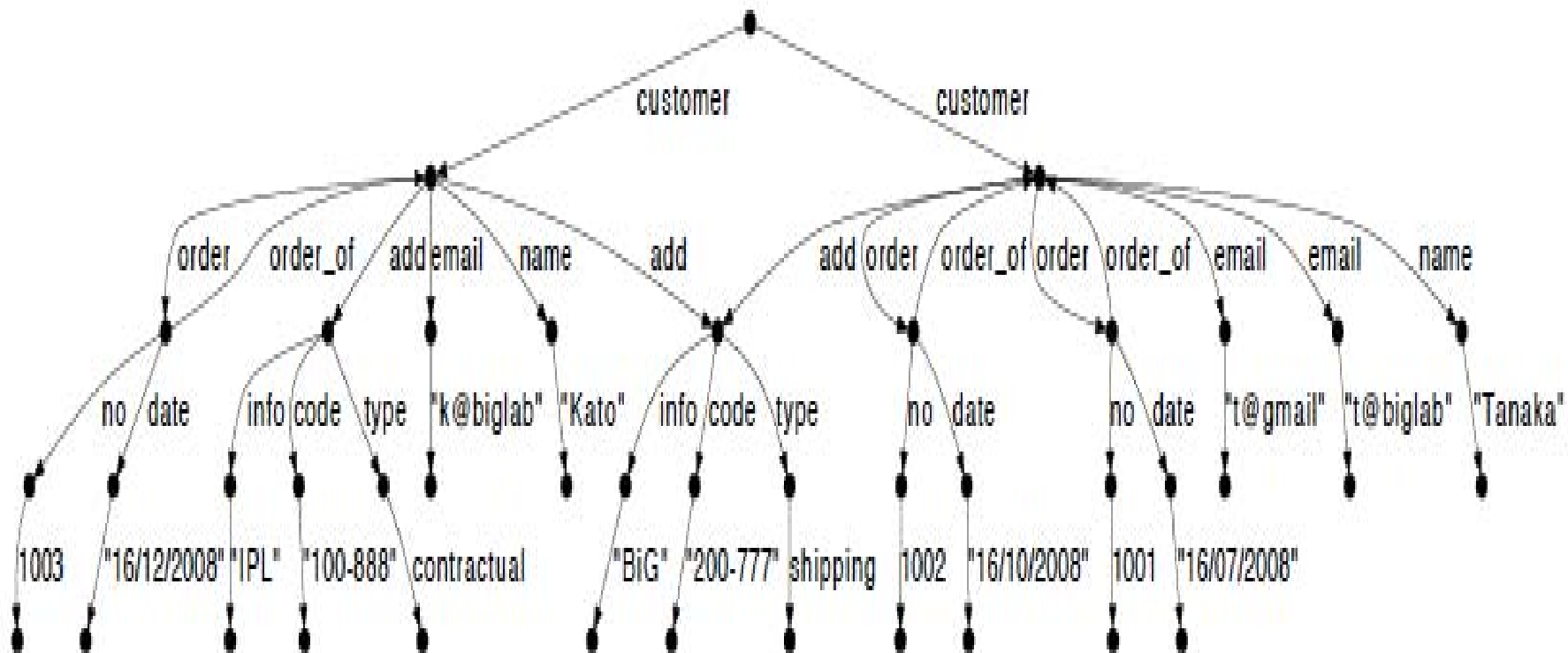
- Bulk semantics



```

a2d_xc = srec(λ(L, g). if L=a then {d:&}
                else if L=c then {ε:&}
                else {L:&}
    )
    
```

Example: A Customer-Order Graph

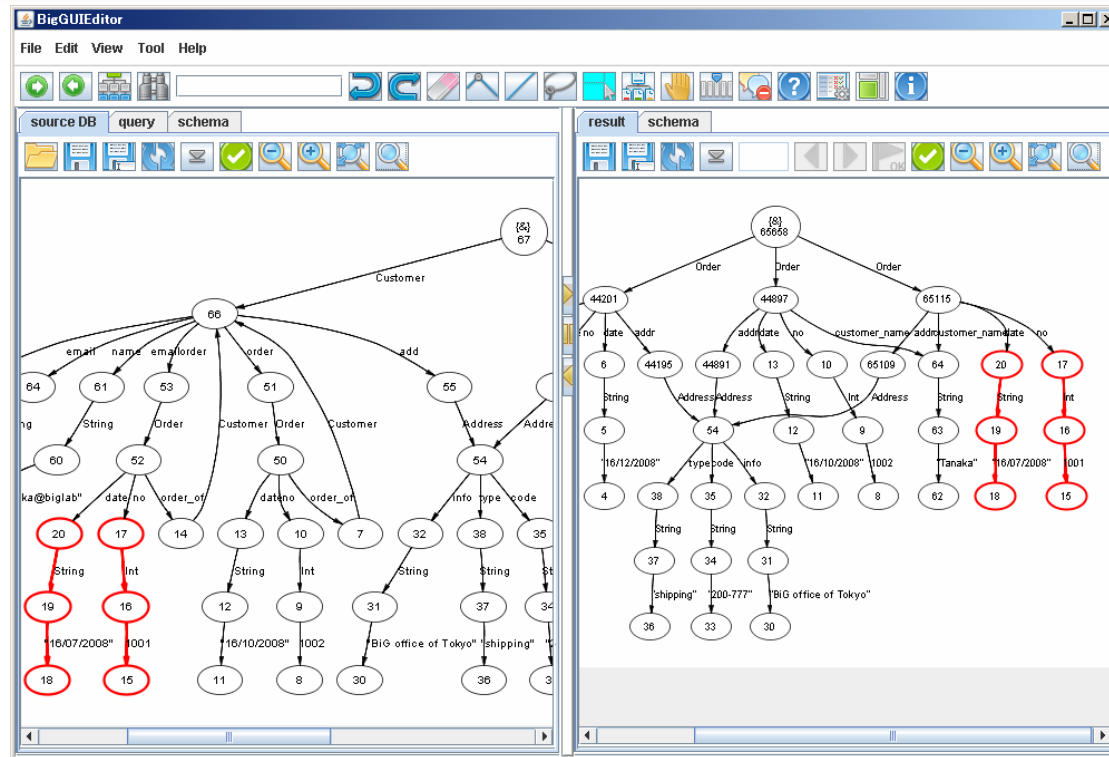


Compositional User Language

- SQL-like graph query language

```
select { tables : $table } where  
  $persistentClass in  
    (* select classes *)  
    (select $class where  
      { Association.(src|dest).Class : $class } in $db,  
      { is_persistent : { Boolean : true } } in $class),  
  $table in  
    (* replace Attribute *)  
    (replace attrs -> $g  
      by (select { Column : $a } where  
        { attrs.Attribute : $a } in $persistentClass)  
      in $persistentClass)
```

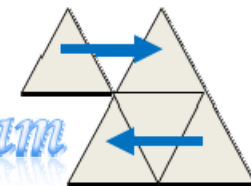
GUI of the GRoundTRam Implementation



- Fwd/bwd transformation by 1 click
- Invalid modification on the target is reported.
- Corresponding source and target nodes are highlighted



GRoundTram



Applications

Application to Software Engineering

Co-evolution of models and codes

Background: Codes generated from models are often modified by the programmers. Models are also updated.



Problem: Changes by the programmer are lost when the codes are regenerated from the updated model



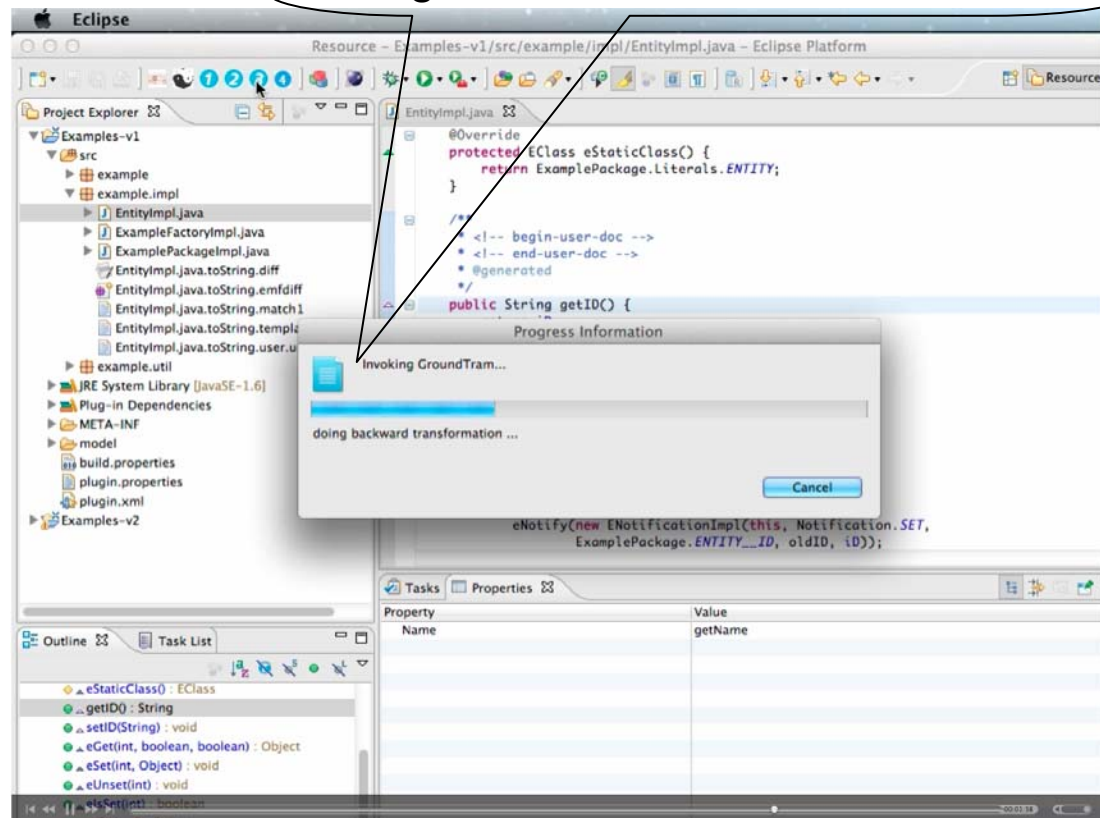
Proposal: 'Undo' of the programmer's change is represented by the forward transformation of BX. Model updates are propagated using backward transformation.



Contribution: Consistent evolution of models and codes



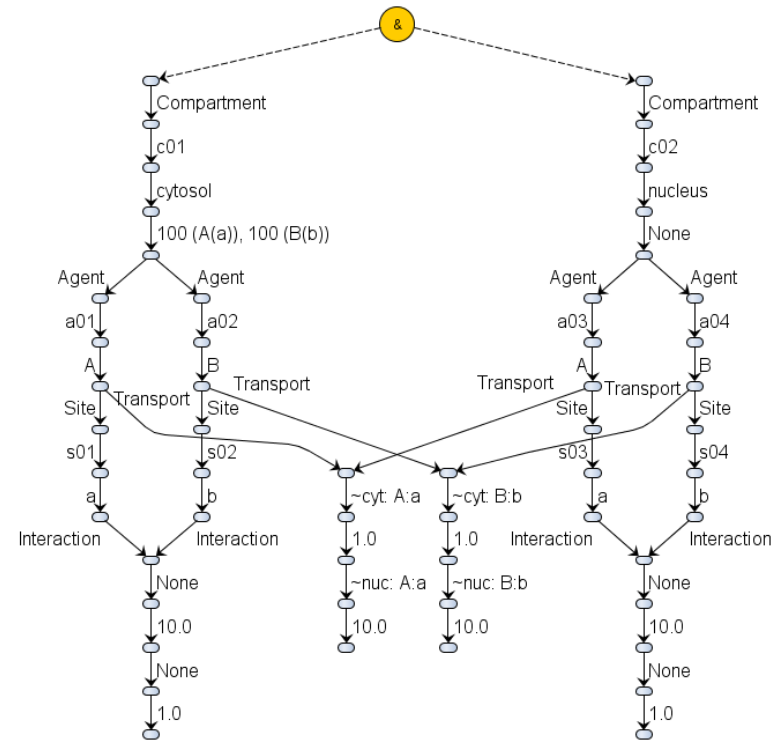
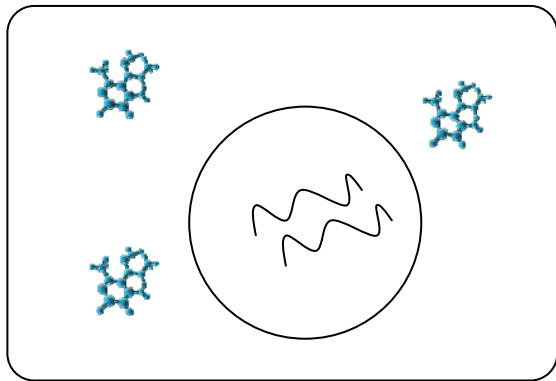
"Invoking GrondTram...
doing backward transformation ..."



Integrated
into Eclipse

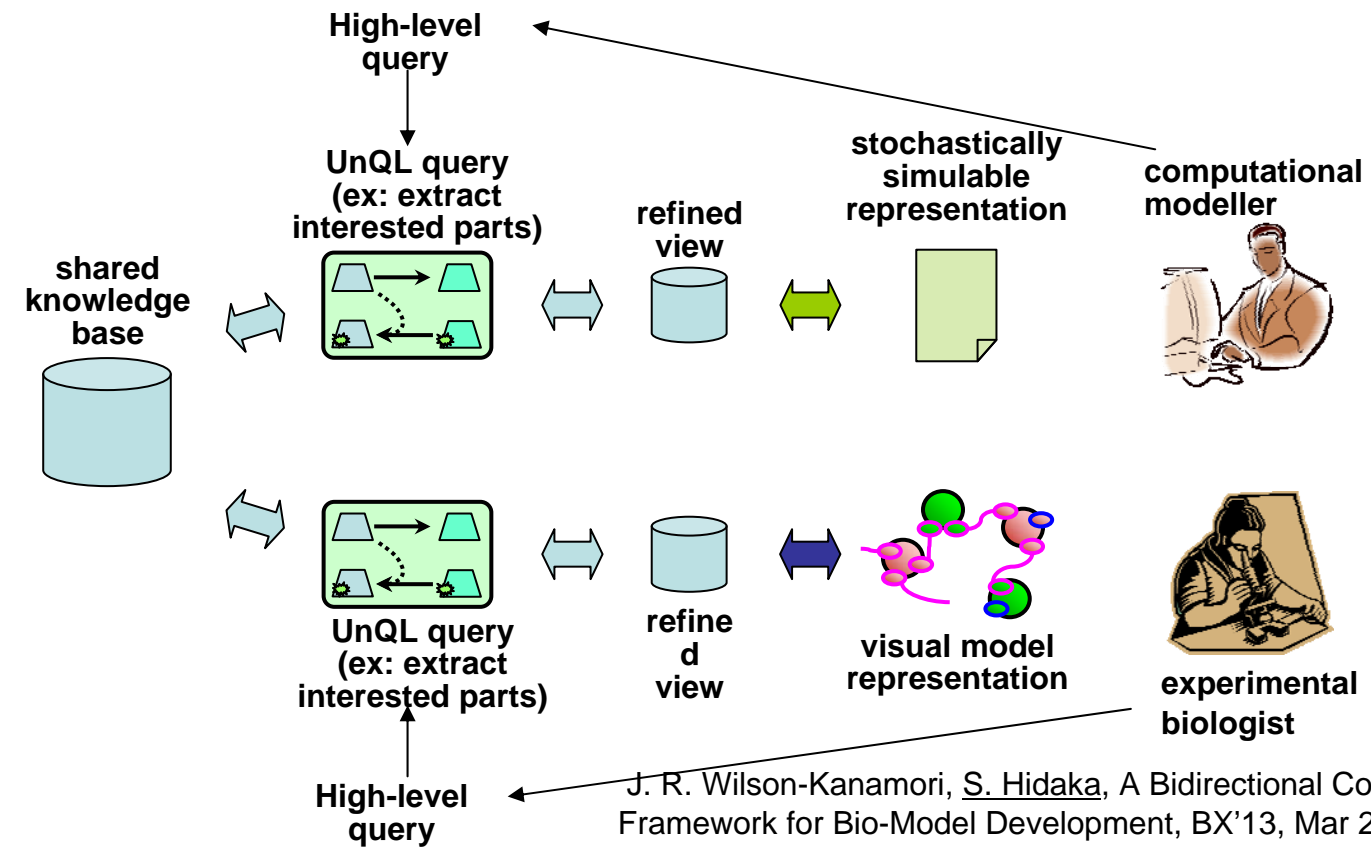
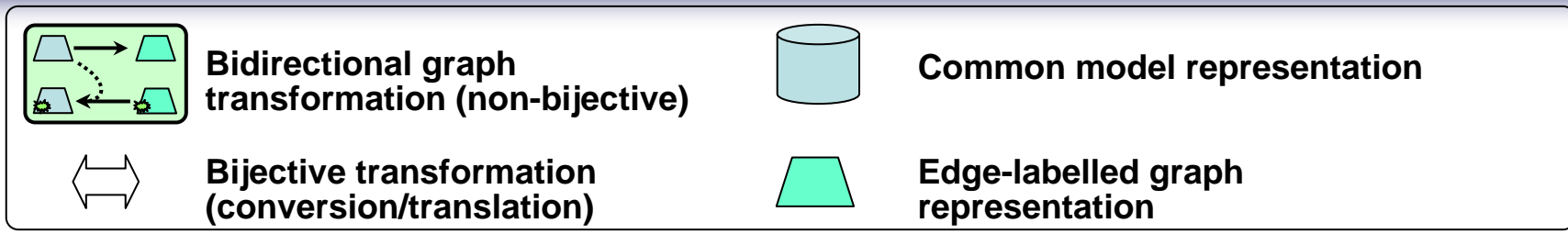
Y. Yu, Y. Lin, Z. Hu, S. Hidaka, H. Kato, L. Montrieux, Maintaining Invariant Traceability through Bidirectional Transformations, (ICSE 2012) pp.540-550

Collaborative development of Bio-models



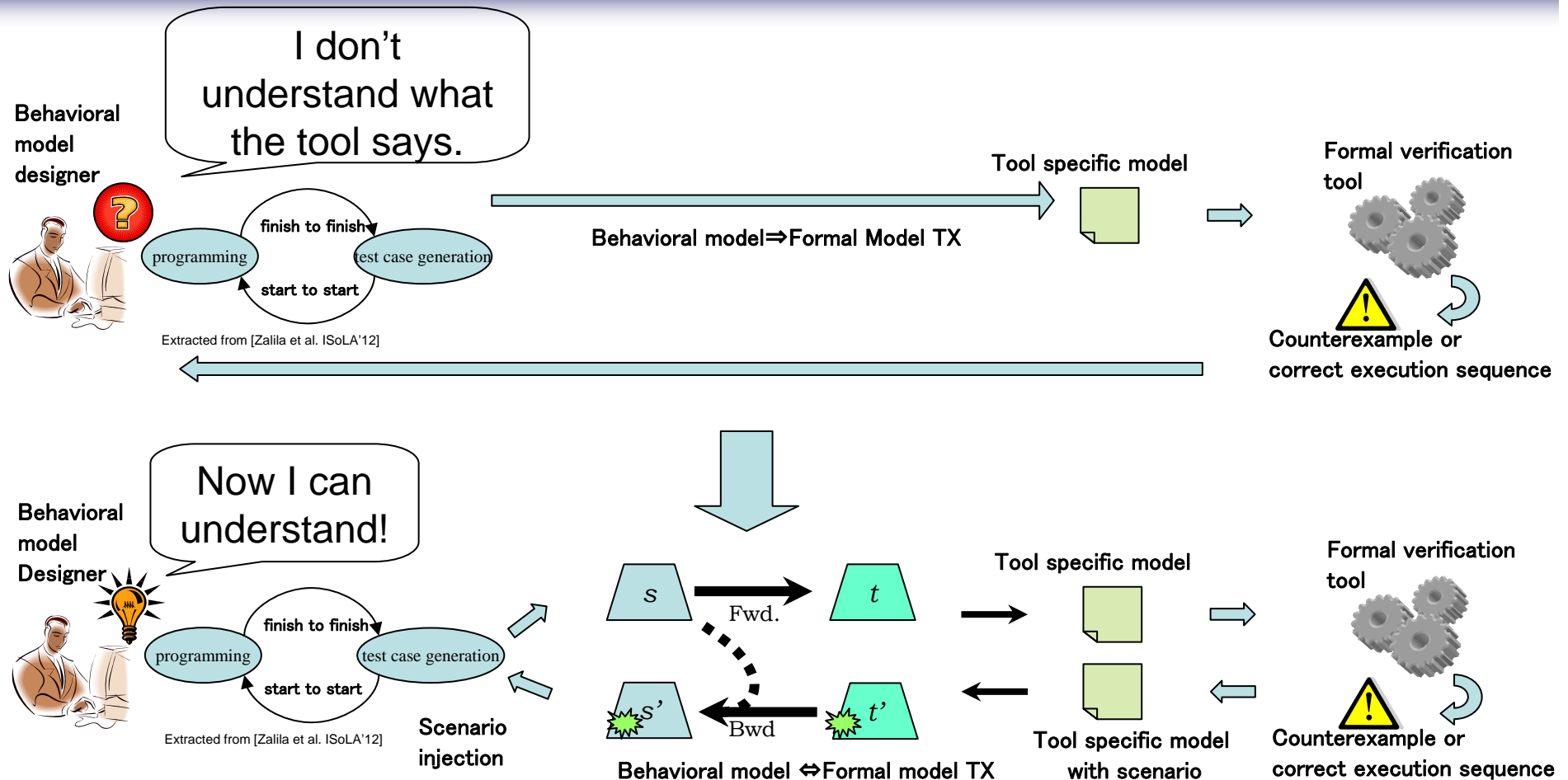
J. R. Wilson-Kanamori, S. Hidaka, A Bidirectional Collaboration Framework for Bio-Model Development, BX'13, Mar 2013

Collaborative development of Bio-models



J. R. Wilson-Kanamori, S. Hidaka, A Bidirectional Collaboration Framework for Bio-Model Development, BX'13, Mar 2013

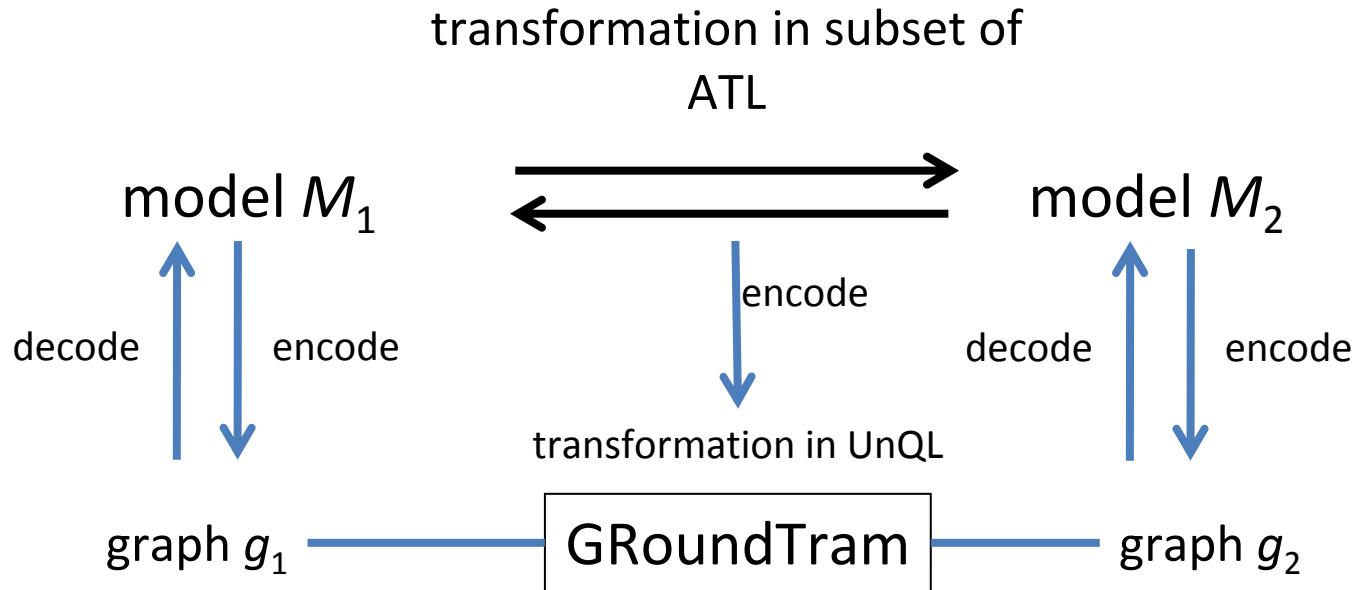
Feedback of verification results to designed activity



F. Zalila, S. Hidaka, Facilitating Verification Results Feedback on DSM Verification Context Using Bidirectional Model Transformation, submitted for publication, Oct 2013

Integration with Unidirectional Transformation

- BXing model transformation language ATL (INRIA, Shibaura Institute of Technology/NII)

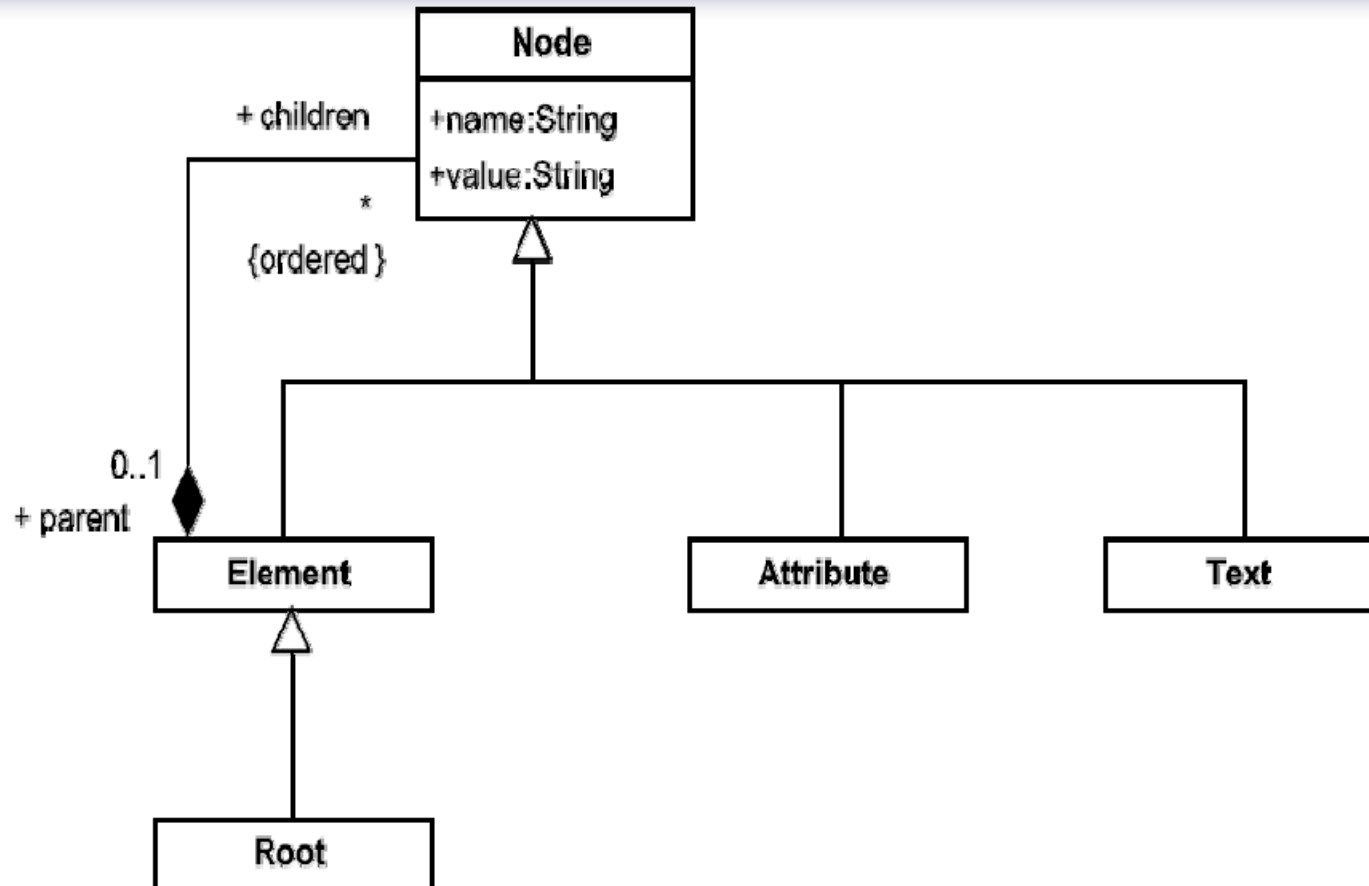


I. Sasano, Z. Hu, S. Hidaka, K. Inaba, H. Kato, K. Nakano, Toward bidirectionalization of ATL with GRoundTram, Proc. of the 4th International Conference on Model Transformation (ICMT 2011) LNCS 6707 pp.138-151 Jun 2011

Cf. BiQuery/iGRT by Zan Tao et al.

Challenges

Ordered branches and mixed



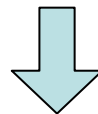
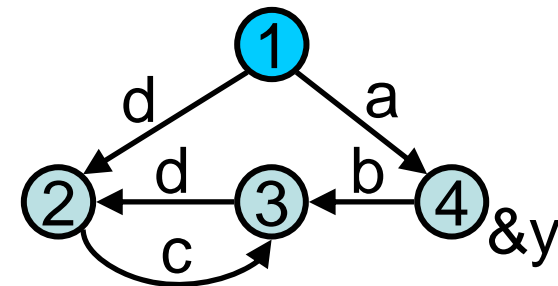
F. Jouault and J. Bezin. KM3: A DSL for metamodel specification. In Formal Methods for Open Object-Based Distributed Systems, pp.171–185. LNCS 4037, 2006.

From Unordered to Ordered Graphs

Unordered Graph

$$B : V \rightarrow \mathcal{P}(L_{\mathcal{E}} \times V + Y)$$

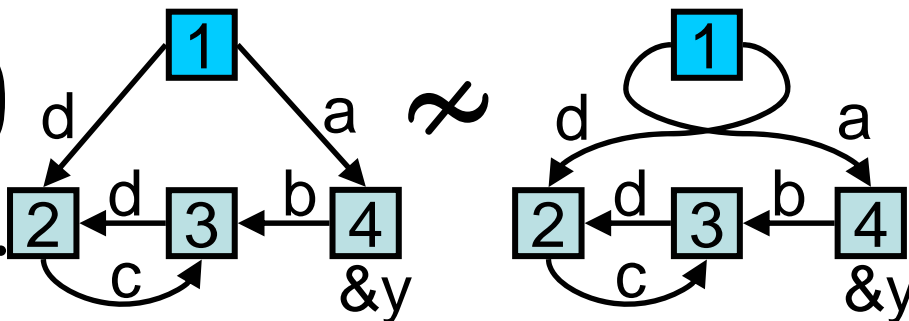
$$B(1) = \{E(a, 4), E(d, 2)\}, \dots$$



Ordered Graph

$$B : V \rightarrow List(L_{\mathcal{E}} \times V + Y)$$

$$B(1) = [E(a, 4), E(d, 2)], \dots$$



Ordered branches and mixed

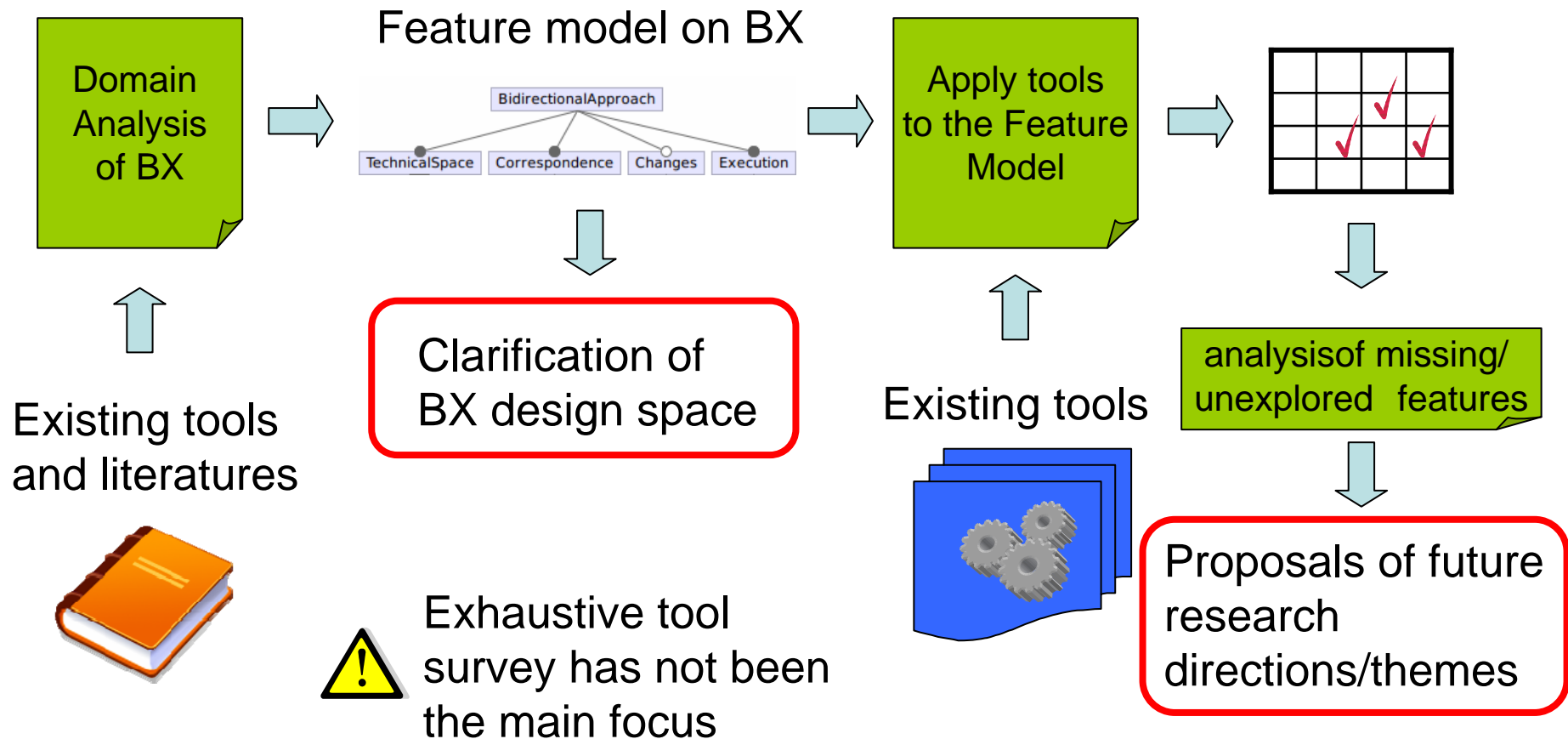
- Our preliminary works
 - Simple bidirectional transformations on ordered graphs
 - Unidirectional transformations with more expressive sibling transformations

Towards Bidirectional Transformations on Ordered Graphs, Soichiro Hidaka, Kazuyuki Asada, Hiroyuki Kato, Keisuke Nakano, Zhenjiang Hu, Technical Report, GRACE Center, National Institute of Informatics (GRACE-TR-2011-07), Dec. 2011

Soichiro Hidaka, Kazuyuki Asada, Zhenjiang Hu, Hiroyuki Kato, Keisuke Nakano, Structural Recursion for Querying Ordered Graphs, ICFP 2013, pp. 305--318, Sep 2013


Feature-Based Classification of Bidirectional Transformation Approaches

Joint work with Massimo Tisi, Jordi Cabot (Ecole des Mines de Nantes/INRIA), Zhenjiang Hu (NII)



Conclusion

- Framework of *compositional* and well-behaved BX of *graphs*
- Implemented *BX platform for graphs*
GRoundTram
 - Used by research groups beside us
- *Applied to model-code co-evolution, synthetic biology, and other research projects*
- Research challenges include BX on *ordered graphs and mixed*



Thank you very much for your kind attentions.

More information can be found at
<http://research.nii.ac.jp/~hidaka/> and
<http://www.biglab.org/>

Appendix

Publications - *Foundations*

- [ICFP'10]** S. Hidaka, Z. Hu, K. Inaba, H. Kato, K. Matsuda, K. Nakano, Bidirectionalizing Graph Transformations, 15th ACM SIGPLAN International Conference on Functional Programming, pp.205-216 Sep 2010
- [PPDP'11]** K. Inaba, S. Hidaka, Z. Hu, H. Kato, K. Nakano, Graph-Transformation Verification using Monadic Second-Order Logic, 13th International ACM SIGPLAN Symposium on Principles and Practice of Declarative Programming, pp.17-28 Jul 2011
- [LOPSTR] S. Hidaka, Z. Hu, K. Inaba, H. Kato, K. Matsuda, K. Nakano and I. Sasano, Marker-directed optimization of UnCAL graph transformations, 21st International Symposium on Logic-Based Program Synthesis and Transformation (LOPSTR 2011) LNCS vol. 7225, pp.123-138 Jul 2011
- [ICFP'13]** S. Hidaka, K. Asada, Z. Hu, H. Kato, K. Nakano, Structural Recursion for Querying Ordered Graphs, 18th ACM SIGPLAN International Conference on Functional Programming, to appear, Sep 2013
- [PPDP'13]** K. Asada, S. Hidaka, H. Kato, Z. Hu, K. Nakano, A Parameterized Graph Transformation Calculus for Finite Graphs with Monadic Branches, 15th International Symposium on Principles and Practice of Declarative Programming, to appear, Sep 2013
- [JSSST.J] K. Nakano, S. Hidaka, Z. Hu, K. Inaba, H. Kato, View Updatability Checking with Simulation-based Graph Schema,, JSSST Computer Software 29(2) pp.174-192 Apr 2012

Publications - *Framework*

- [PI]** S. Hidaka, Z. Hu, K. Inaba, H. Kato, K. Nakano: GRoundTram: An Integrated Framework for Developing Well-Behaved Bidirectional Model Transformations, Progress in Informatics, No. 10, Apr 2013
- [ASE]** S. Hidaka, Z. Hu, K. Inaba, H. Kato and K. Nakano, GRoundTram: An Integrated Framework for Developing Well-Behaved Bidirectional Model Transformations (short paper), 26th IEEE/ACM International Conference on Automated Software Engineering (ASE 2011) pp.480-483 Nov 2011
- [ICSE NIER]** S. Hidaka, Z. Hu, H. Kato, K. Nakano, A compositional approach to bidirectional model transformation, 31st International Conference on Software Engineering Companion Volume pp.235-238 May 2009
- [SAC] S. Hidaka, Z. Hu, H. Kato, K. Nakano, Towards a Compositional Approach to Model Transformation for Software Development, ACM symposium on Applied Computing pp.468-475 Mar 2009

Publications - *Applications*

- [ICSE]** Y. Yu, Y. Lin, Z. Hu, S. Hidaka, H. Kato, L. Montrieux, Maintaining Invariant Traceability through Bidirectional Transformations, 34th International Conference on Software Engineering (ICSE 2012) pp.540-550 Jun 2012
- [BX] J. Wilson-Kanamori and S. Hidaka, A Bidirectional Collaboration Framework for Bio-Model Development, Second International Workshop on Bidirectional Transformations (BX 2013), Mar 2013, Rome, Italy, colocated with ETAPS 2013
- [ICMT] I. Sasano, Z. Hu, S. Hidaka, K. Inaba, H. Kato, K. Nakano, Toward bidirectionalization of ATL with GRoundTram, Proc. of the 4th International Conference on Model Transformation (ICMT 2011) LNCS 6707 pp.138-151 Jun 2011