Model Management

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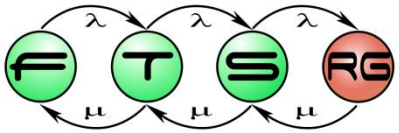
Mostly Contributed by

M. Brambilla, J. Cabot and M. Wimmer

Model Driven Software Development
Lecture 12



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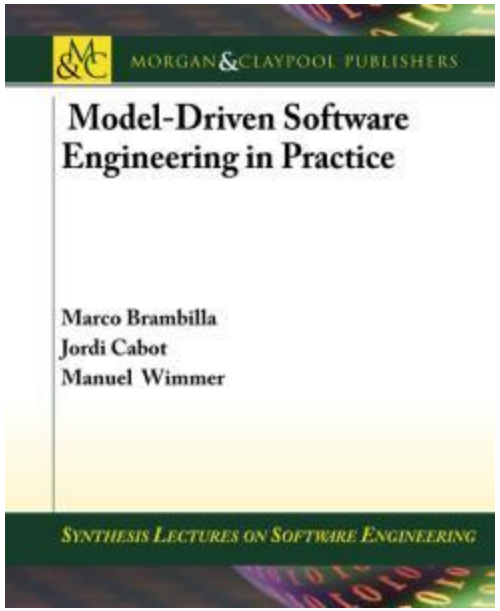
Chapter #10

MANAGING MODELS

Teaching material for the book
Model-Driven Software Engineering in Practice
by Marco Brambilla, Jordi Cabot, Manuel Wimmer.
Morgan & Claypool, USA, 2012.

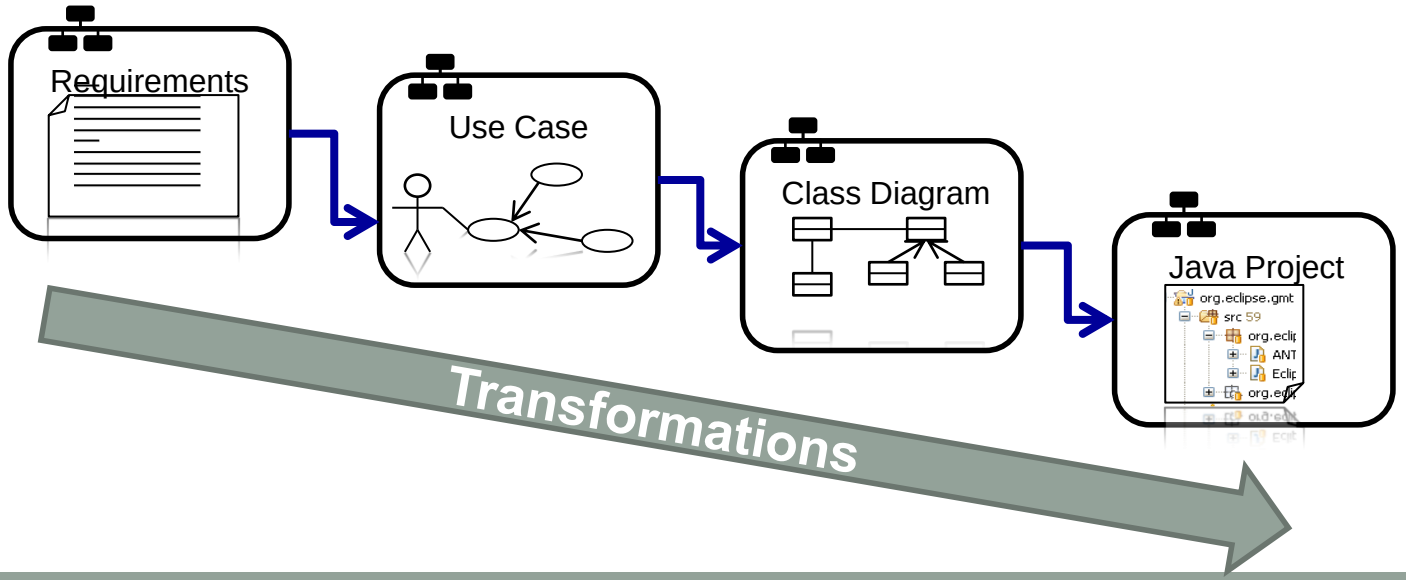


Motivation

Why Model managing?

- In MDE *everything is a model* but as important as that, *no model is an island*

- All modeling artefacts in a MDE project are interrelated. These relationships must be properly managed during the project lifecycle



Content

- Model interchange
- Model Persistence
- Model Comparison
- Model Versioning
- Model Co-Evolution
- Global Model Management
- Model Quality
- Collaborative modeling

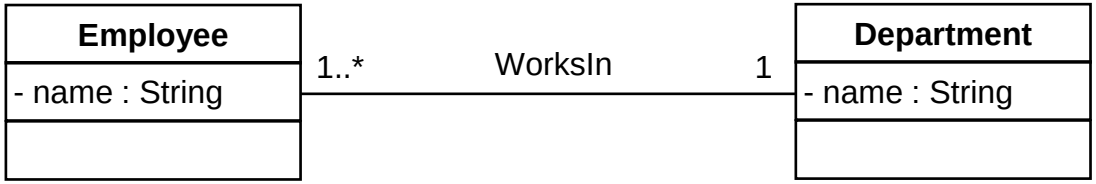
MODEL INTERCHANGE

Model Once Open Everywhere

- There's a clear need to be able to exchange models among different modeling tools
  - In a perfect world, you'd be able to choose ToolA for specifying model, ToolB to check its quality, ToolC to execute it….
- We are still far away from this goal
- Solution attempt: XMI (XML Metadata Interchange), a standard adopted by OMG for serializing and exchanging UML and MOF models
- But each tools seems to understand the standard in a different manner

XMI example

(simplified and partial versions of the actual XMI files)



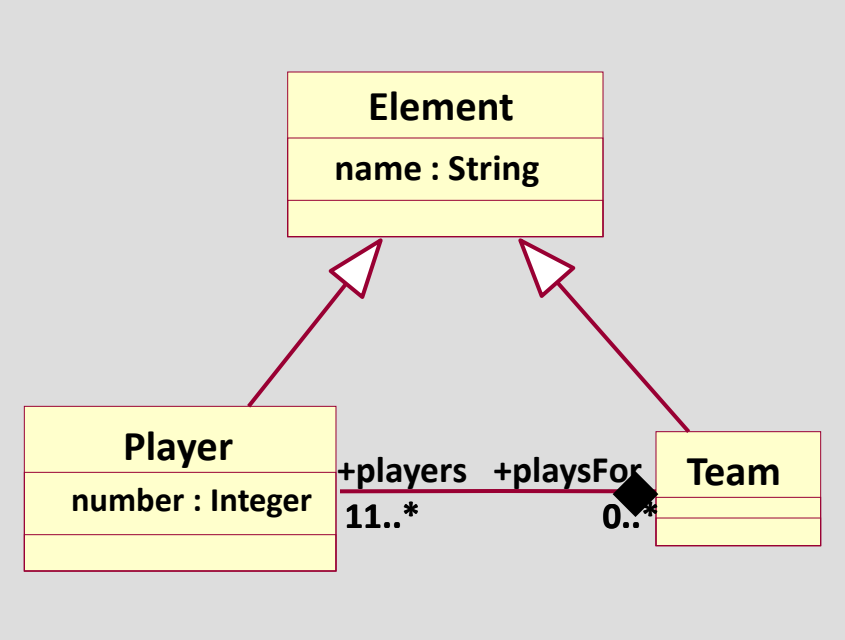

```
<packagedElement xmi : type="uml : Clas s " xmi : id=" c001 "
name="Employee">
<ownedAt t r ibute xmi : id=" a001 " name="name"/>
</packagedElement>
<packagedElement xmi : type="uml : Pr imi t iveType " xmi : id="
t001 " name="St r ing "/>
<packagedElement xmi : type="uml : Clas s " xmi : id=" c002 "
name="Department">
<ownedAt t r ibute xmi : id=" a002 " name="name" type=" t001 "/>
</packagedElement>
<packagedElement xmi : type="uml : As s o c i a t i on " xmi : id="
as001 " name="WorksIn"
memberEnd=" e001 e002">
<ownedEnd xmi : id=" e001 " type=" c002 " a s s o c i a t i o n="
as001"/>
<ownedEnd xmi : id=" e002 " name="" type=" c001 " a s s o c i a t i
o n=" as001">
<upperValue xmi : type="uml : Li t e r a lUnl imi t edNa tur a l " xmi :
id="un001" value=""/>
</ownedEnd>
</packagedElement>
```

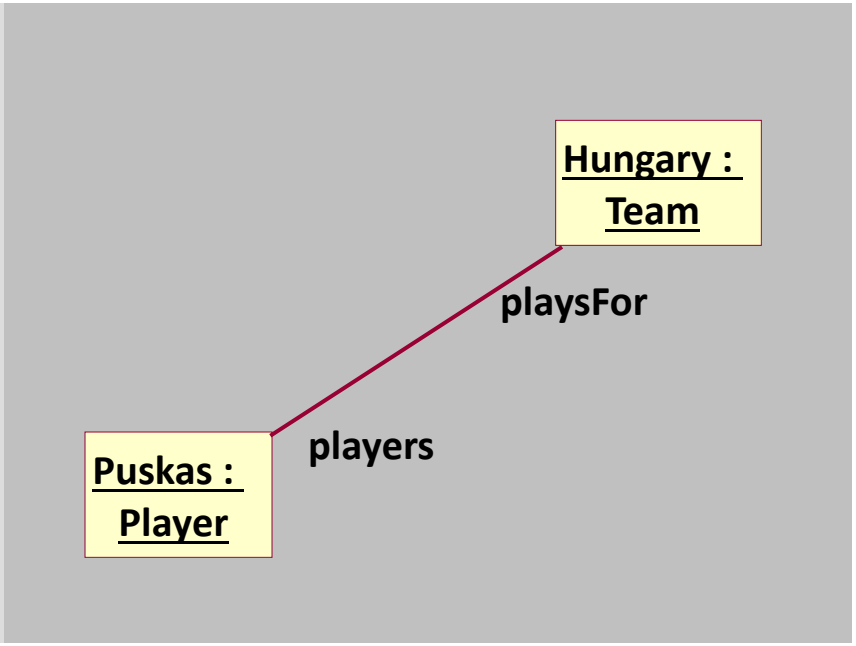
ECLIPSE

```
<UML: Clas s xmi . id = ' c001 '
name = 'Employee ' v i s i b i l i t y = ' publ i c ' i s S p e
c i f i c a t i o n = ' f a l s e ' isRoot = ' f a l s e '
i sLe a f = ' f a l s e ' isAbs t r a c t = ' f a l s e ' i sAc t i v
e = ' f a l s e '>
<UML: C l a s s i f i e r . f e a tur e>
<UML: At t r ibut e xmi . id = ' a001 '
name = 'name ' v i s i b i l i t y = ' publ i c ' i s S p e c i f i
c a t i o n = ' f a l s e '
ownerScope = ' ins tanc e ' c h a n g e a b i l i t y = '
changeable ' targe tScope = ' ins tanc e '>
<UML: St ruc tur a lFe a tur e . mu l t i p l i c i t y >
<UML: Mu l t i p l i c i t y xmi . id = ' m001'>
<UML: Mu l t i p l i c i t y . range>
<UML: Mul t ipl i c i tyRang e xmi . id = ' mr001 '
lower = '1 ' upper = '1 '/>
</UML: Mu l t i p l i c i t y . range>
</UML: Mu l t i p l i c i t y>
</UML: St ruc tur a lFe a tur e . mu l t i p l i c i t y >
</UML: Clas s>
```

ArgoUML

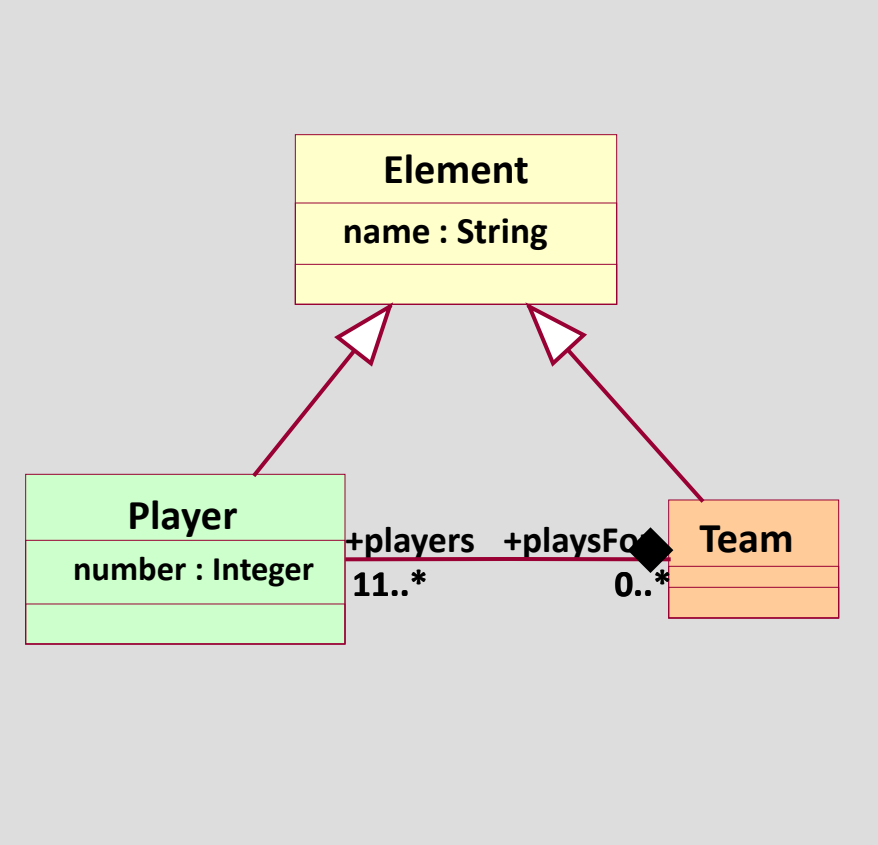
Example: metamodel and model





- Team metamodel
- Team model

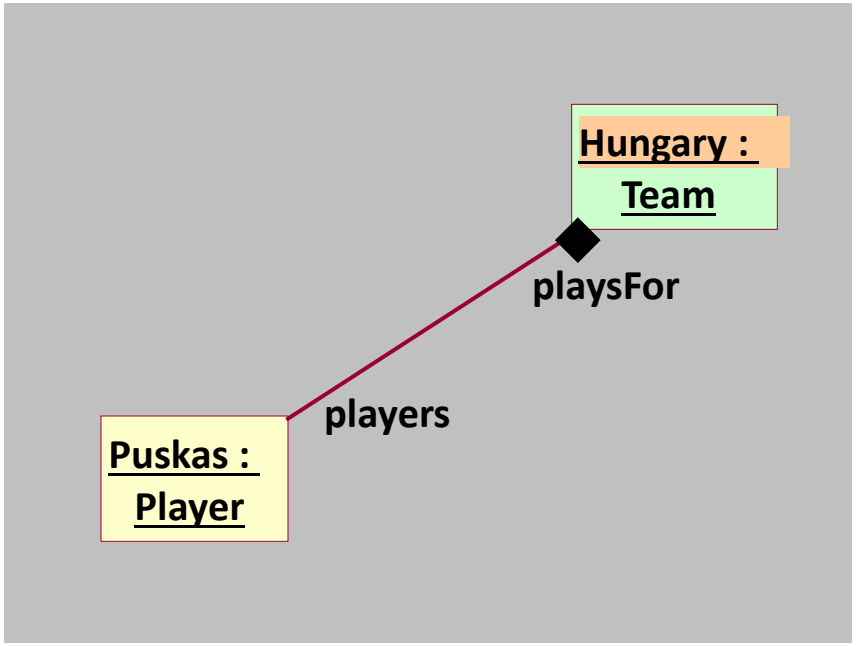
Example: XMI 1.0 DTD




```
<!ELEMENT Team.players (Player)*>
<!ELEMENT Player.playsFor (Team)*>

<!ELEMENT Element.name
          (#PCDATA|XMI.reference)* >

<!ELEMENT Team (Element.name,
          XMI.extension*,
          Team.player) >

<!ATTLIST Team
          %XMI.element.att
          %XMI.link.att >

<!ELEMENT Player (Element.name,
          XMI.extension*,
          Team.playsFor) >

<!ATTLIST Player
          %XMI.element.att
          %XMI.link.att >
```

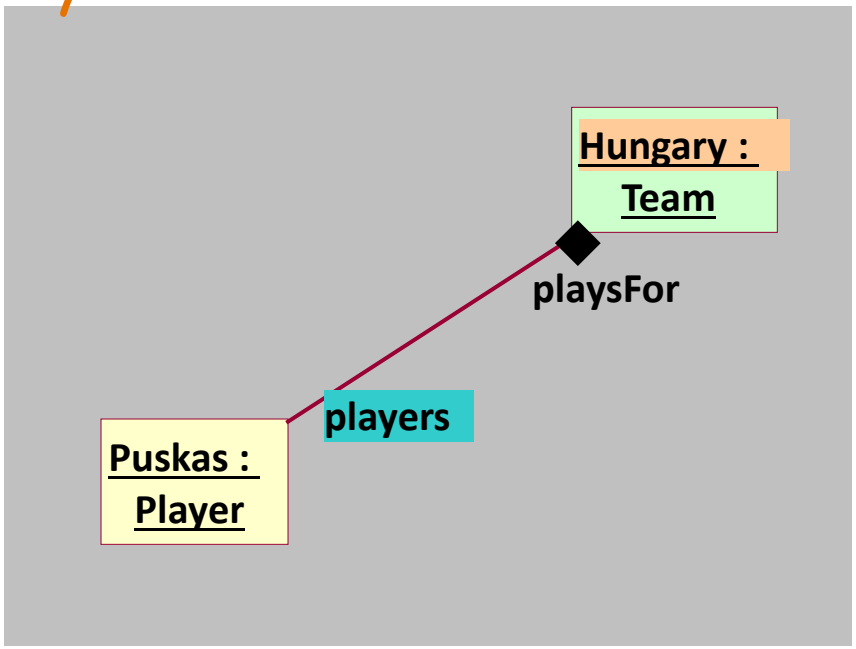
Example: XMI 1.0 document

```
<Team id='t1'>
 <Element.name>
     Hungary
 </Element.name>
 <Team.players>
   <Player id='p1'>
     <Element.name> Puskas
     </Element.name>
     <Player.number> 10
     </Player.number>
     <Player.playsFor
          xmi.idref='t1'/>
     </Player>
 </Team.players>
</Team>
```



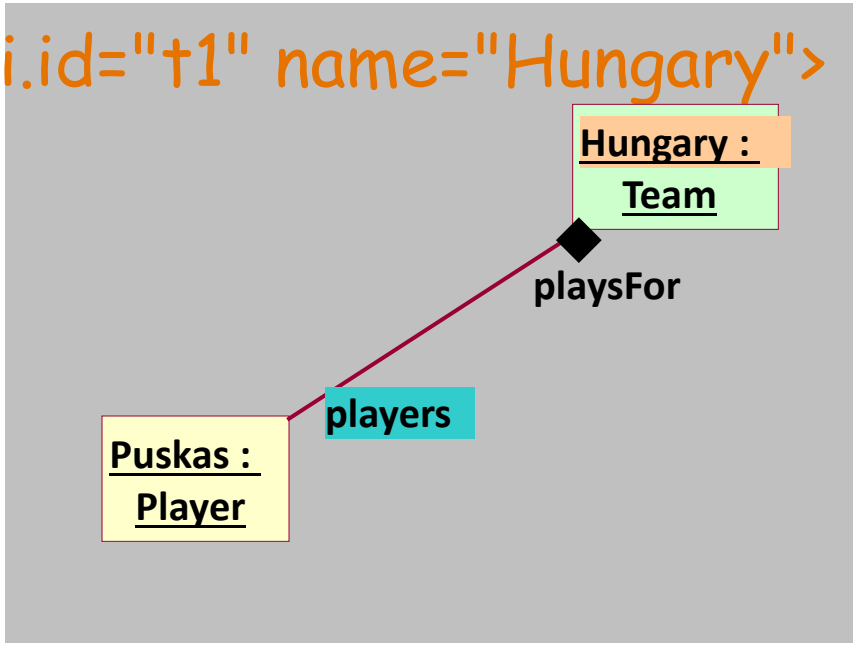
Example: XMI 1.1 document

```
<FB:Team id='t1' name='Hungary'>
  <FB:Team.players>
    <FB:Player id='p1'
      name='Puskas'
      number='10'
      playsFor='t1'/>
    </FB:Player>
  </FB:Team.players>
</FB:Team>
```



Example: XMI 2.0 document

```
<fb:Model xmlns:fb="…„ xmlns:xmi="…"
 <teams xmi.type="Team" xmi.id="t1" name="Hungary">
  <players xmi.id='p1'
    name='Puskas'
    number='10'
    playsFor='t1'/>
 </teams>
</fb:Model>
```



Model Once Open Everywhere

Recent advances

- Model Interchange Working Group3 (MIWG) to enable the assessment of model interchange capability of modeling tools by comparing the vendor XMI exports for a test suite

- New The new Diagram Definition standard will allow to exchange not only the modeling content but also the graphical layout of the models

MODEL PERSISTENCE

Model Persistence

- Typically models are serialized in plain files, following the previous XMI format or any other proprietary XML format

- Doesn’t work well with large models. Scalability issues
  - Loading the whole model in memory may not be an option
  - Random access strategies plus lazy loading (i.e. loading on demand) are needed

Model Persistence

Alternatives

- CDO (Connected Data Objects) Model Repository
  - Run-time persistence framework optimized for scalable query and transactional support for large object graphs.
  - Back-ends: object, NoSQL, and relational databases.
  - For relational databases, CDO relies on Teneo6, a Model-Relational mapping and runtime database persistence

- Pure NoSQL solutions: Morsa and MongoEMF. Both use MongoDB as backend.

- Newer alternatives aim at using the Cloud as model storage solution

MODEL COMPARISON

Model Comparison

- Comparing two models is a key operation in many model-management operations like model versioning
- Goal of model comparison is to identify the set of differences between two models
- These differences are usually represented as a model themselves, called a *difference model*

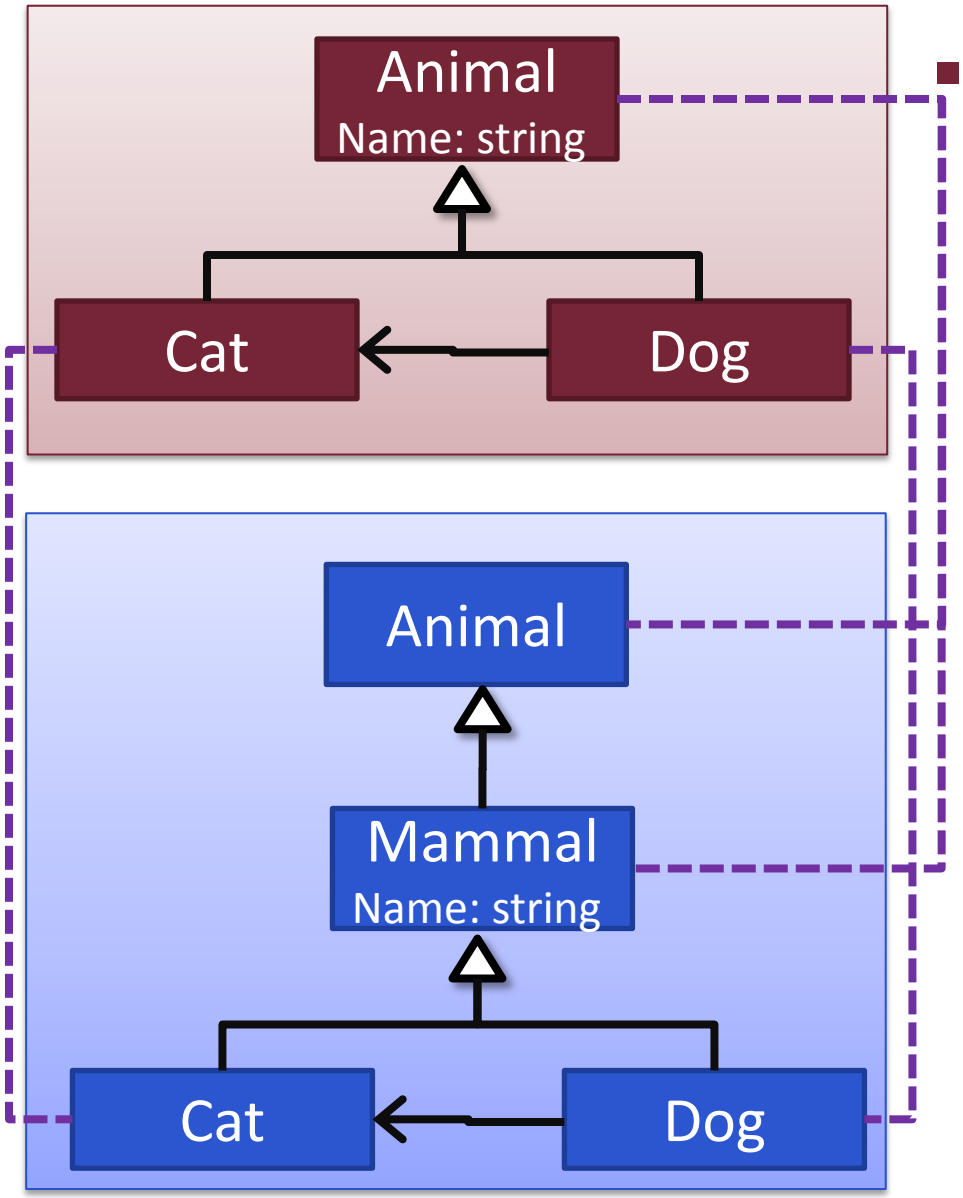
Model Comparison: Model matching

Phase 1 of a model comparison process

- Identify the common elements in the two models
- How do we establish which elements have the same identity?
  - Static identity: explicit id's annotating the elements
  - Signture identity: Identity based on the model element features (i.e. name, contained elements,…)
- Identity can be a probabilistic function (similarity matching)
- Works better if users redefine the concept of matching for specific DSLs (so that their specific semantic can be taken into account)

Model comparison = Graph similarity problem

Example: Model Comparison



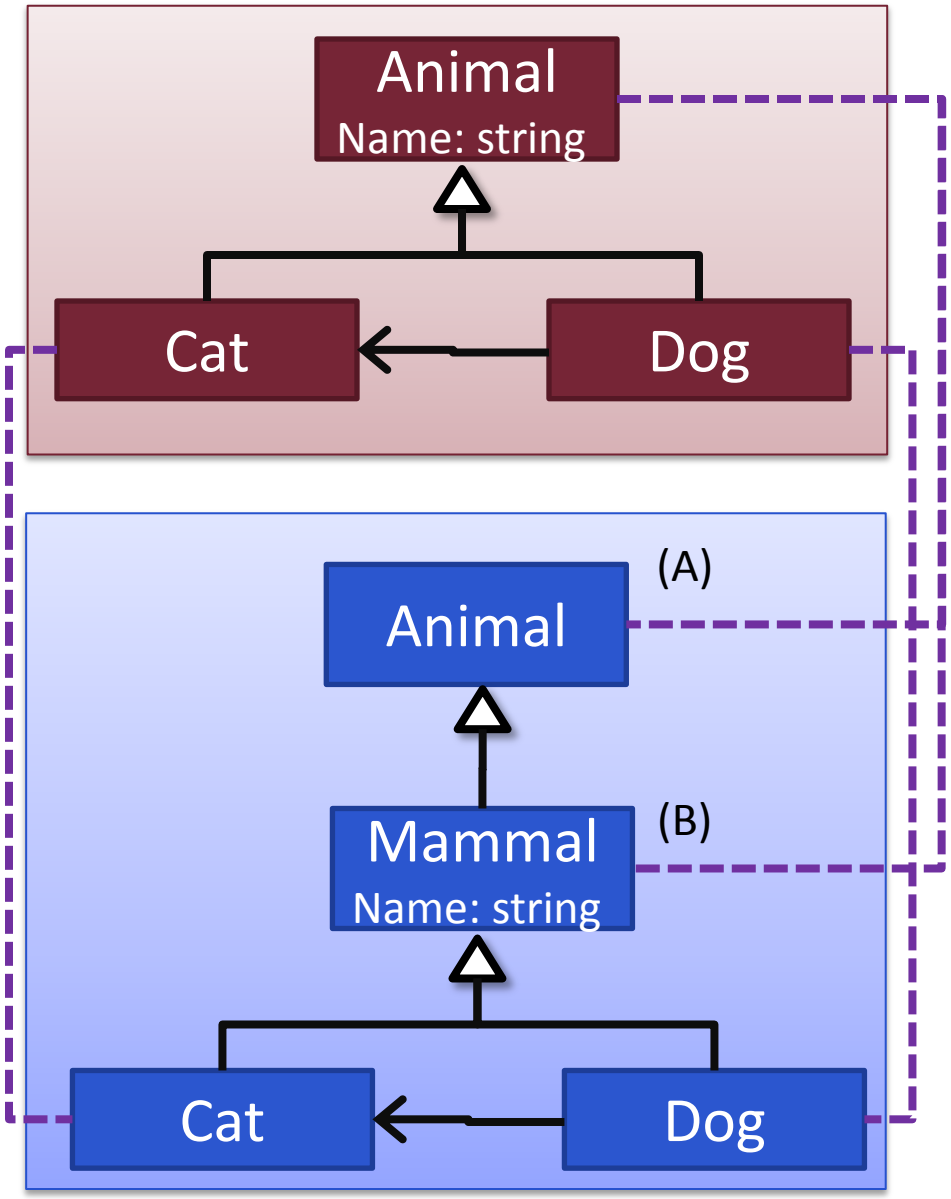
- What is the best matching?

Model Comparison: Model differencing

Phase 2 of a model comparison process

- Matched elements are searched for differences
- A difference corresponds to an atomic add / delete / update / move operation executed on one of the elements
- These differences are collected and stored in the difference model

Example: Model Difference



- What is the difference?
- Matching (A)
  - Del Gen: Cat → Animal
  - Del Gen: Dog → Animal
  - Add Cls: Mammal
  - Add Gen: Mammal → Animal
  - Add Gen: Cat → Mammal
  - Add Gen: Dog → Mammal
  - Move Att:
    Name: Animal → Mammal
- Matching (B)
  - Rename: Animal → Mammal
  - Add Cls: Animal
  - Add Gen: Mammal → Animal

Model Comparison tools

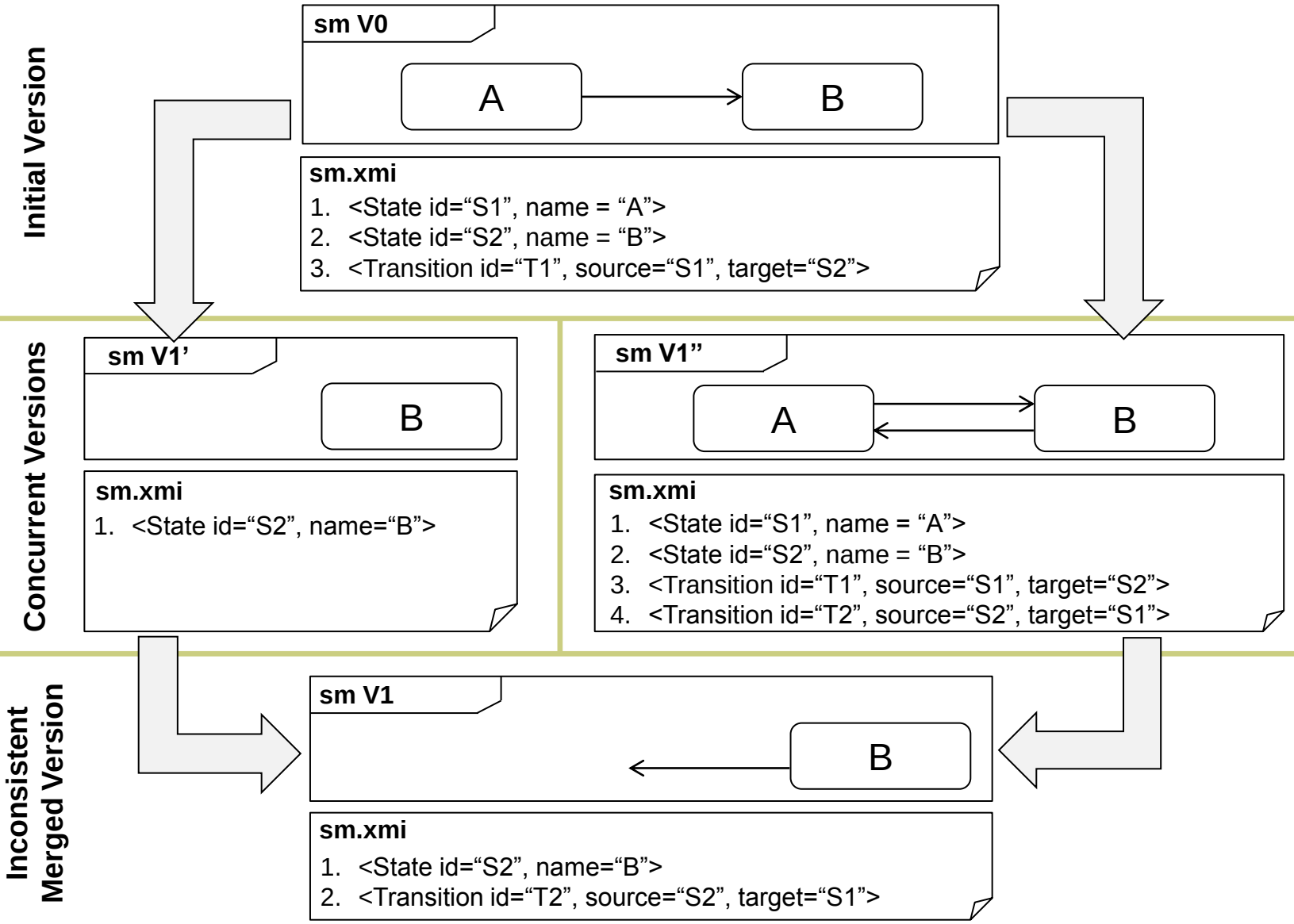
- EMF compare:
  - Most popular one
  - Generic comparison facilities for any kind of EMF model
  - Differences can be exported as a model patch
- SiDiff:
  - Mainly similarity-based matching
  - Adaptable to any graph-like model
- Epsilon Comparison Language:
  - Includes a DSL to enable the implementation of specialized higher-level changes
  - With it, high-level changes such as refactorings may be also detected

MODEL VERSIONING

Model Versioning

- Programmers can’t live without version control systems like SVN or GIT. Designers need the same for models
- VCSs help detect, manage and resolve conflicts arising when merging models
- Current VCSs are text-based. Using them to merge models may result in inconsistent results due to the graph-based semantics of models.

Model Versioning



Model Versioning

Tools

- Dedicated model-based VCSs are needed

- Some first attempts:
  - **EMFStore**: Official Eclipse project for model repositories. Follows the same SVN interaction protocol at the model-level
  - **AMOR** (Adaptable model versioning): Several conflict detection and resolution strategies possible. Visual merge process by means of annotations of conflicts directly on the graphical view of the models
  - CDO includes branching support for models
  - Epsilon Merging Language is a rule-based language for merging (heterogeneous) models

- Versioning of the graphical layout is still an open question (should moving a class two inches to the right count as a change?)

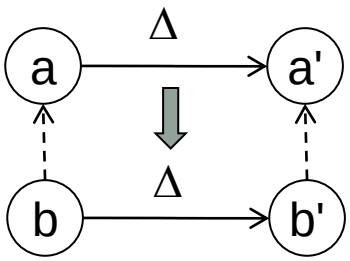
MODEL CO-EVOLUTION

Model Co-Evolution

Tools

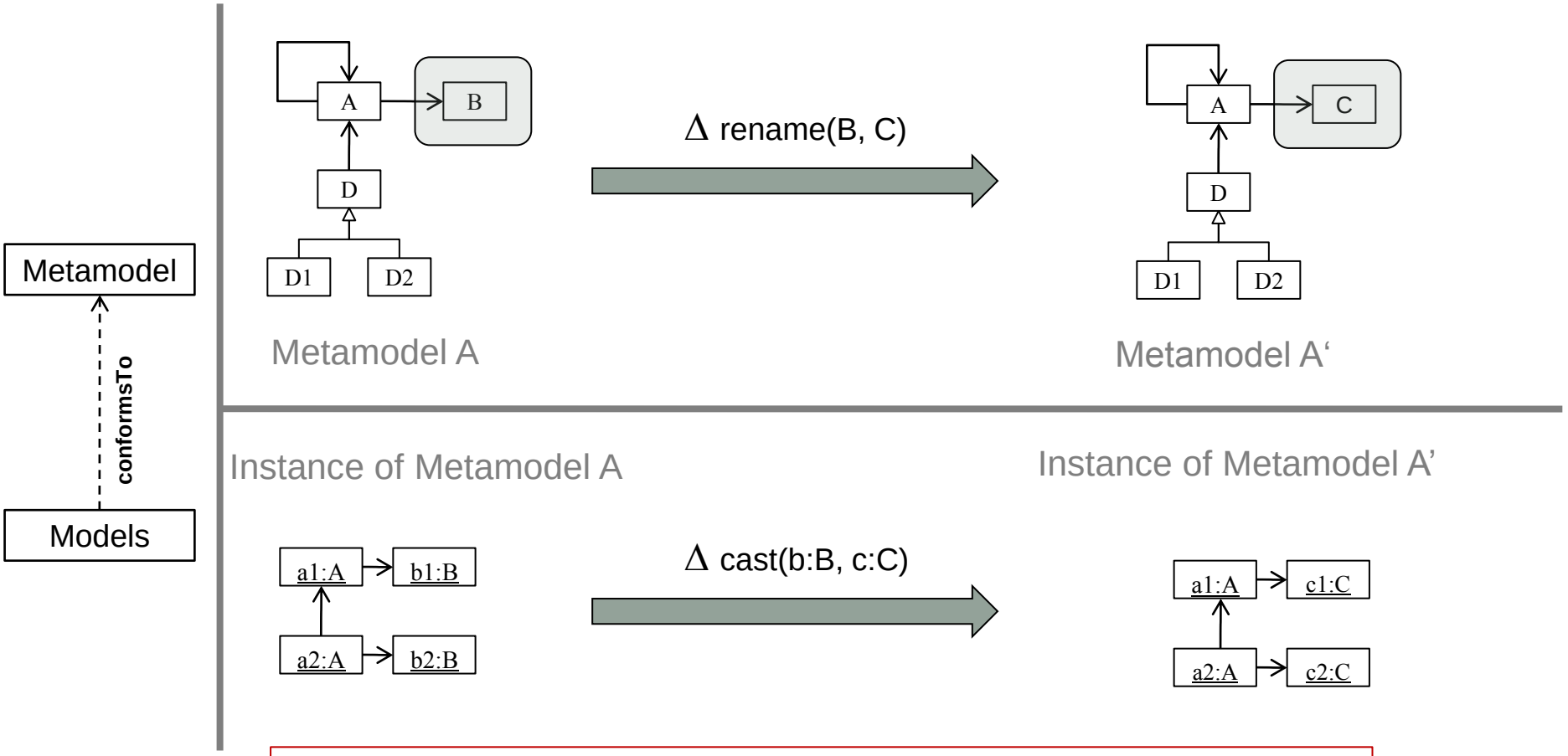
- Model versioning keeps track of the changes in a single modeling artefact but each change may affect many other related artefacts

- Co-Evolution in MDE
  - Co-evolution is the **change** of a model **triggered** by the **change** of a **related** model
  - Current View
    - Relationship: r(a,b)
    - a $\rightarrow$ a'
    - b $\rightarrow$ b' | r(a',b')
    - **Challenge: Relationship Reconciliation**
  - Current research focus is on one-to-one relationships:
    - Model / Metamodel evolution
    - Metamodel / Transformation evolution
    - …



Model / Meta-model Co-evolution

Example



Assumption: Renamed Class does not represent a new modeling concept!

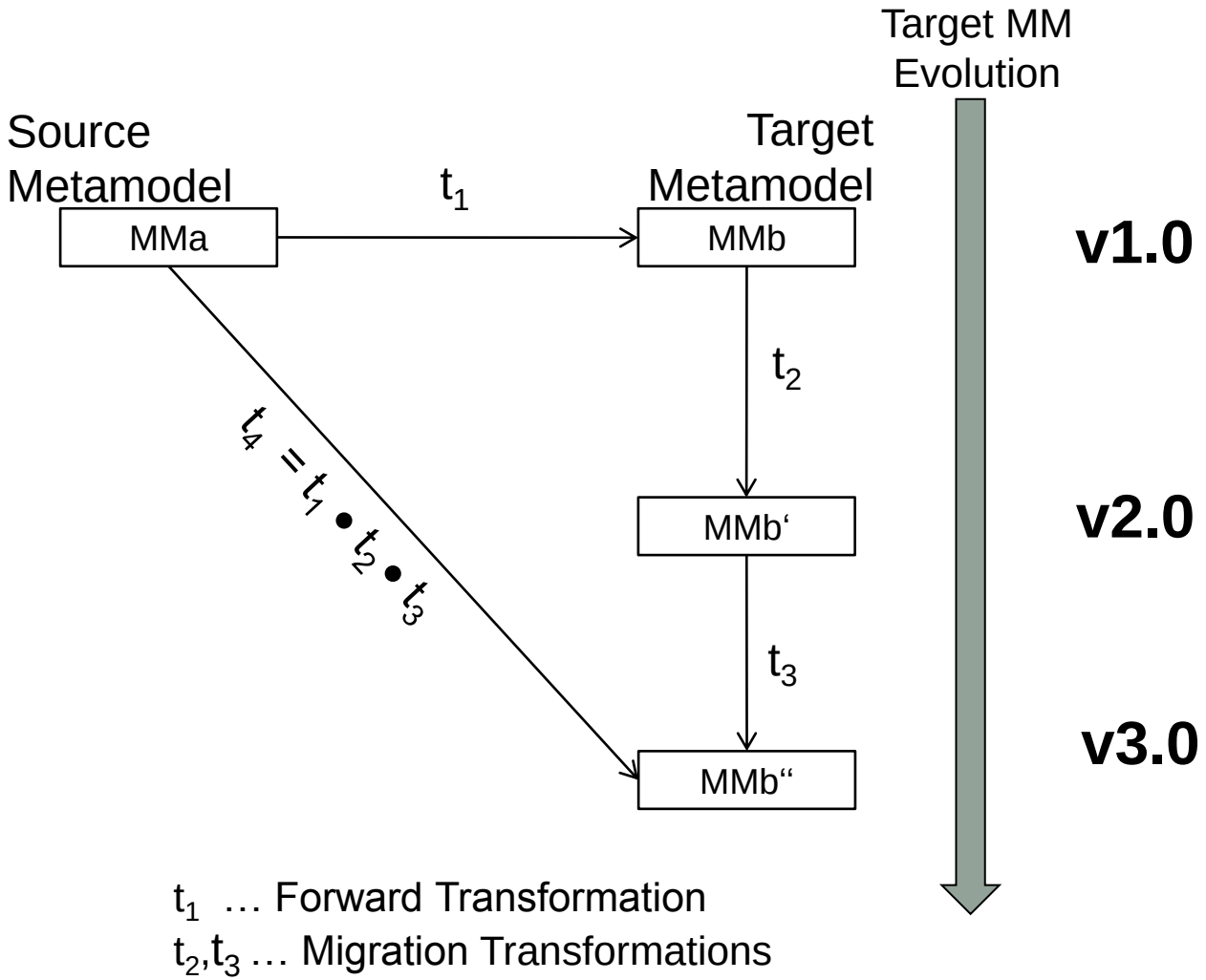
Model / Meta-model Co-Evoltion

Process

- Classification of meta-model changes
  - Non-breaking operations: No need to migrate the models
  - Breaking and resolvable: Automatic migration of existing models is possible
  - Breaking and unresolvable: User intervention is necessary
- Tools like Edapt and Epsilon Flock can derive a migration transformation to adapt current models to the new metamodel structure when possible

Meta-model / Transformation co-evolution

Other co-evolution scenarios



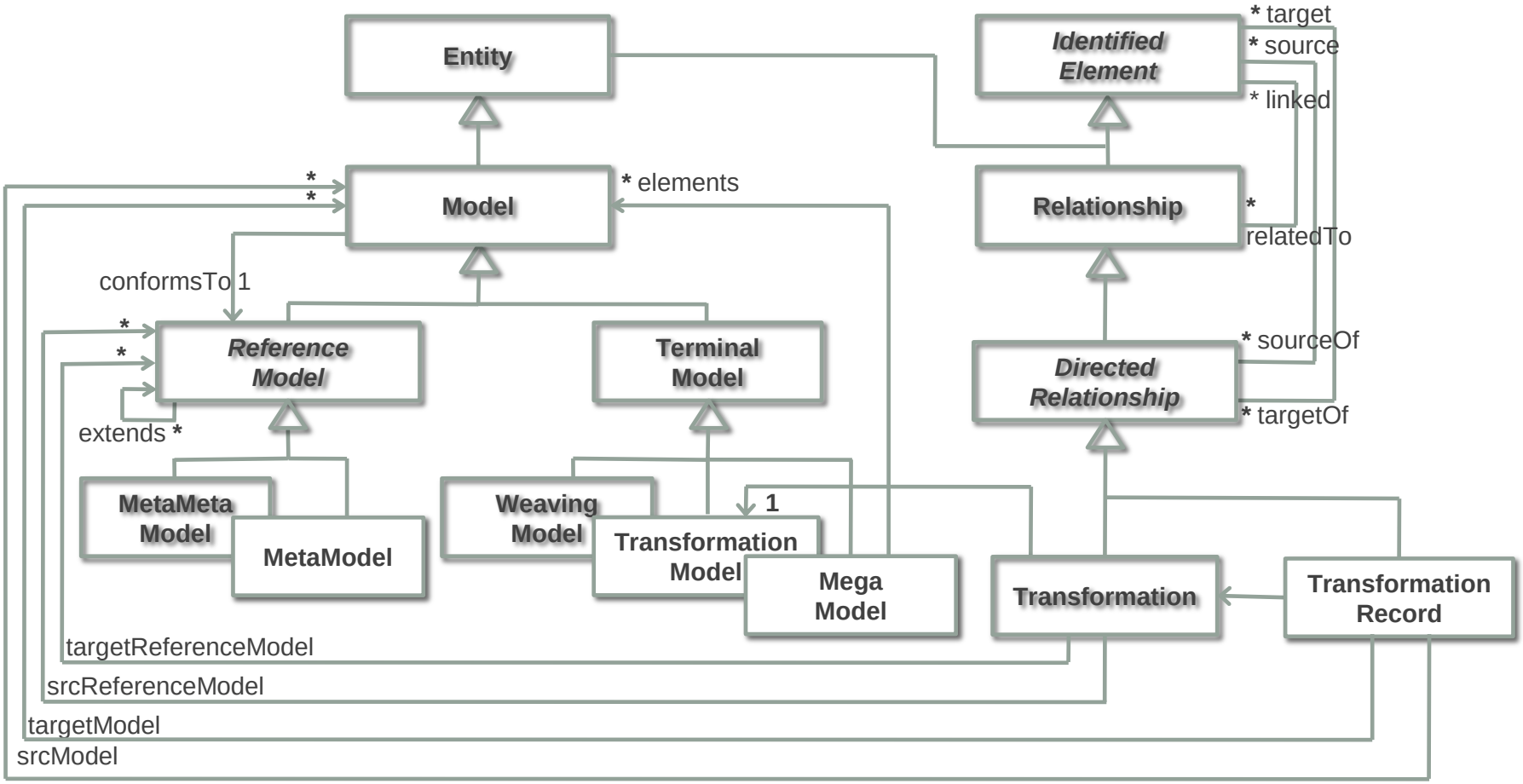
GLOBAL MODEL MANAGEMENT

Global Model Management

- Model-based solution to the problem of managing all this *model ecosystem* appearing in any MDE project
- We represent with a model, the *megamodel*, all the models (and related artefacts like configuration files) and relationships in the ecosystem
- A megamodel can be viewed as a metadata repository for the project
- A megamodel is a model whose elements are in fact other models
- As a model, a megamodel can be directly manipulated using the same tools employed to manipulate “normal” models

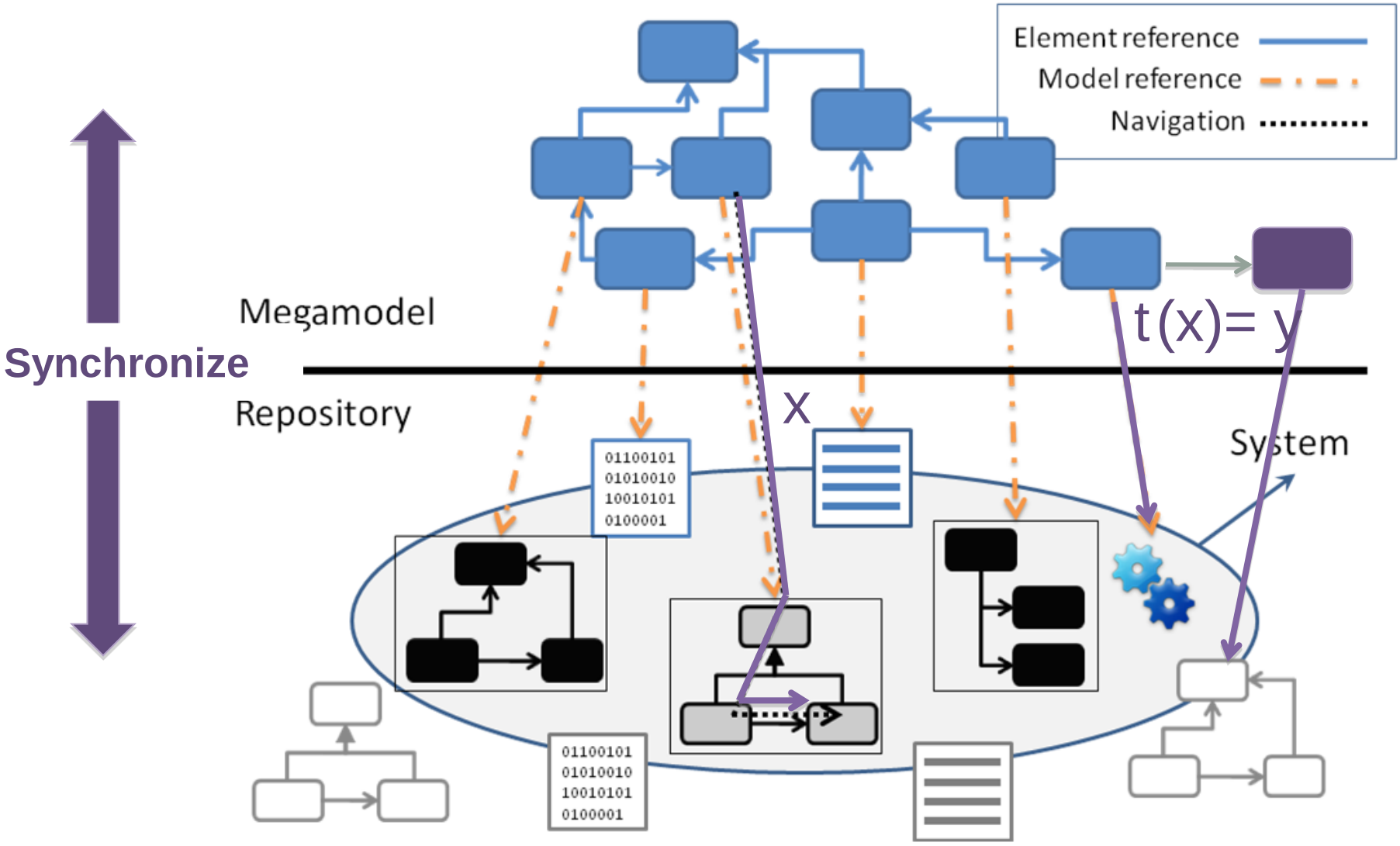
Global Model Management

The metamodel of a megamodel



Global Model Management

Using megamodels



Global Model Management

MoScript

- DSL to write model management scripts on megamodels
- It allows the automation of complex modelling tasks, involving several (batch) consecutive manipulations on a set of models.

Global Model Management

MoScript Examples

- Query operations

```
Model::allInstances()->any(m | m.indentifier = 'SimpsonFamily')
->allContents()->collect(el | el.name))
```

Collection {'Bart', 'Homer', 'Lisa', 'Maggie', 'Marge'}

- Model to Model transformations (M2M)

```
1  let j2dNet : Transformation = Transformation::allInstances()
2              ->any(t | t.identifier = 'j2dNet')
3  in
4
5  Model::allInstances()
6              ->select(m | m.conformsTo.kind = 'Java'))
7              ->collect (jModel | j2dNet.applyTo(jModel))
```

```
TransformationRecord::allInstances()->collect(tr | tr.run())
```

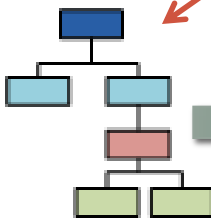

MODEL QUALITY

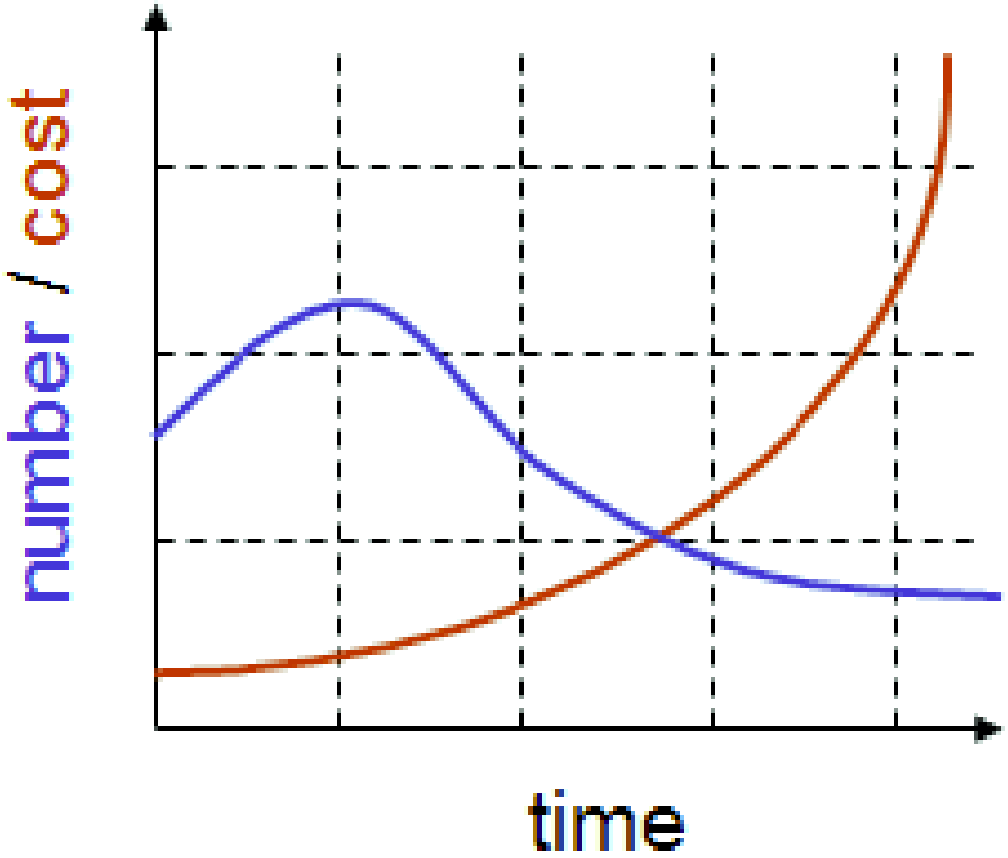
Motivation

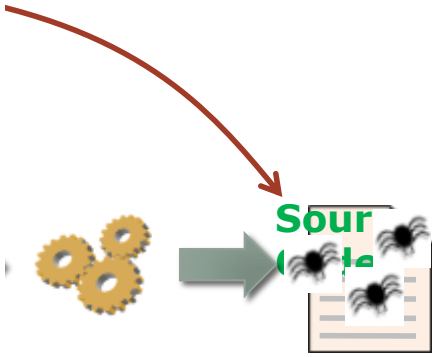
MDE-b

rocess

Original model







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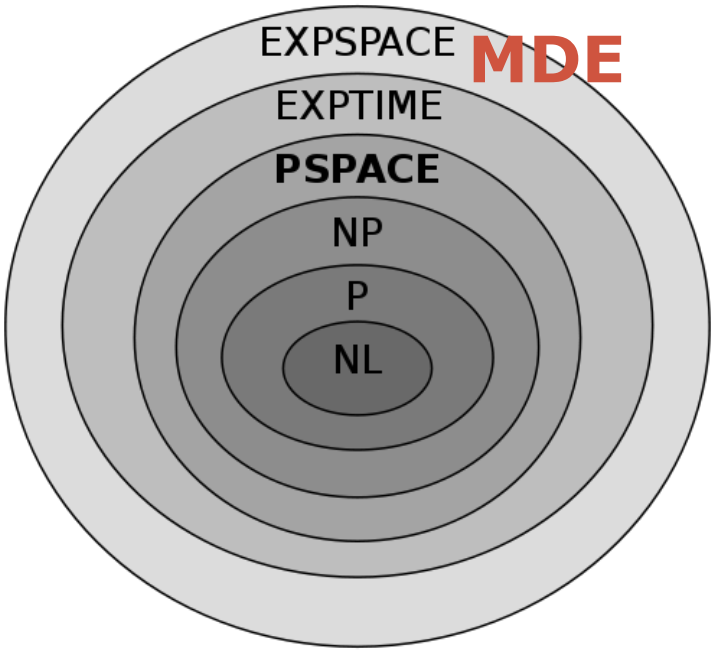
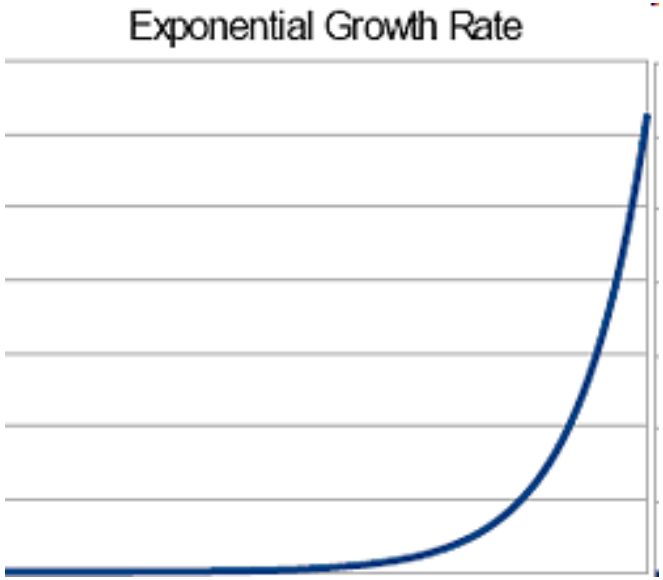
Model Quality

- Modeling Tools only check for well-formedness
  - Is a model conforming to its metamodel? i.e. is a model a valid instance of its metamodel?
- But this is just the tip of iceberg when it comes to evaluate the quality of a model. There are many other properties to verify:
  - For static models: satisfiability, liveliness, redundancy, subsumption …
  - For dynamic models: absence of deadlocks, reachability,…
- Evaluation of these properties can be done through formal model verification or testing

Example property: satisfiability

- A model is satisfiable if it is possible to create a valid instantiation of that model. A instantiation is valid if it satisfies all model constraints
- More difficult than it seems





Model Quality

- Modeling Tools only check for well-formedness
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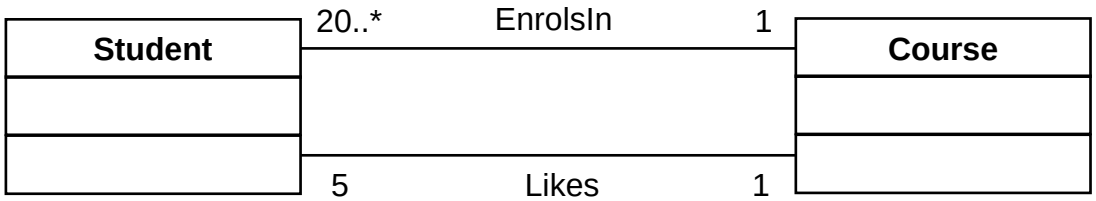
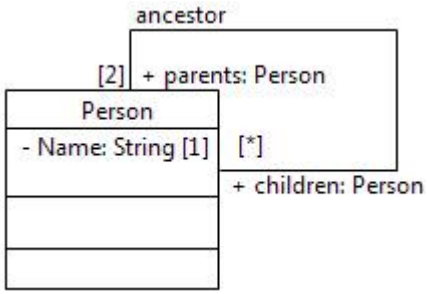
- But this is just the tip of iceberg when it comes to evaluate the quality of a model. There are many other properties to verify:
  - For static models: satisfiability, liveliness, redundancy, subsumption …
  - For dynamic models: absence of deadlocks, reachability, infinite recursion…
- Evaluation of these properties can be done through formal model verification or testing

Example of unsatisfiability (1)

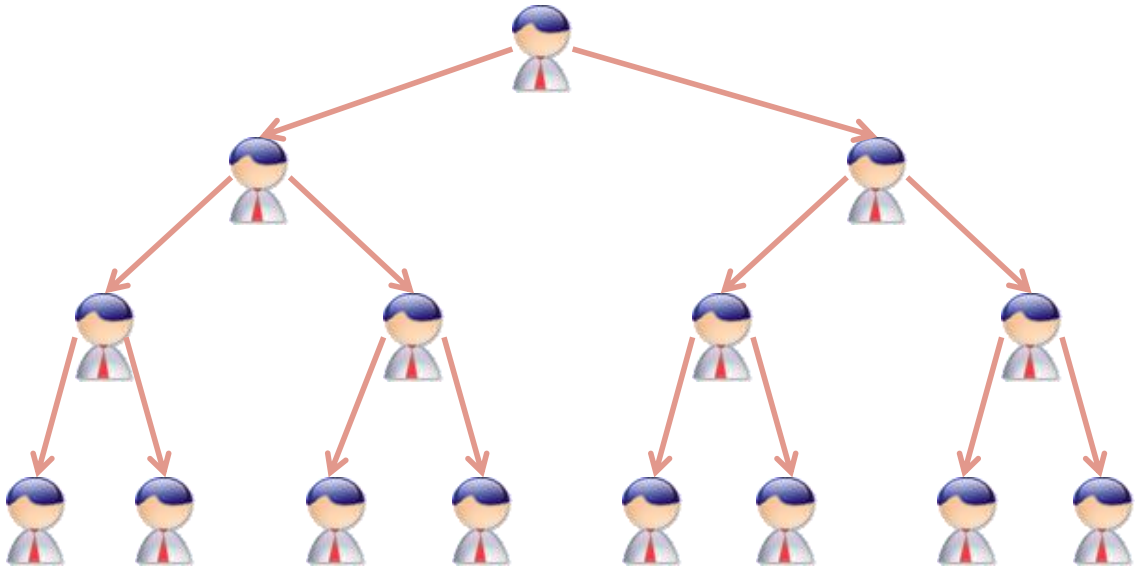


- Due to EnrolsIn |student|>=20*|course|
- Due to Likes |student|=5*|course|

Example of unsatisfiability (2)

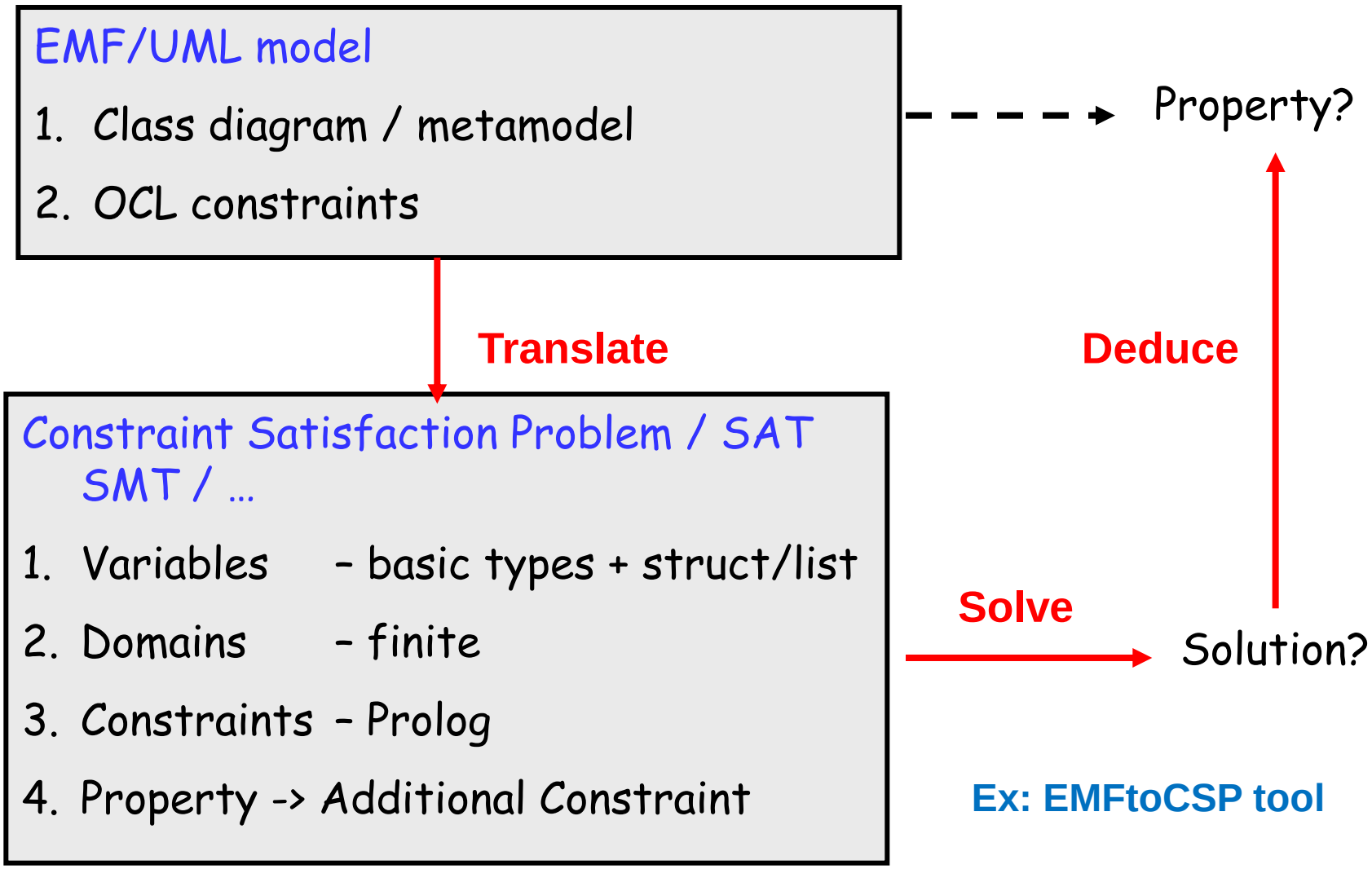


And no person is his own ancestor



Strong Satisfiability

Typical formal verification approach



Testing models

Derive tests from your models

- Same as we test code, models can also be tested
  - Tools like USE can create snapshots of a system and evaluate OCL constraints on them to test the OCL expressions
- Specially useful for dynamic models & operations like model transformations
  - E.g. we may want to check a transformation generates a valid output model every time a valid input model is provided
- Several black-box and white-box techniques for model testing have been proposed

COLLABORATIVE MODELING

Collaborative modeling

- Modeling is by definition a team activity
- Offline synchronization of models can be handled using the model versioning tools seen before
- Online collaborative modeling (several users updating the same model at the same time) is more problematic
  - Based on a short transaction model where changes are immediately propagated to everybody
  - Very lightweight conflict management mechanisms (e.g. voluntary locking)
  - Conflict resolution by explicit consensus among all parties

Collaborative modeling

Tools

- EMFCollab
  - Master copy in a server. Slave copy in each client.
  - Commands to modify the models are serialized and distributed across the network
- SpacEclipse-CGMF
  - Integration of collaborative functionality in GMF-based editors
  - This functionality can be generated as part of the generation of the own GMF editor and workspace
- Dawn
  - Subproject of CDO
  - Aimed at providing collaborative access to GMF diagrams.

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