Towards a Formal Diagrammatic Framework for Model Driven Architecture (MDA)

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08.07.2008
ECOOP 2008, Paphos, Cyprus

Motivation

- Raise of abstraction level of programming languages ⇒ Modeling vs coding ⇒ MDA ⇒ Models and Model Transformations

```
Public class Person{
  public String p_name;
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  public Person(...){...}
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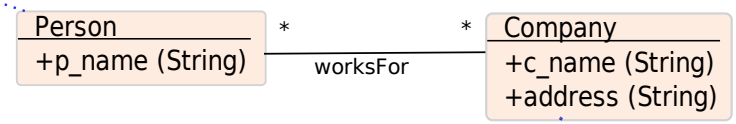


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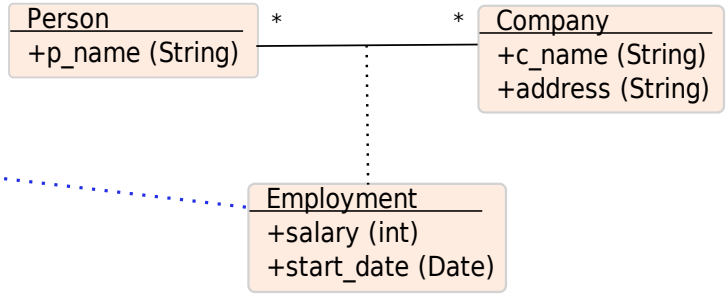


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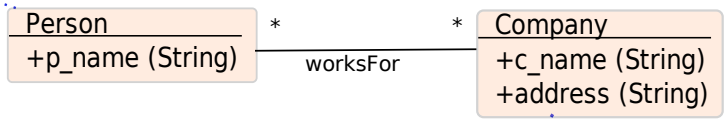


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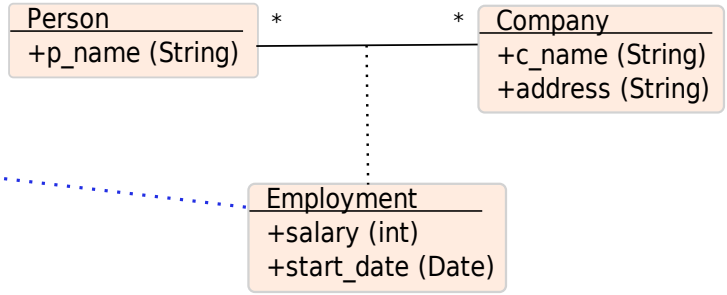


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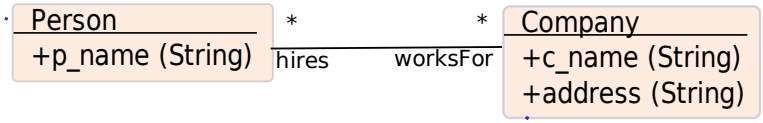


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Instances:

p1	c1
p2	c2
p2	c1
p1	c1

- Need for OCL to put constraints ⇒ Mixing text and diagrams

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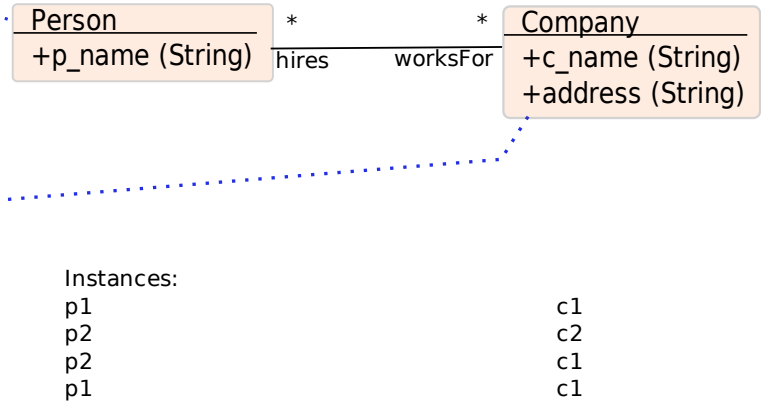

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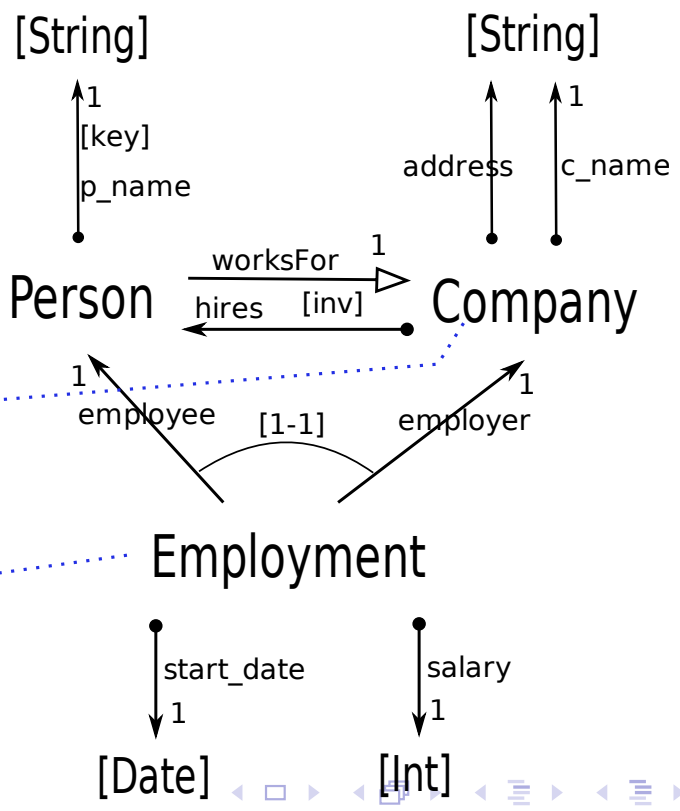

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- MDA ⇒ Models and Model Transformations ⇒ Code generation, model integration, model versioning, reverse engineering ...

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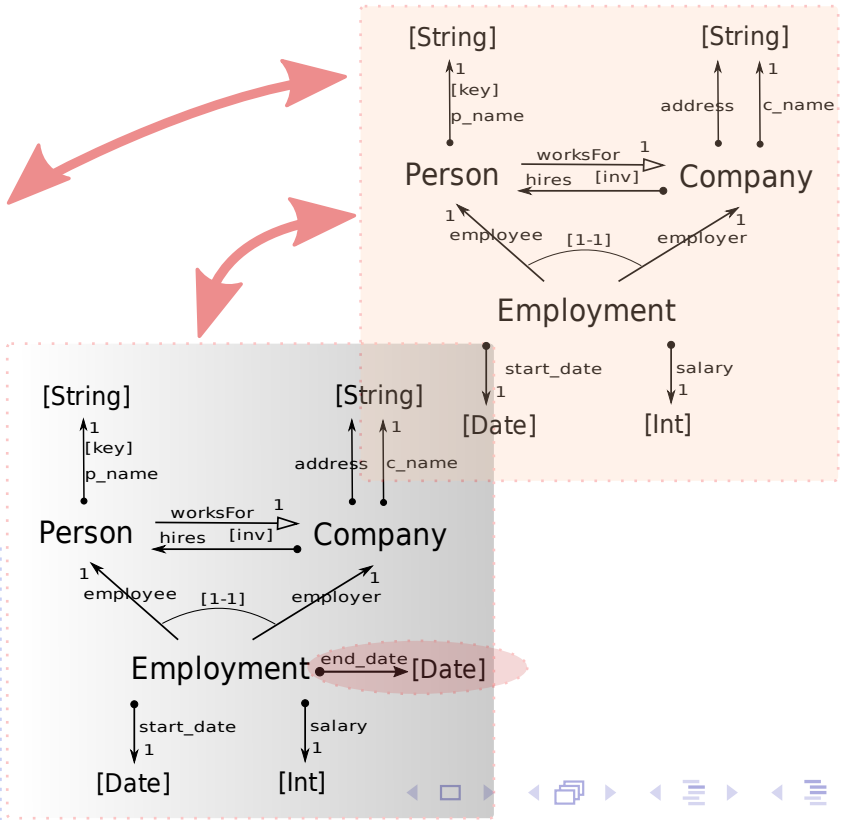

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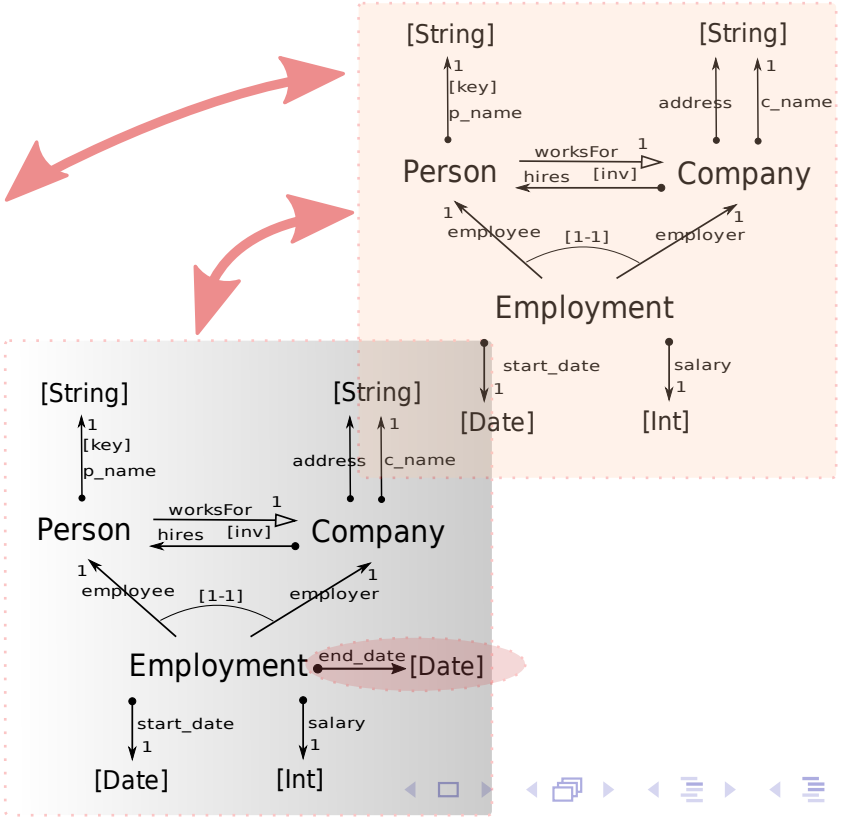

Key-points for the Success of MDA

Models are no longer only for documentation

- Models should be **both**:
  - intuitive to ease their interception by **software engineers** and **domain experts**
  - formal such that **machines** can have a precise understanding of (and able to reason about) the models

⇒ Diagrammatic approach enhances human understanding
⇒ One challenge is to combine intuition with formalization
⇒ Another challenge is to implement the formalization approach

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Outline

UML vs Formal Modeling Languages

UML ...

- is considered *de facto* industry standard for modeling
- has serious issues regarding semantics, complexity, expressibility (uses OCL for constraints on higher order relations)

Formal Modeling Languages ...

- has precise semantics and proven abilities
- has set based semantics, while models are graph based
- is hard for software engineers to apply in practice
- lacks good software development tools

Outline

Our Approach: Diagrammatic Predicate Logic (DPL)

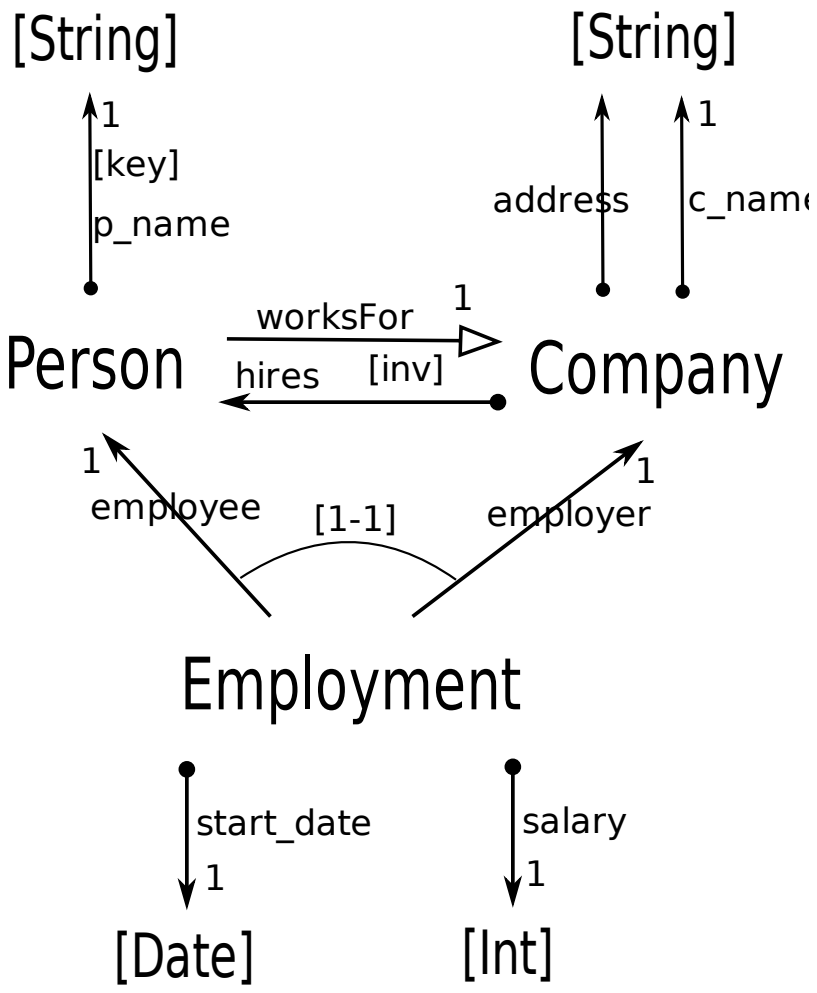
- Aims to combine the intuition from graphical modeling languages with the semantic rigor of formal methods
- Based on Generalized Sketches/Category Theory
- In DPL, sketches are generalized and adapted for use in MDA
- Potentials to use the machinery from category theory to implement MDE tools

Outline

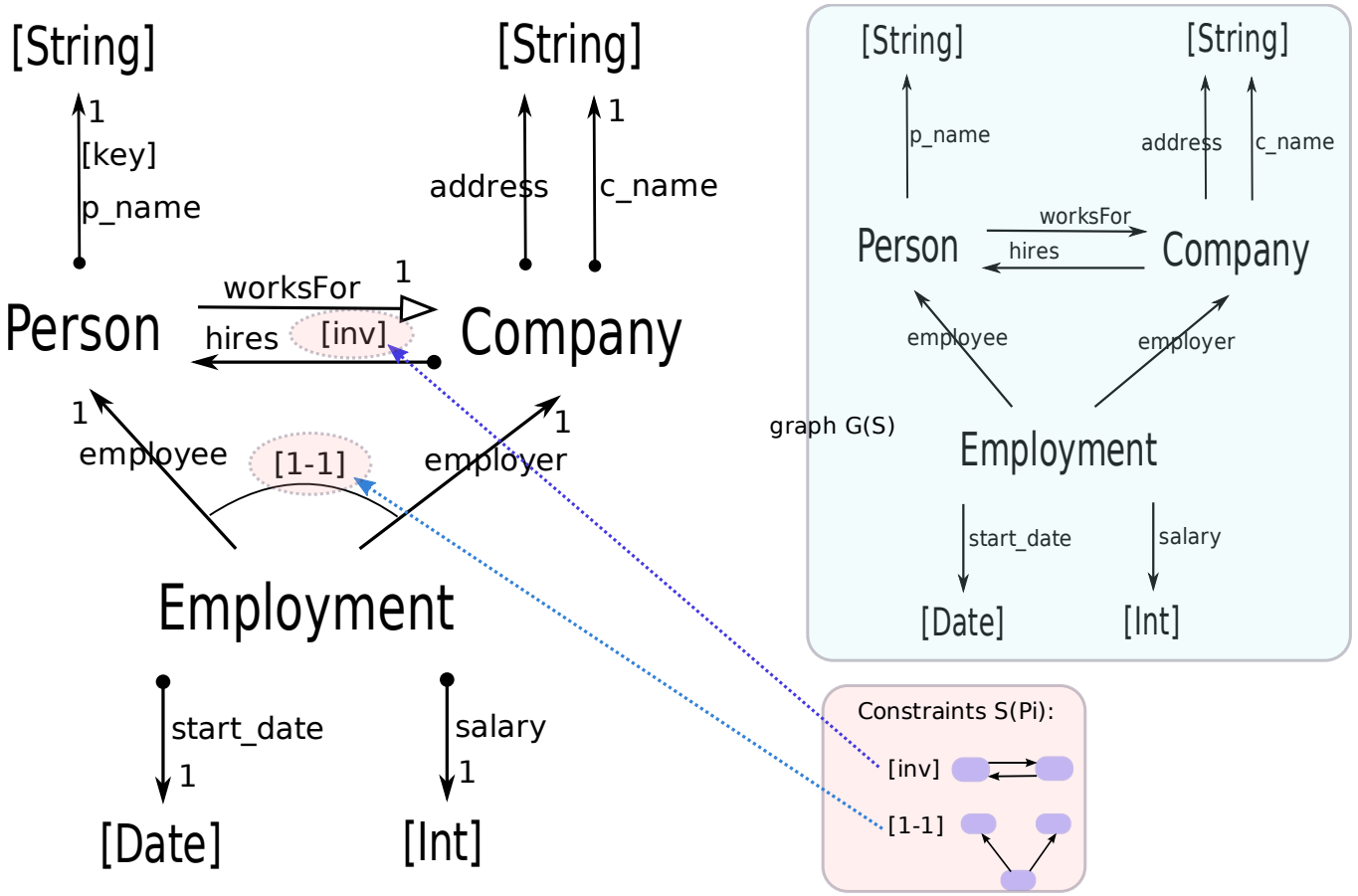
Signature – Example

Π	α	visualization	intended semantics
[total]	$1 \xrightarrow{x} 2$	$A \xrightarrow{f} B$	$\forall a \in A : \lvert f(a) \rvert \geq 1$
[key]	$1 \xrightarrow{x} 2$	$A \xrightarrow{f\ [key]} B$	$\forall a, a' \in A : a \neq a'$ implies $f(a) \neq f(a')$
[inv]	$1 \underset{y}{\overset{x}{\rightleftarrows}} 2$	$A \underset{g}{\overset{f}{\underset{[inv]}{\rightleftarrows}}} B$	$\forall a \in A$, $\forall b \in B : b \in f(a)$ iff $a \in g(b)$
[jointly-key] or [1-1]	$\begin{tikzcd} 1 \arrow[r, "x"] \arrow[d, "y"] & 2 \\ 3 & \end{tikzcd}$	$\begin{tikzcd} A \arrow[r, "f"] \arrow[d, "g"'] & B \arrow[dl, bend left, "{[1-1]}"] \\ C & \end{tikzcd}$	$\forall a, a' \in A :\ a \neq a'$ *implies* $f(a) \neq f(a')$ or $g(a) \neq g(a')$

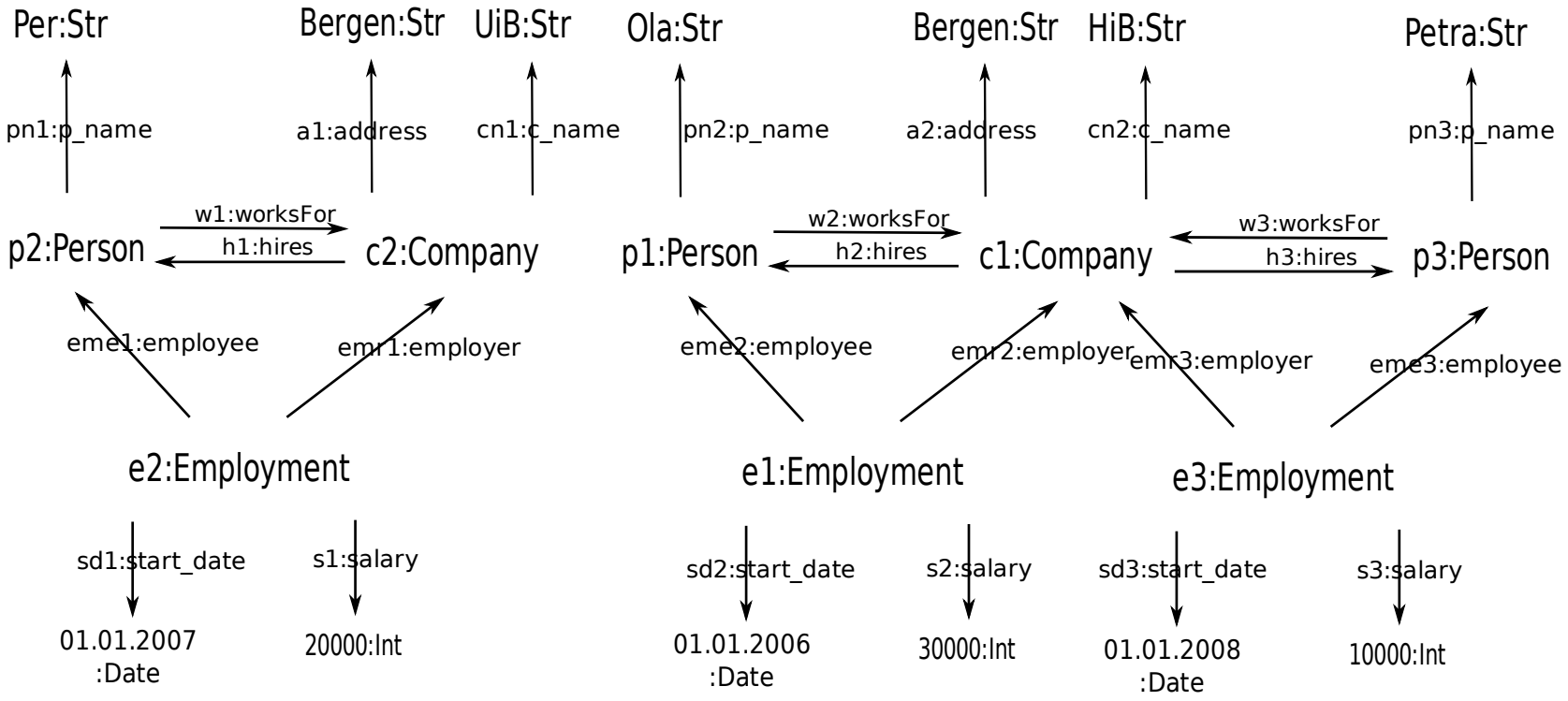
Diagrammatic Specification – Example



Diagrammatic Specification – Example

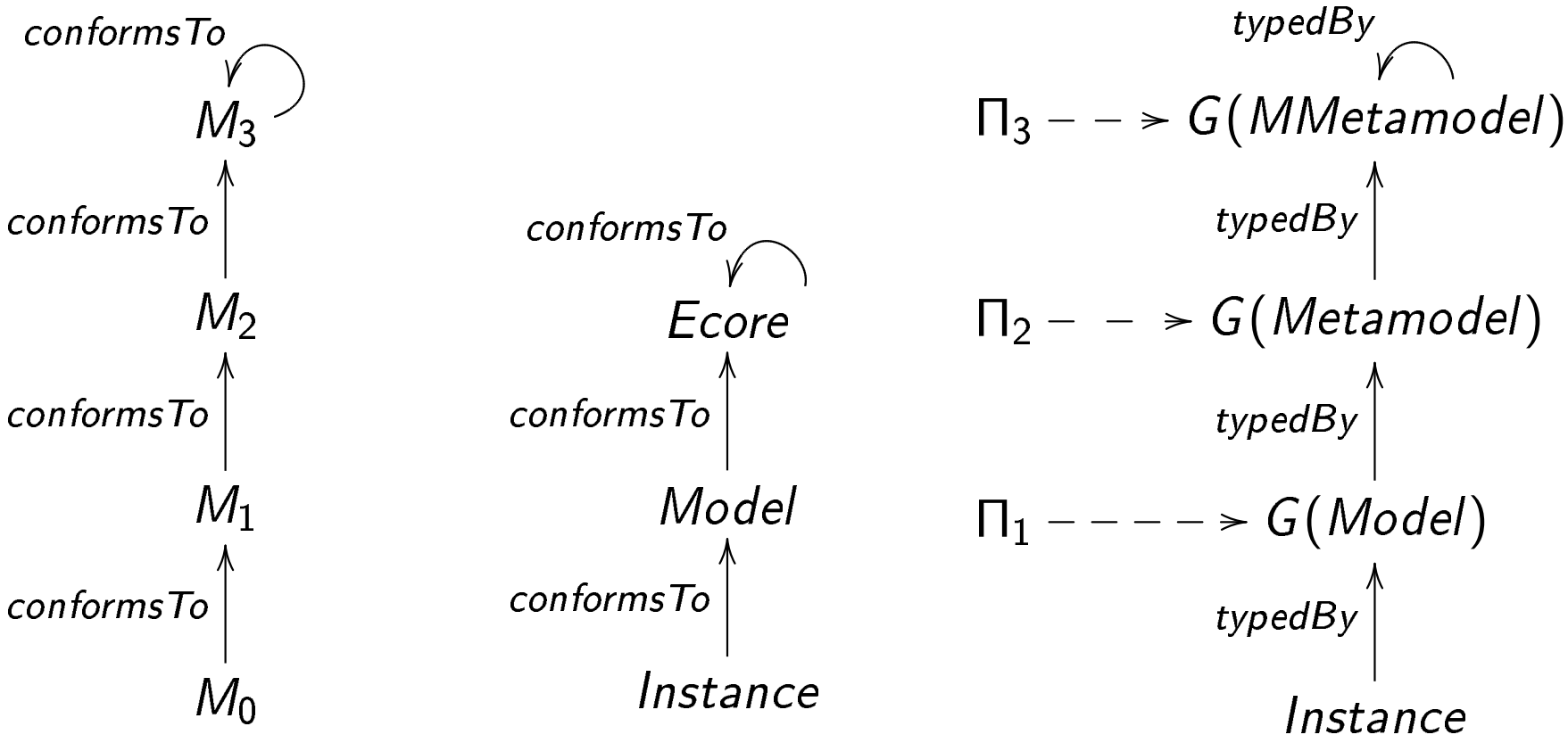


Instance of Diagrammatic Specification – Example



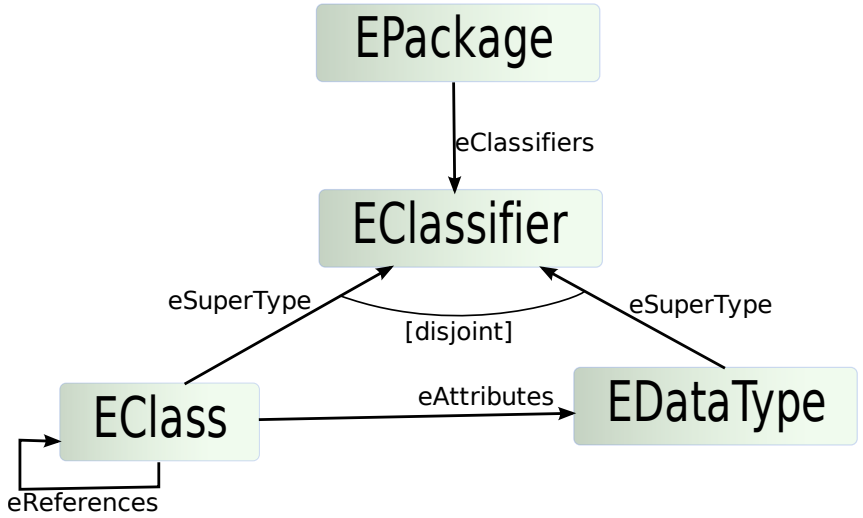
Outline

DPL Methodology and Modeling Formalisms



Outline

Ecore model expressed in DPL



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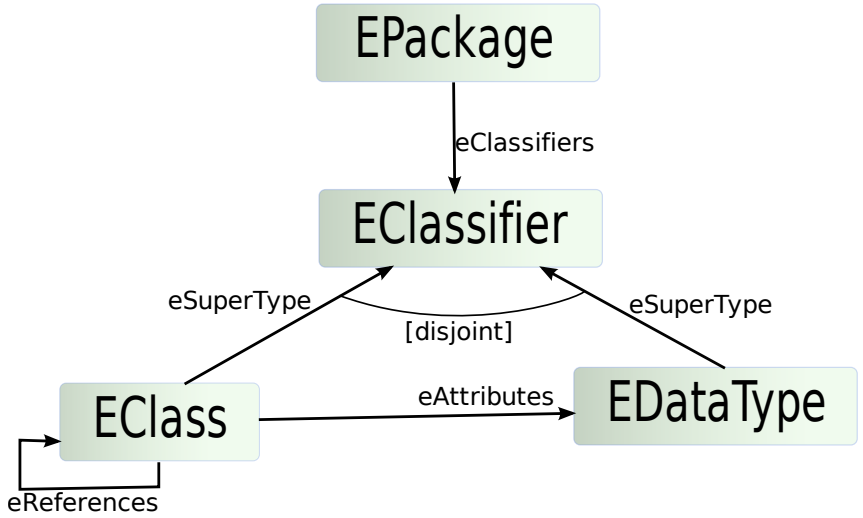

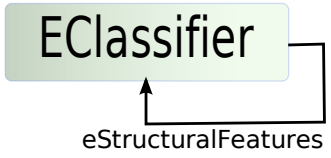

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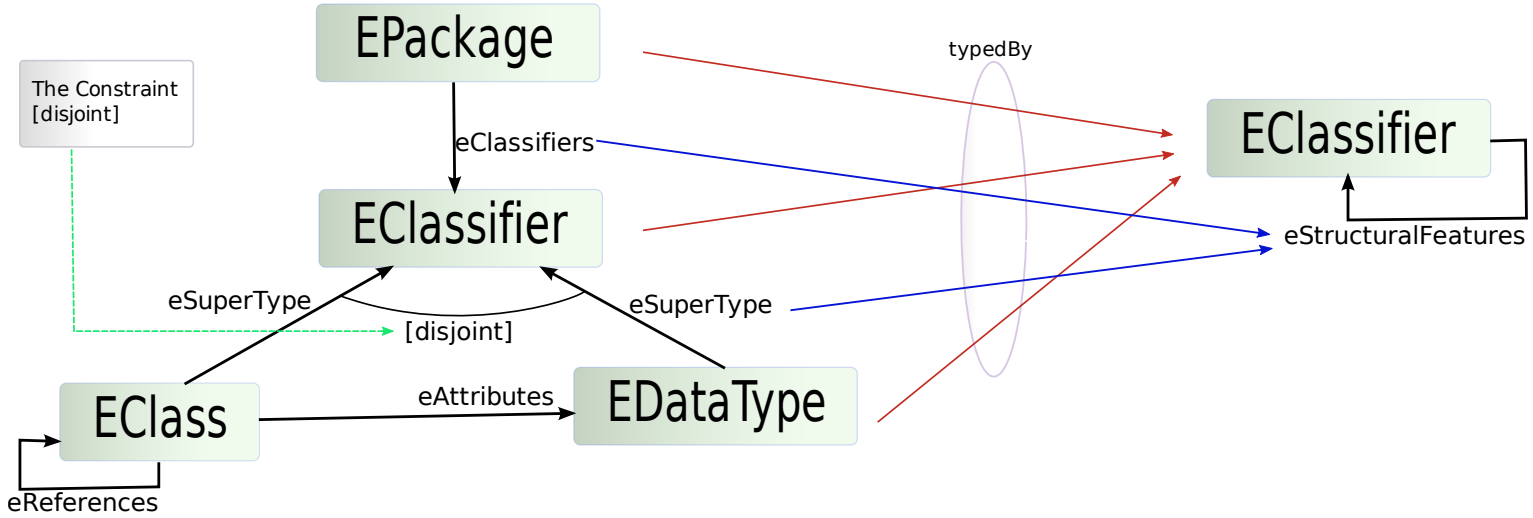
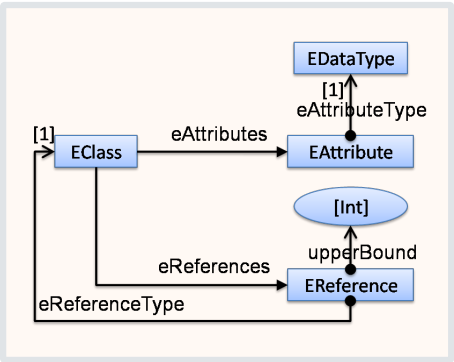
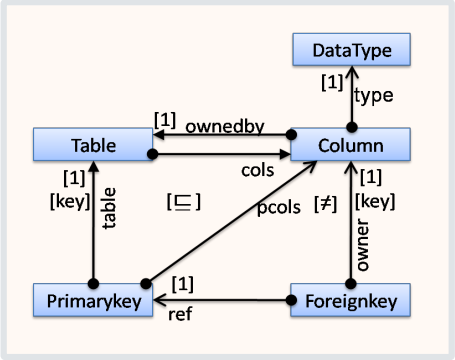


Model Transformation

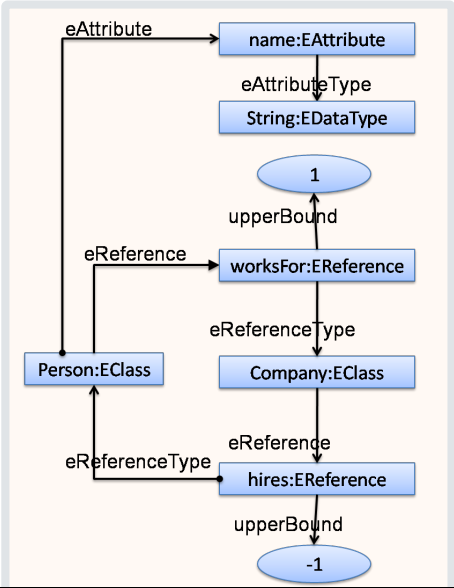


MT Language

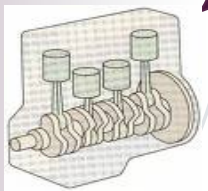
MT Definition



conformsTo



MT Execution



?

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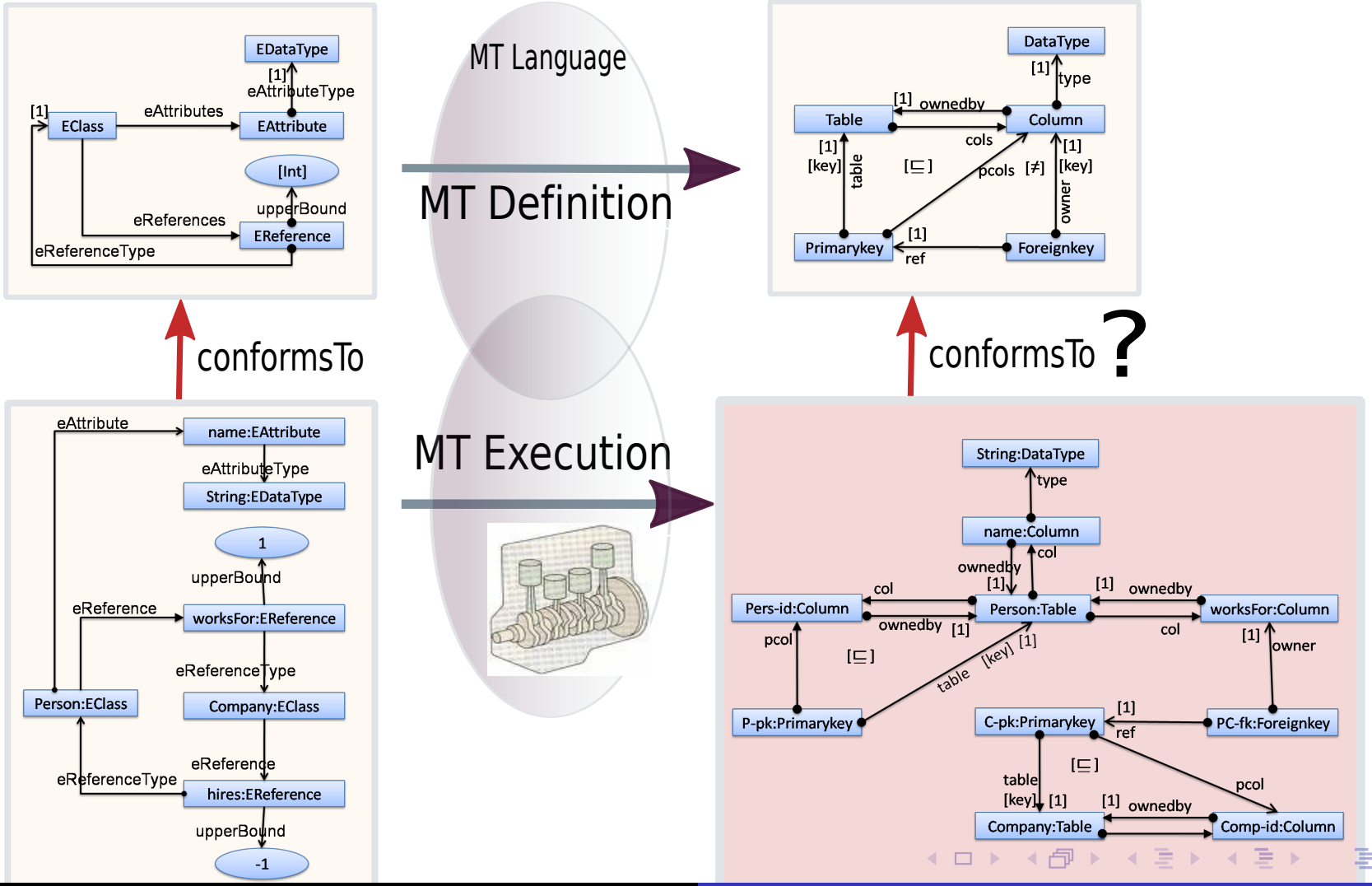

Outline

Model Transformation Concepts

- Model Transformation = set of Transformation Rules + Coordinations ($\Rightarrow$ operational)
- Model Transaction = declarative definition of the transformation
- Transformation Engine = executes the rules

Transformation Rules

$$
\begin{tikzcd}
 & P \arrow[dl, "\iota_P"'] \arrow[d, "m"] \arrow[r, mapsto] \arrow[dr, phantom, "[=]"] & P' \arrow[d, "[\![t]\!](m)"] \arrow[dr, "\iota_{P'}"] & \\
G(M_1) & I \arrow[l, "\iota"] & I' \arrow[l, dotted, "trace"] \arrow[r, "\iota'"'] & G(M_2)
\end{tikzcd}
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- Input and output patterns P and P'
- Input and output instances I and I'
- The models M_1 and M_2
- The matches m and $[\![t]\!](m)$

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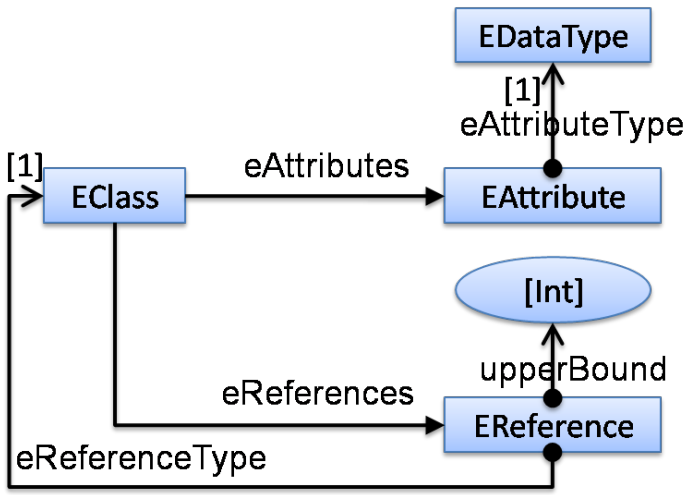
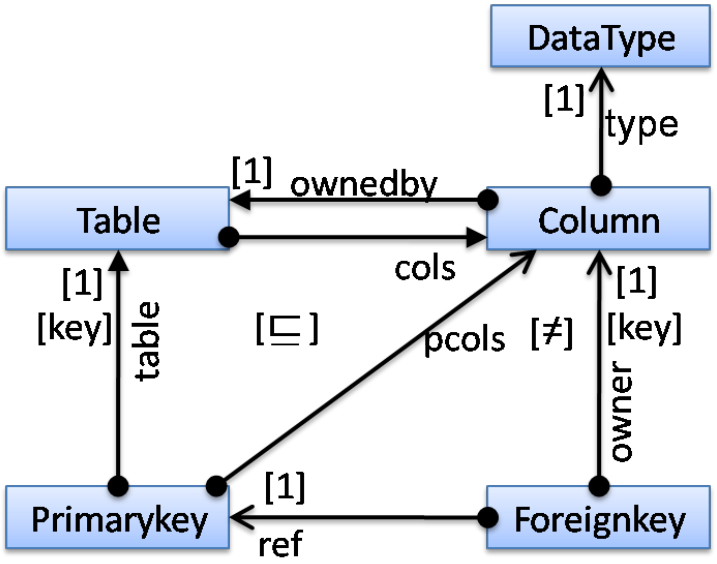
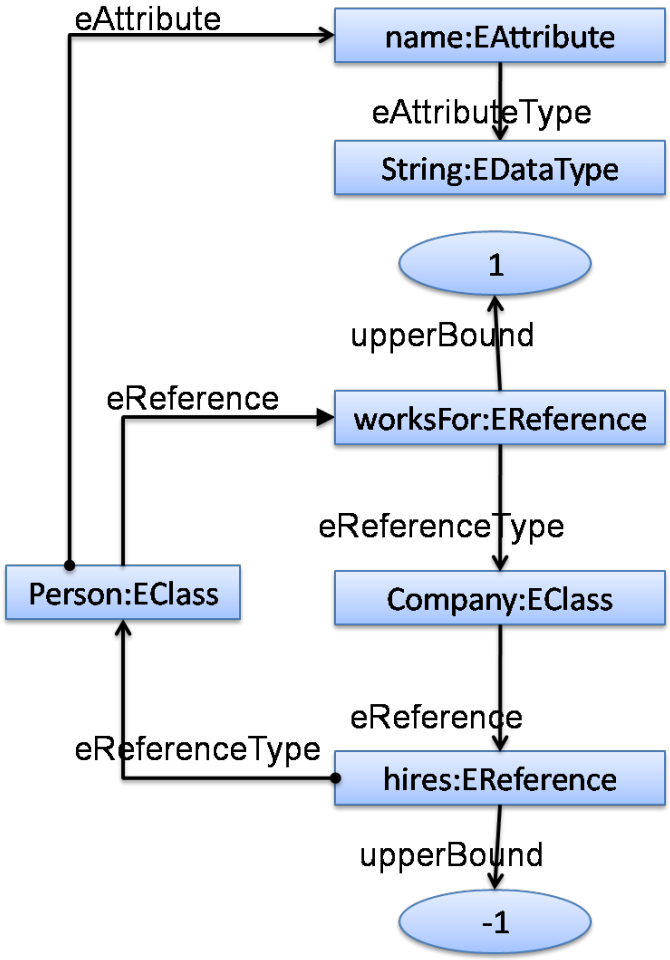
Model Transaction: Ecore to RDB

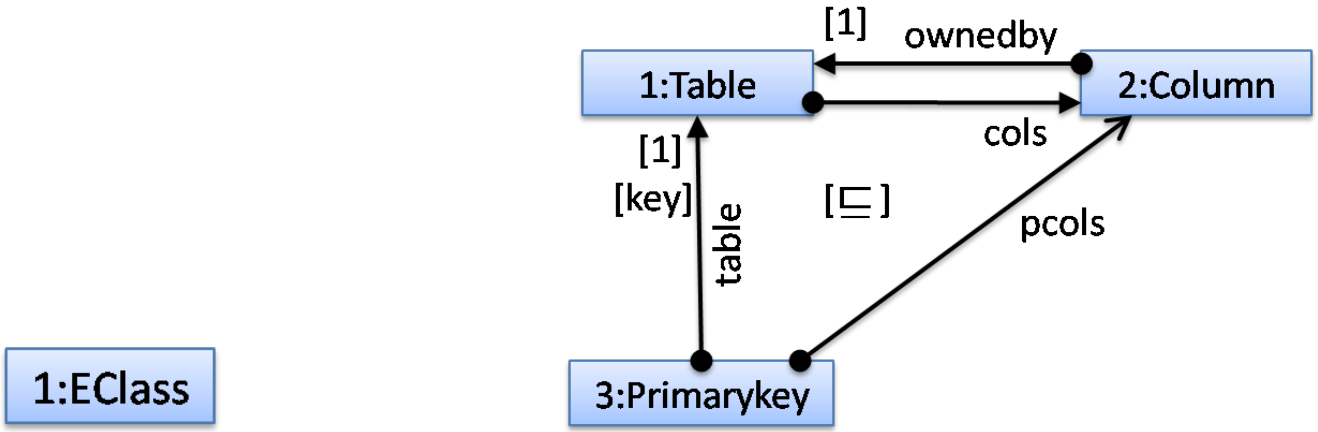




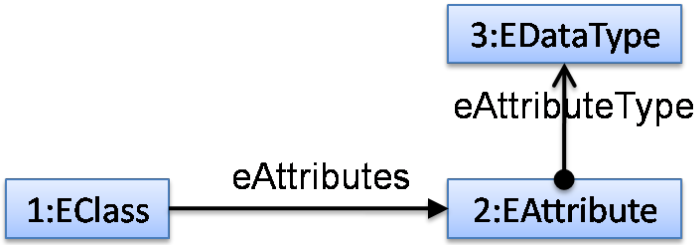
The Input EMF Model

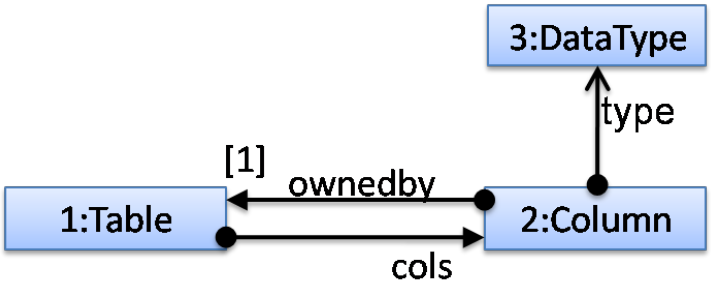


Rule1: EClass to Table + PrimaryKey

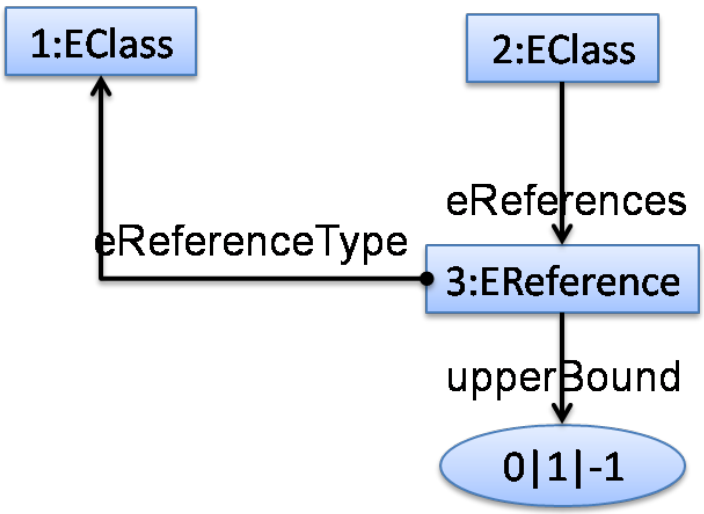


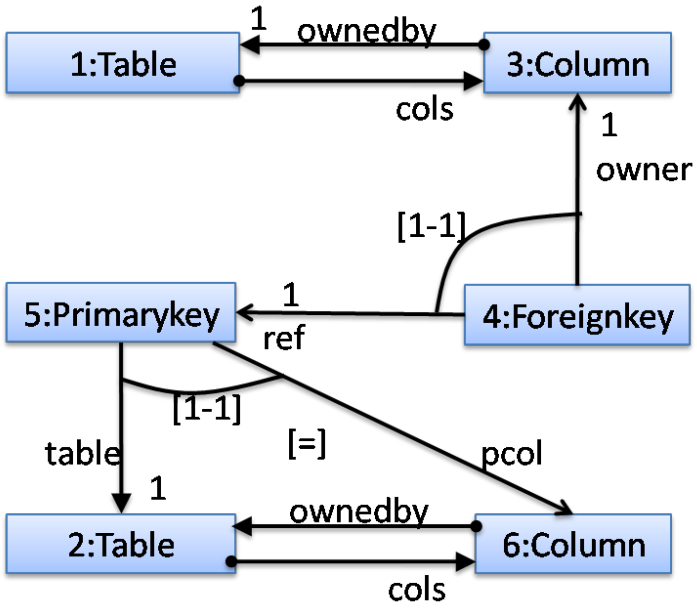
Rule2: EAttribute to Column



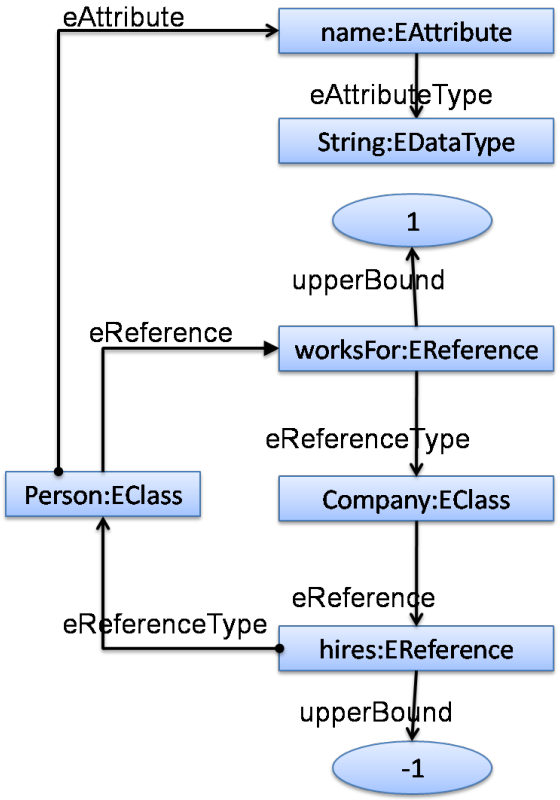


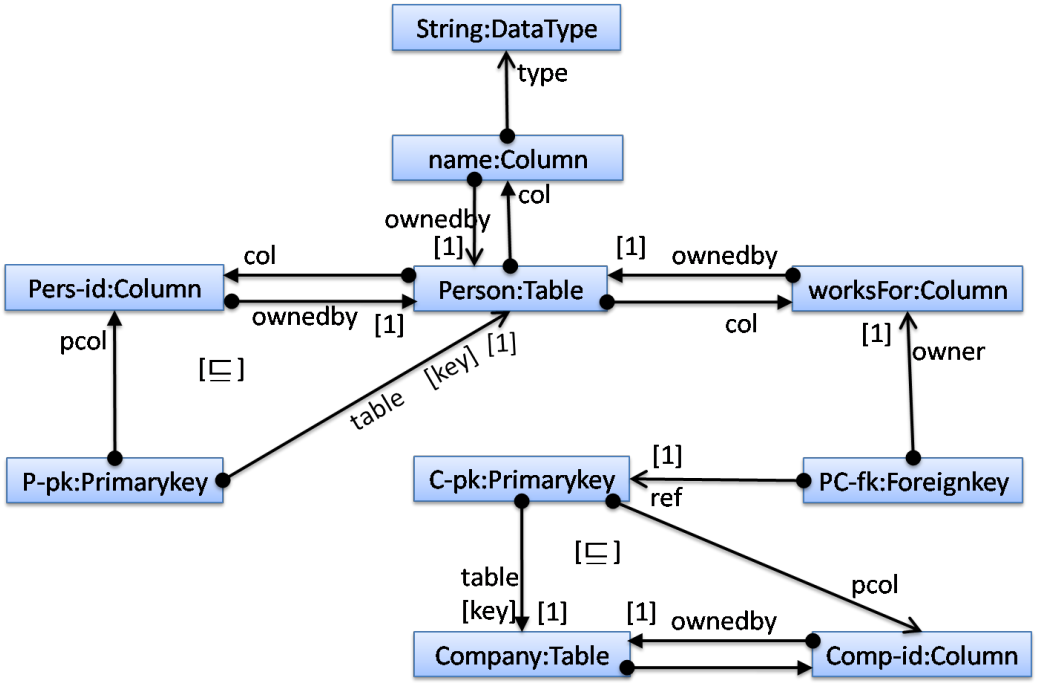
Rule3 EReference to ForeignKey





The Output RDB Model





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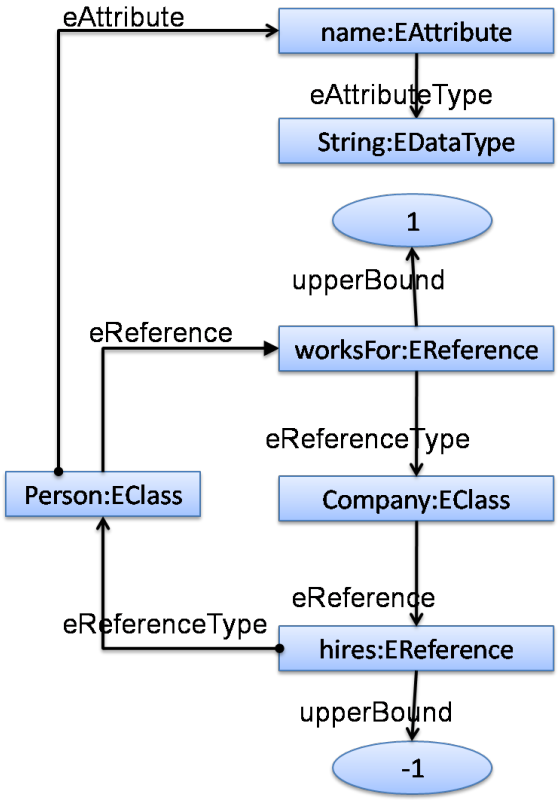
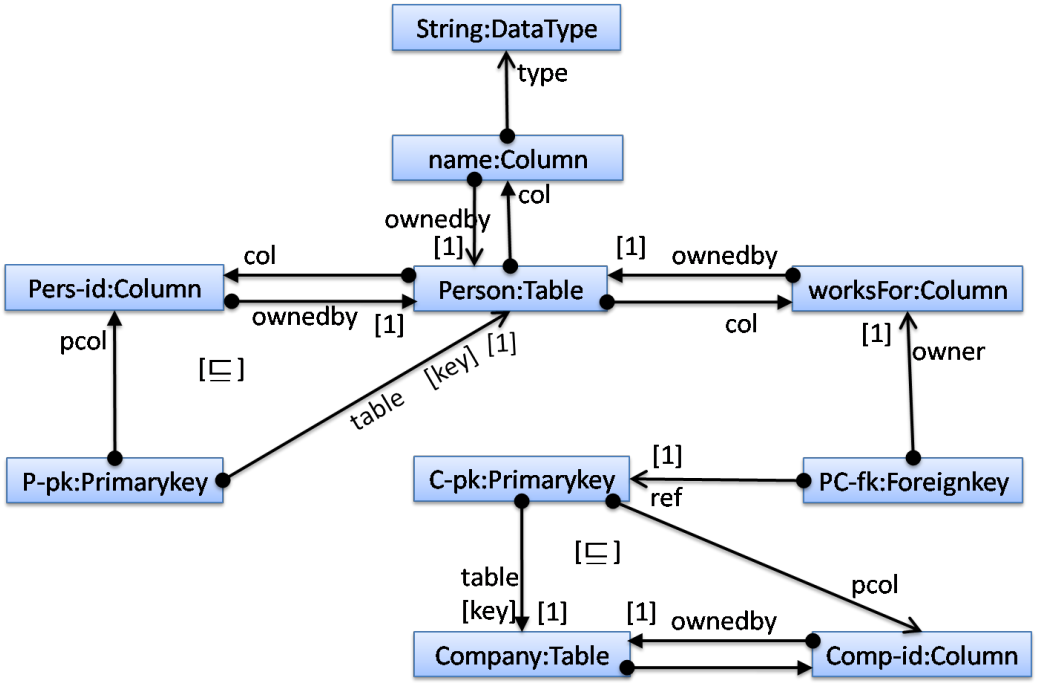
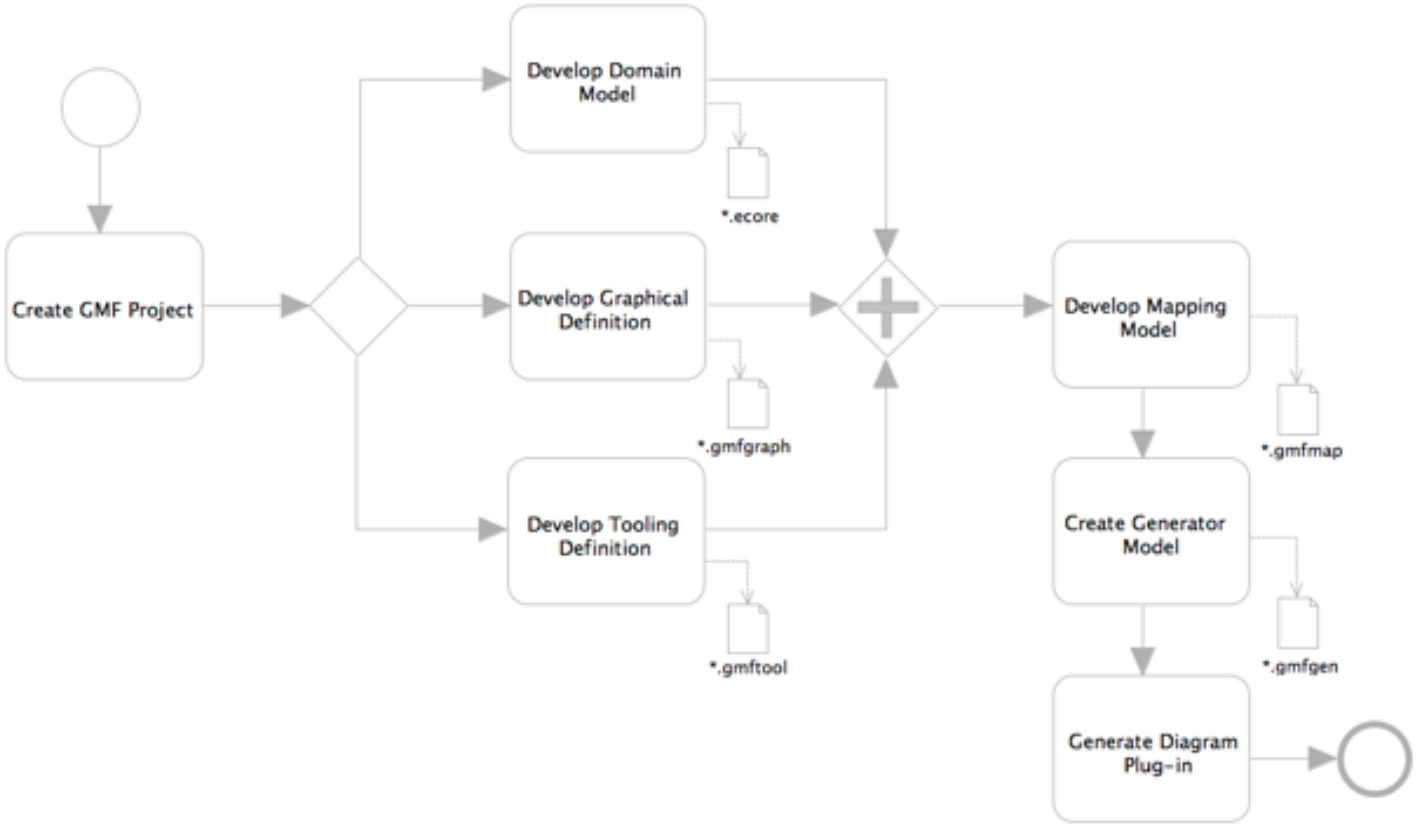




Tools

- Tools implemented as plug-ins to the Eclipse platform
- Need tools for:
  - Drawing of models (GMF-based editor), partly finished June 2008
  - Serialization of models, work started
  - Validation of models, future research project
  - Model transformation tools, research started

Generation of GMF-based Editors



Summary

- The MDD is a promising approach for software development processes
- The MDD requires tools for automatic model management
- Automatic model management requires formal modeling and model transformation languages
- Using DPL as a generic framework for formalization of modeling and model transformation languages