Simple UML Representation of Relational Database Schema

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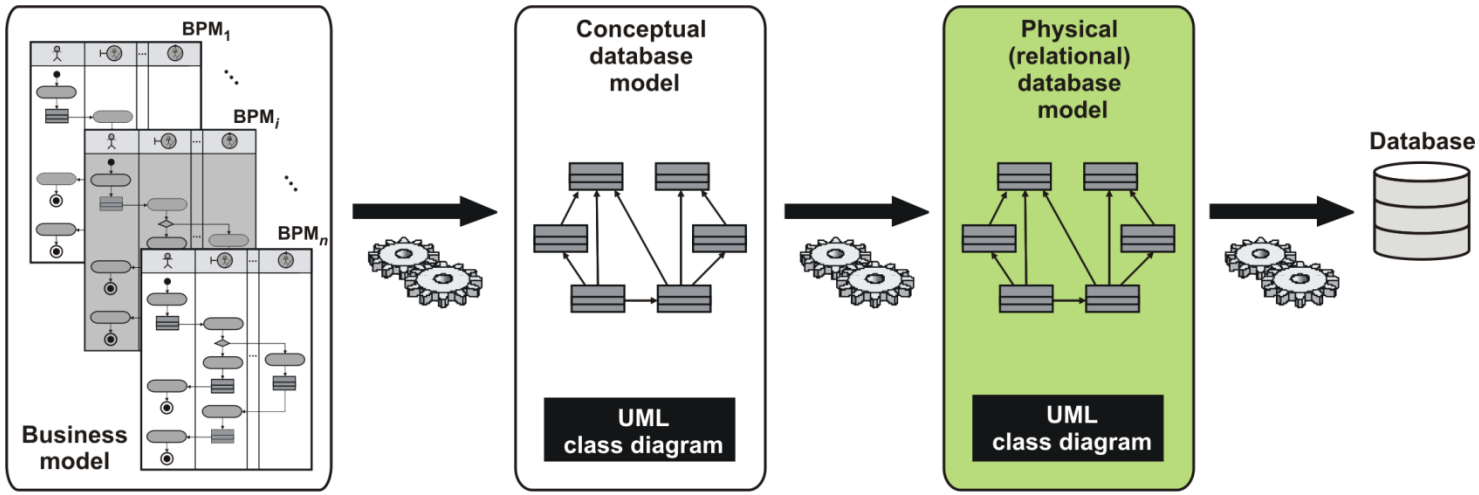
Presentation outline

- Motivation
- (Un)suitability of the standard UML for RDBS representation
- UML-profile based approaches for RDBS representation
- Disadvantages of the UML-profile based approaches
- Our approach for representation of (complex) keys
- Example of forward database engineering
- Conclusion and future work

Motivation

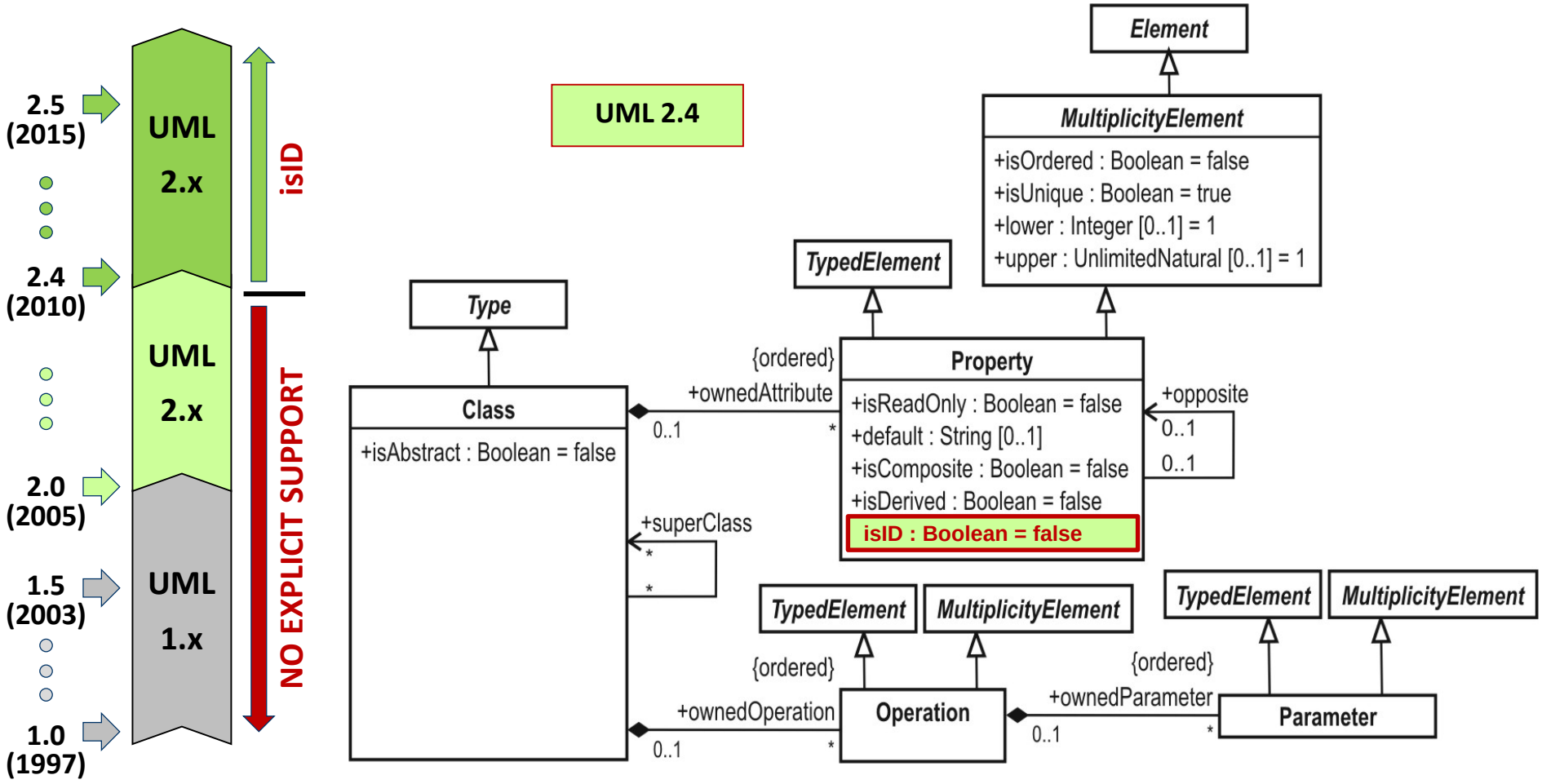
- A part of long-term research devoted to model-driven database design



- There is no single and standardized approach to (UML-based) RDBS representation
- The standard UML notation is not fully adapted for RDBS representation – **RDBS represents a model containing some specific concepts which cannot be represented by the standard UML notation?! – UML profile is required?!**
- **Our research question: Is it possible to represent RDBS by standard UML?**

(Un)suitability of the standard UML

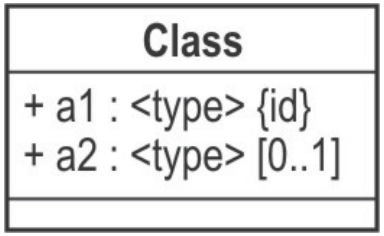
- The UML-based RDBS representation has been the subject of research since the beginning of UML development



Representation of PK by “isID” property

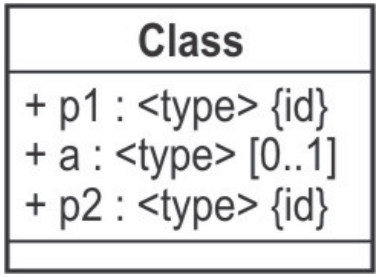
It is possible to represent a PRIMARY KEY by setting isID=true for all attributes belonging to the primary key.

Simple PK




```
CREATE TABLE Class
(
   a1 <type> NOT NULL PRIMARY KEY,
   a2 <type>
);
```

Composite PK




```
CREATE TABLE Class
(
    p1 <type> NOT NULL,
    a <type>,
    p2 <type> NOT NULL,
    PRIMARY KEY (p1, p2)
);
```

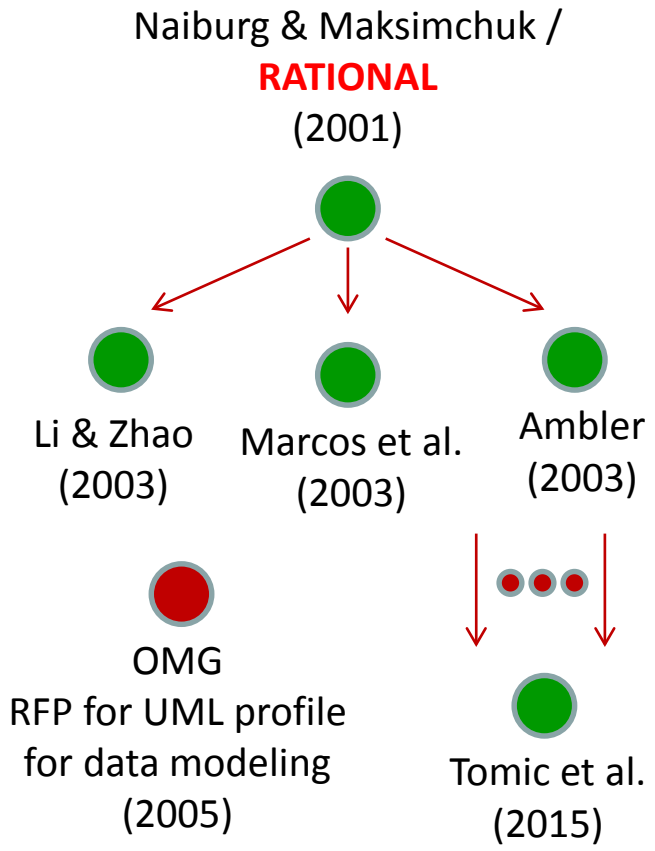
Simple DDL generation by using specialized Model-to-Text transformation languages (e.g. ACCELEO)

However:

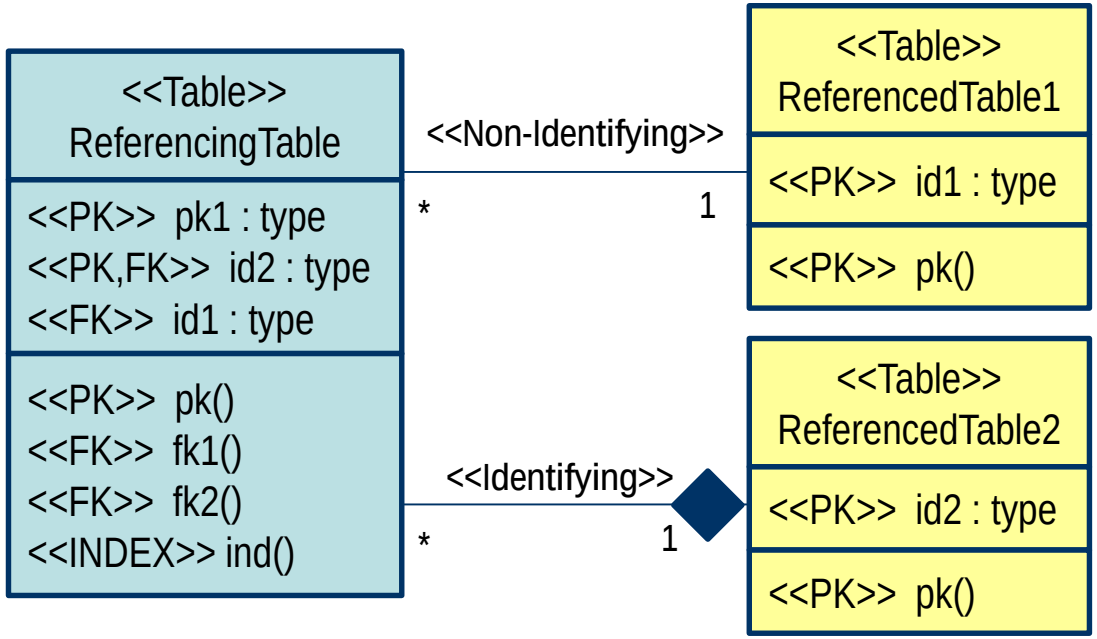
- **Some modeling tools**, including some open source development platforms, **still** do not support the recent UML specifications and **do not allow representation of the primary key by applying the isID property**.
- **How to represent foreign keys and other RDBS specific concepts?**

UML-profile based approaches

- The UML-based RDBS representation has been the subject of research since the beginning of UML development

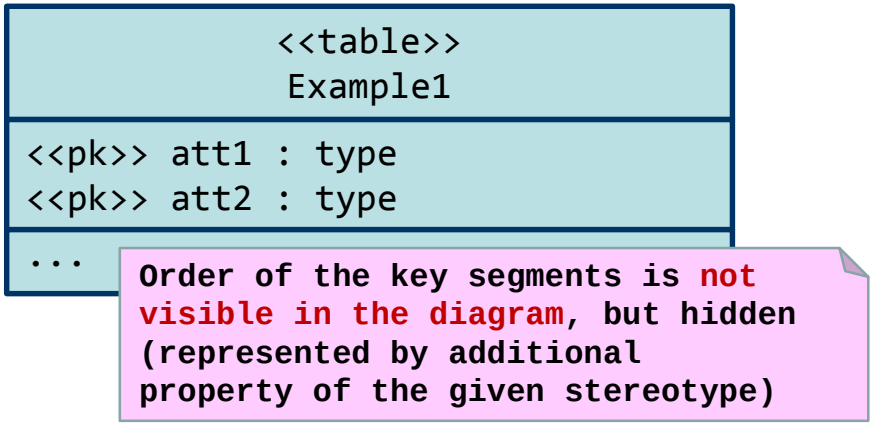


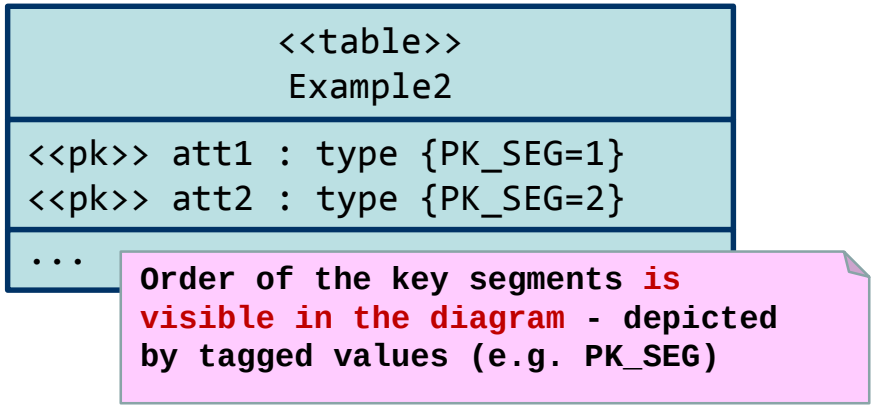
Typical UML stereotypes for RDBS representation
(Naiburg & Maksimchuk)



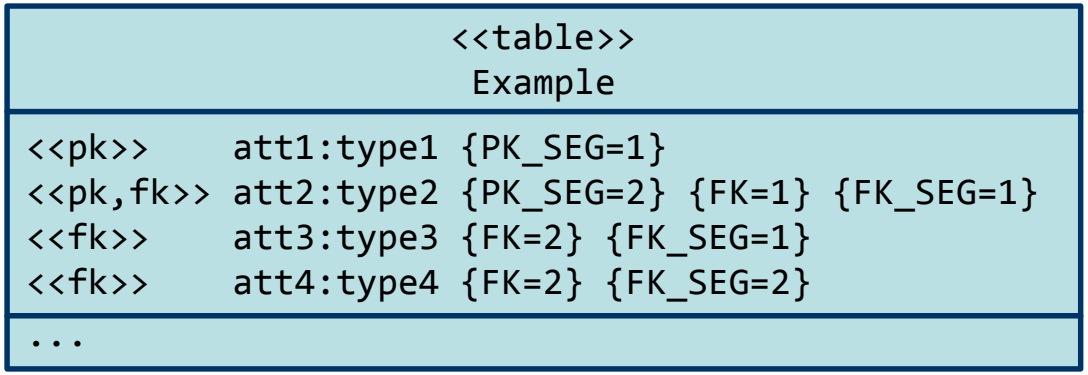
Disadvantages of the existing approaches

Representation of complex keys



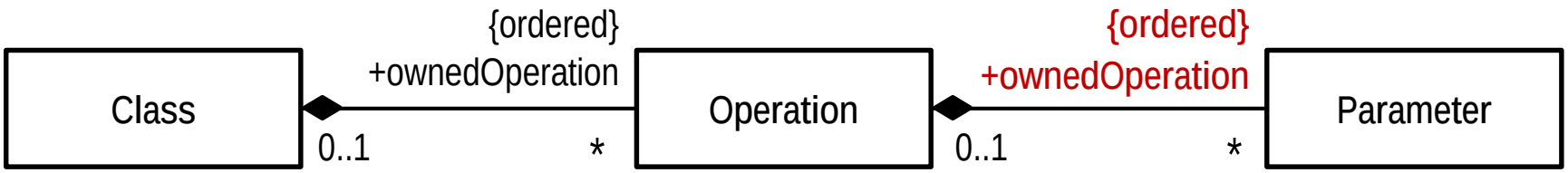


Even more difficulties with the existing approaches?



Representation of keys by class operations

- **UML possesses another inherent (but not explicit) mechanism that also provides the possibility for very simple and efficient representation of keys as attribute sequences.**



KEY is ordered sequence of colums. **Operation parameters constitute the sequence.**

$key(p_1, \ldots, p_k) \Leftrightarrow operation(op_1{:}type, \ldots, op_k{:}type)$

KEYS can be modeled by OPERATIONS!
Key segments $p_1,\ldots,p_k$ are represented by corresponding operation parameters $op_1,\ldots,op_k$.

Primary key:

$PK(p_1, \ldots, p_k)$

Foreign key:

$FK(f_1, \ldots, f_k)$

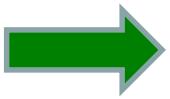
Table
a1 : type1 a2 : type2
PK(a1:type1, a2:type2)

Representation of keys by class operations

Example

Existing approaches

<<table>> Table
<<pk>> a1:t1 {PK_SEG=1} <<pk,fk>> a2:t2 {PK_SEG=2} {FK=1} {FK_SEG=1} <<fk>> a3:t3 {FK=2} {FK_SEG=1} <<fk>> a4:t4 {FK=2} {FK_SEG=2}
...



Our solution based on **the operation signature semantics!**

Table
a1 : t1 a2 : t2 a3 : t3 a4 : t4
PK(a1:t1, a2:t2) FK_1(a2:t2) FK_2(a3:t3, a4:t4)

Direct advantages of this approach:

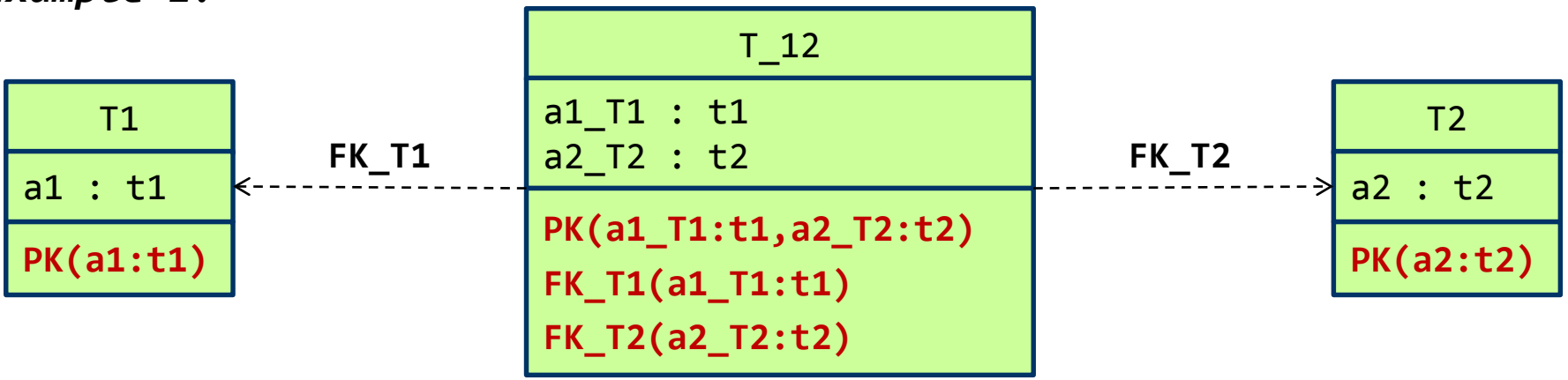
- RDBS is represented by **standard UML notation;**
- There is **no need to define and apply the specific profile**;
- **Modeling is easier and faster** than using the specialized notation;
- **Visualization is better** (without specific stereotypes, order of operation parameters represents the key's segments, order of the key segments is visible in the diagram).

D. Brdjanin, S. Maric, Z. S. Pavkovic: "On Suitability of Standard UML Notation for Relational Database Schema Representation", R. Schmidt et al. (Eds.): BPMDS/EMMSAD 2016, LNBIP 248, pp. 399–413, 2016.

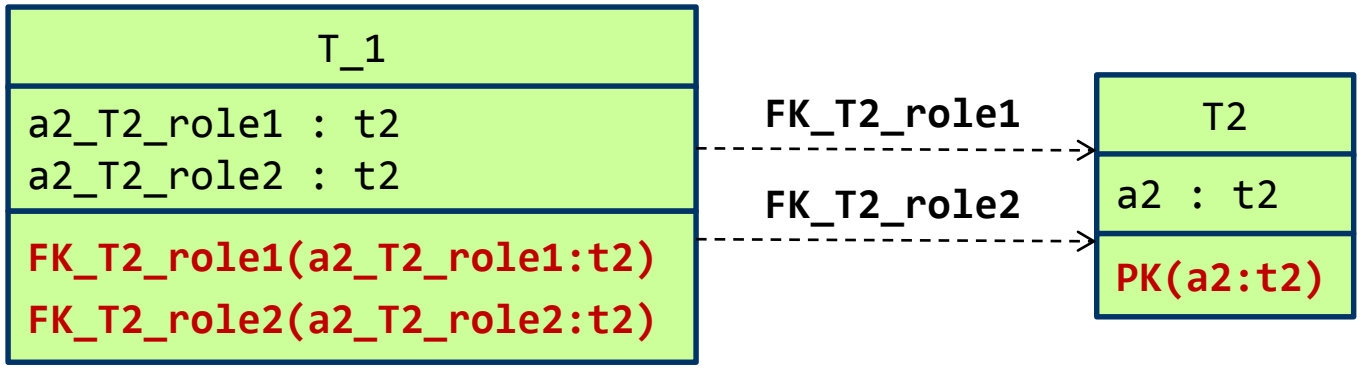
Representation of keys by class operations

How to deal with multiple foreign keys?

Example 1:



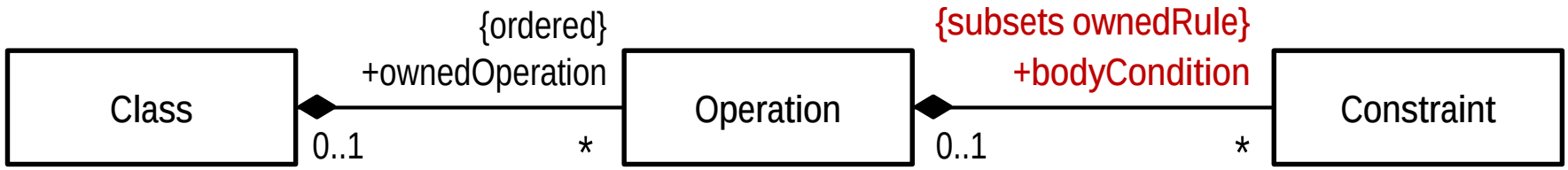
Example 2:



Specification of referential actions

How to specify referential actions for foreign keys?

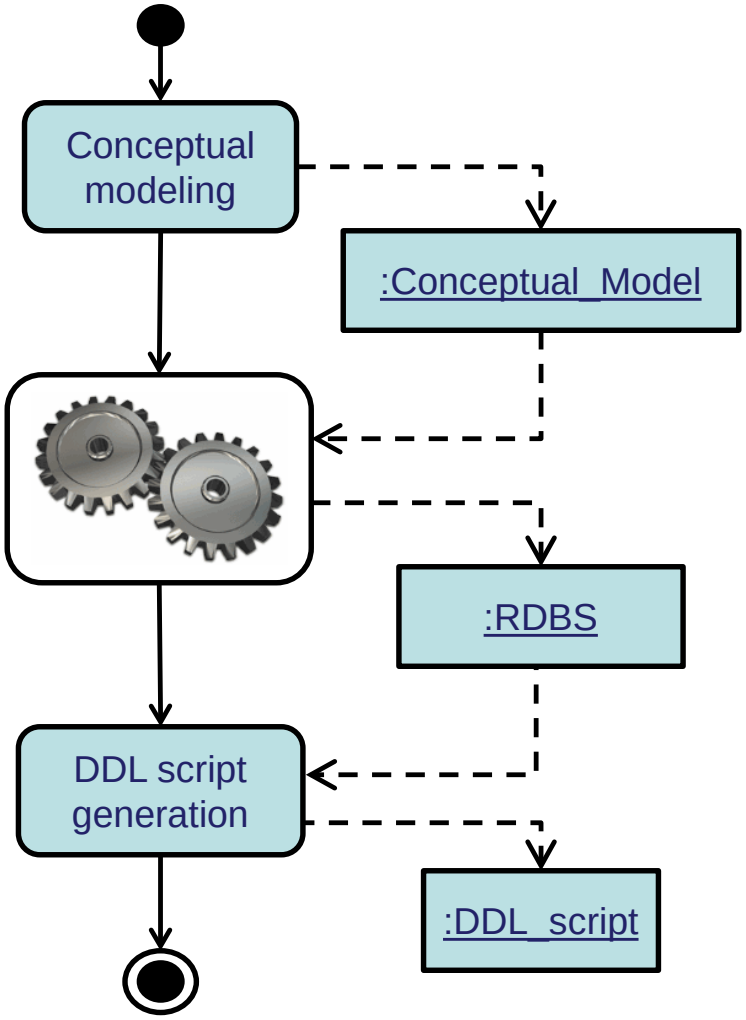
- UML allows specification of operation constraints.
- A set of constraints (`ownedRule`) can be specified for each operation.



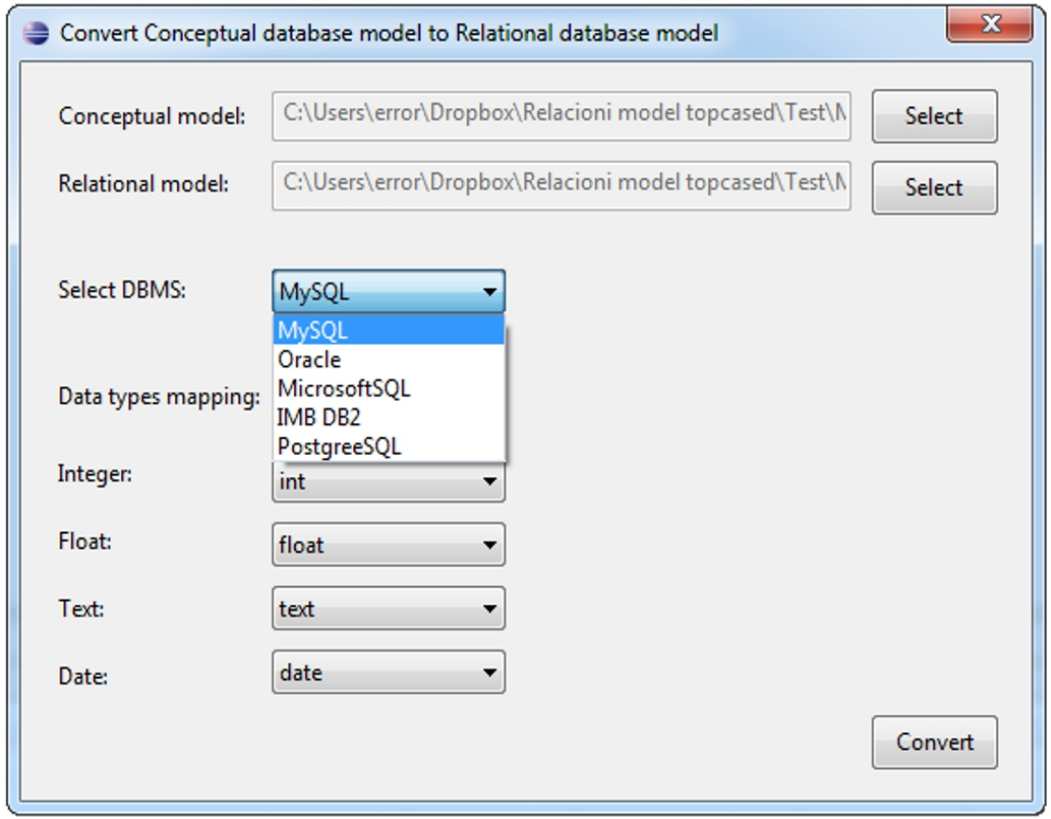
- **In our case, the appropriate constraint specifying the referential integrity actions, is to be defined for each operation representing the foreign key.**
- Although constraints can be specified by using the OCL, they can be specified in another way, as well.
- **The easiest way is to directly specify the DDL statement part**, e.g.

```
ON DELETE RESTRICT ON UPDATE CASCADE
```

Example of forward database engineering



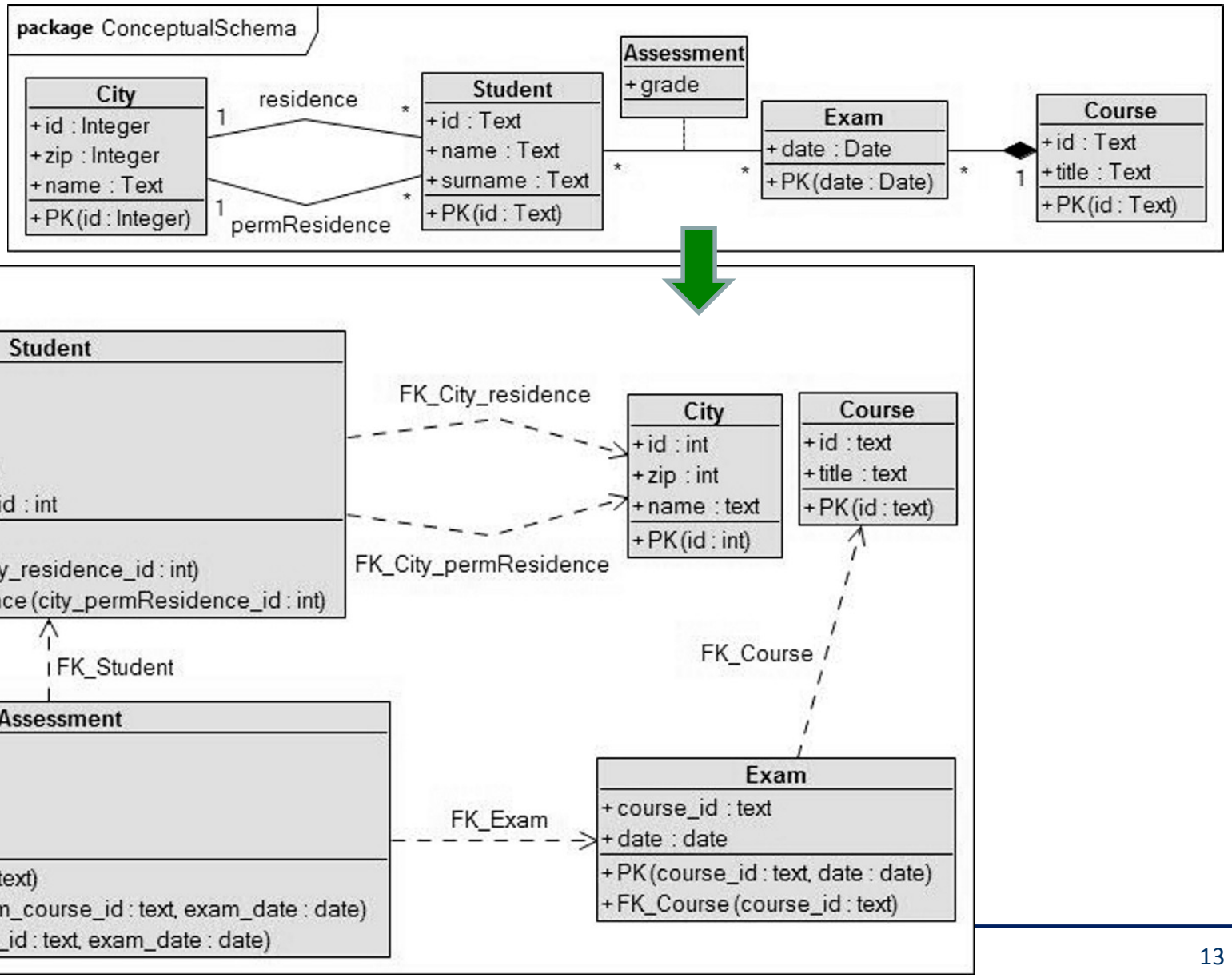
ECLIPSE-TOPCASED plug-in



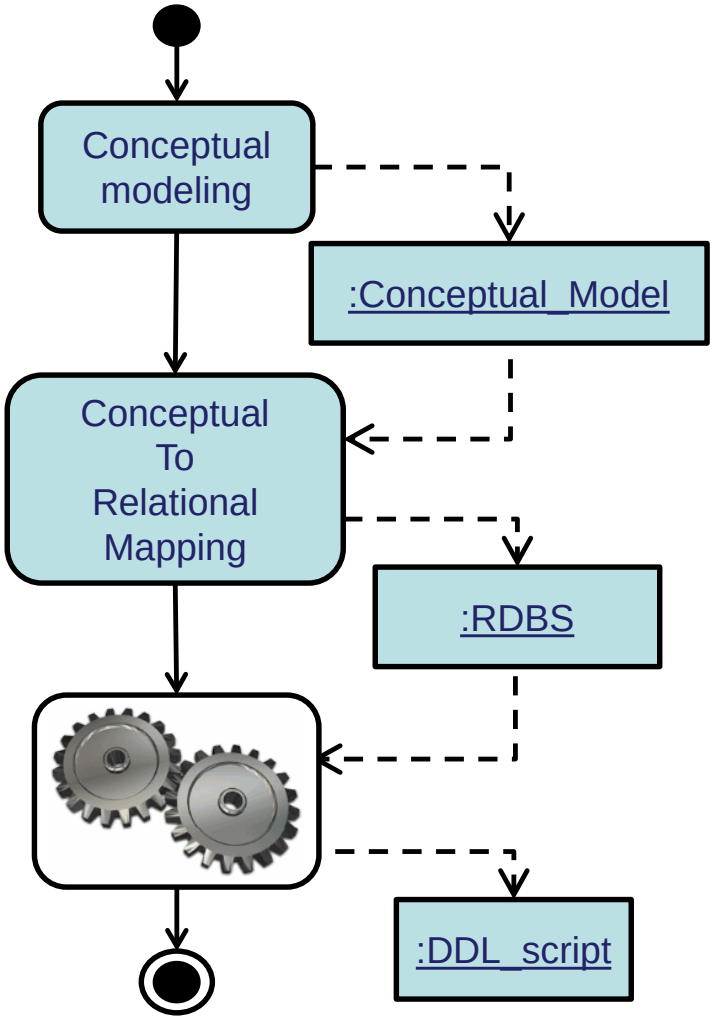
Z. Spasic Pavkovic, "UML-based Forward Engineering of Relational Database", Diploma Thesis (2016)

Z. S. Pavkovic and D. Brdjanin, "A UML-based approach to forward engineering of SQLite database", ZINC 2016 (Best Paper)

Example of forward database engineering



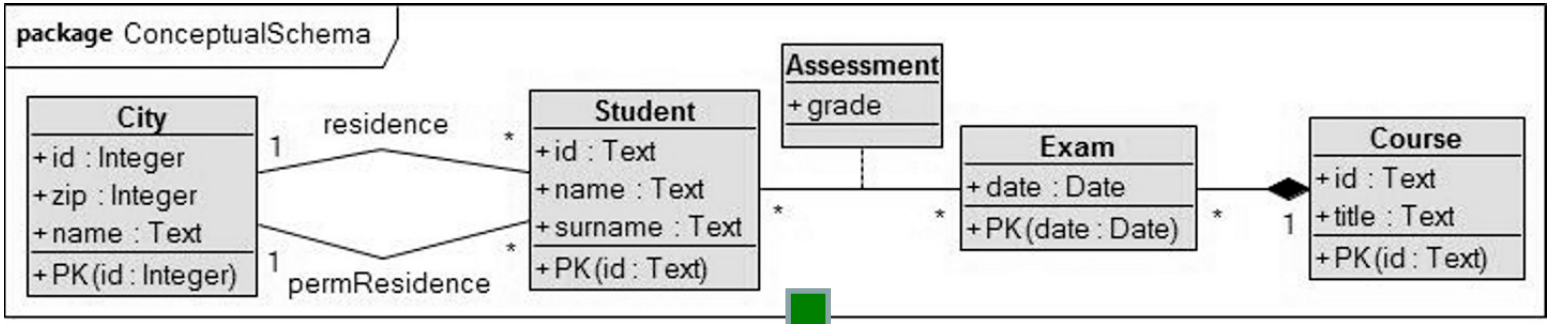
Example of forward database engineering




```
[comment encoding = UTF-8 /]
[module generate('http://www.eclipse.org/uml2/3.0.0/UML')]
[template public generateElement(aPackage : Package)]
[comment @main/]
[file (aPackage.name.concat('.ddl'), false, 'UTF-8')]
CREATE SCHEMA  [aPackage.name/];
  [for (aClass:Class | aPackage.ownedElement) after('\n')]
CREATE TABLE [aPackage.name.concat('.').concat(aClass.name)/]
(
  [for (aProperty:Property | aClass.ownedAttribute) separator('\n') after('\n')]
  [aProperty.name/] [aProperty.type.name/][if (aProperty.lower>0)] NOT NULL[/if],[/for]
  [for (aOperation:Operation | aClass.ownedOperation->
          select(o | o.name.startsWith('FK') or o.name.equalsIgnoreCase('PK')) )
   separator(',\n') after('\n')]
    [if (aOperation.name.equalsIgnoreCase('PK'))]
  PRIMARY KEY ([for (op:Parameter | aOperation.ownedParameter)
     separator(', ')][op.name/][/for])[/if]
    [if (aOperation.name.startsWith('FK'))]
  CONSTRAINT [aOperation.name/]
    FOREIGN KEY ([for (op:Parameter | aOperation.ownedParameter)
     separator(', ')][op.name/][/for])
    REFERENCES [for (aDependency:Dependency | aPackage.ownedElement)]
      [if (aDependency.name.equalsIgnoreCase(aOperation.name))]
[aPackage.name.concat('.')/][aDependency.supplier.name/][/if][/for]
[for (r:Constraint | aOperation.ownedRule)] [r.name/][/for][/if]
  [/for]
);
[/for] [/file]
[/template]
```

Acceleo transformation program (30 LOC!!!)

Example of forward database engineering




```
CREATE SCHEMA RDB_schema;
CREATE TABLE RDB_schema.Assessment
(
   student_id text NOT NULL,
   exam_course_id text NOT NULL,
   exam_date date NOT NULL,
   grade int NOT NULL,
   PRIMARY KEY (student_id, exam_course_id, exam_date),
   CONSTRAINT FK_Student
      FOREIGN KEY (student_id)
      REFERENCES RDB_schema.Student ON DELETE RESTRICT ON UPDATE CASCADE,
   CONSTRAINT FK_Exam
      FOREIGN KEY (exam_course_id, exam_date)
      REFERENCES RDB_schema.Exam ON UPDATE CASCADE ON DELETE RESTRICT
);
...
```

Conclusion

- UML has a **built-in mechanism for representation of primary keys**, but **there are no concepts for representation of other RDBS concepts** (foreign keys, indices, etc).
- In this presentation we presented a simple **representation of composite keys by using class operations.** The main idea of the proposed approach is based on the fact that the **standardized order of operation parameters can be used to represent the order of key segments** (primary, foreign, alternate).
- This approach has several direct advantages compared to the existing approaches:
  - RDBS is represented by standard UML;
  - there is no need to define and apply the specific profile;
  - modeling of RDBS is easier and faster than using the specialized notation;
  - visualization of RDBS is better;
  - forward database engineering is easier and more efficient.
- In the future work we will focus on:
  - further analysis of the suitability of standard UML notation to represent other important RDBS-related concepts (indices, views, queries, triggers, etc.),
  - integrating the implemented tool in the ADBdesign tool for automated MDD of RDBS.

Simple UML Representation of Relational Database Schema

Thank You!