30. Analysis in Graphware: Graph Querying, Metrics, Flat Analysis and Megamodel Dependency Analysis

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    1) Relational Schema
    2) Entity-Relationship Diagrams
    3) MOF and ERD
2) Graph Query Languages
    1) .QL
    2) Metrics with .QL
    3) TGreQL
3) Megamodel Dependency Analysis
4) Model Invariant Specification
    1) OCL
    2) Spider Diagrams
    3) RUML

Obligatory Literature

- http://en.wikipedia.org/wiki/List_of_UML_tools
- http://en.wikipedia.org/wiki/Entity-relationship_model
- http://www.utexas.edu/its/archive/windows/database/datamodeling/index.html
- [deMoor] Oege de Moor, Mathieu Verbaere, Elnar Hajiyev, Pavel Avgustinov, Torbjorn Ekman, Neil Ongkingco, Damien Sereni, Julian Tibble, "Keynote Address: .QL for Source Code Analysis", SCAM, 2007, 2013 IEEE 13th International Working Conference on Source Code Analysis and Manipulation (SCAM), 2013 IEEE 13th International Working Conference on Source Code Analysis and Manipulation (SCAM) 2007, pp. 3-16, doi:10.1109/SCAM.2007.31

References

- [Chen] P. P.-S. Chen. The entity-relationship model - towards a unified view of data. Transactions on Database Systems, 1(1):9-36, 1976
- A Comparison of ATL and Story-Driven Modeling (Fujaba-style GRS)

http://www.es.tu-darmstadt.de/fileadmin/download/publications/spatzina/PP_AGTIVE_201

Obligatorische Literatur

- http://en.wikipedia.org/wiki/List_of_UML_tools
- http://en.wikipedia.org/wiki/Entity-relationship_model
- http://www.utexas.edu/its/archive/windows/database/datamodeling/index.html
- Sebastian Schaffert, François Bry. Querying the Web Reconsidered: A Practical Introduction to Xcerpt (2004). In Proc. Extreme Markup Languages.
  - http://www.pms.informatik.uni-muenchen.de/publikationen/PMS-FB/PMS-FB-2004-7.pdf

http://www.rewerse.net/publications/download/REWERSE-RP-2006-069.pdf

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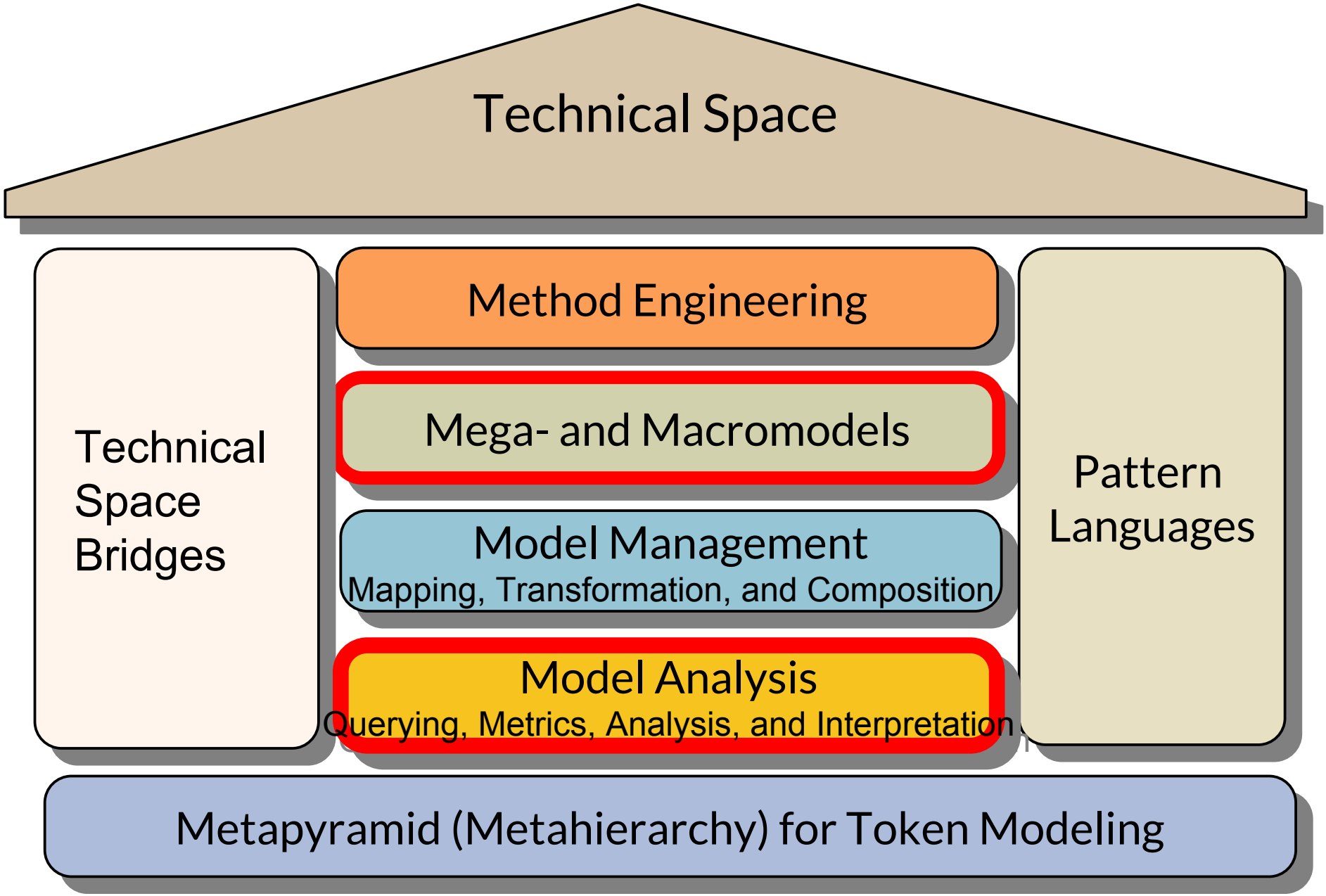
Datenkataloge als Grundlage für Informationssysteme und Softwarewerkzeuge

- Ein **Datenkatalog (data dictionary, schema)** enthält alle Modelle und Typen von Daten, die in einem System benutzt werden
  - Der Datenkatalog *typisiert* die Datenablage oder den Datenstrom
  - Datenkataloge können lokal zu einer Anwendung, zu mehreren oder zum ganzen Unternehmen und der Zuliefererkette bezogen sein
- Ein **homogener Datenkatalog** wird in *einer* DDL, ein **heterogener Datenkatalog** in mehreren DDL spezifiziert
  - EBNF definiert Stringsprachen, d.h. Setn von Strings oder Typen
  - Relationales Model (RM) definiert Relationen und Tabellen
  - XML Schema (XSD) definiert Baumsprachen, d.h. Setn von Baum-Typen
  - ERD oder UML-Klassendiagramm definieren Graph-Modelle
- Ein **Informationssystem** ist ein Softwaresystem, das Datenanalysen über einer **Datenablage** (einem **Repositorium**) durchführt.
  - Informationssysteme werden in den Datenbank-Vorlesungen gesondert betrachtet
  - Data warehouses, business intelligence, data analytics
- Ein **strombasiertes Informationssystem** ist ein Softwaresystem, das Datenanalysen über einem Datenstrom durchführt.

Q10: The House of a Technical Space



Flat and Deep Model and Code Analysis

- DQL answer questions about the materials in a repository or in a stream
  - Analytics for one document alone (metrics, “Business Intelligence”)
  - Filtering of a stream
  - Combining input streams

CQL do the same for programs and models:

- **Flat model analysis** asks questions on
  - the direct context of a model element (context-free queries, pattern matching)
  - the global knowledge about a model element
- **Deep model analysis** (value flow analysis, data-flow analysis, inter-procedural analysis, inter-component analysis) respects the main structure of a model and asks the question
  - whether certain parts of a model are reachable from each other (connected)
  - what is the context of a model element in a structured environment (abstract syntax tree, control flow graph, value flow graph, dependency graph)
  - where do attributes flow (in an attribution)
- **Software metrics:** counting objects, relationships, dependencies
- **Inter-model dependencies** between models in a megamodel

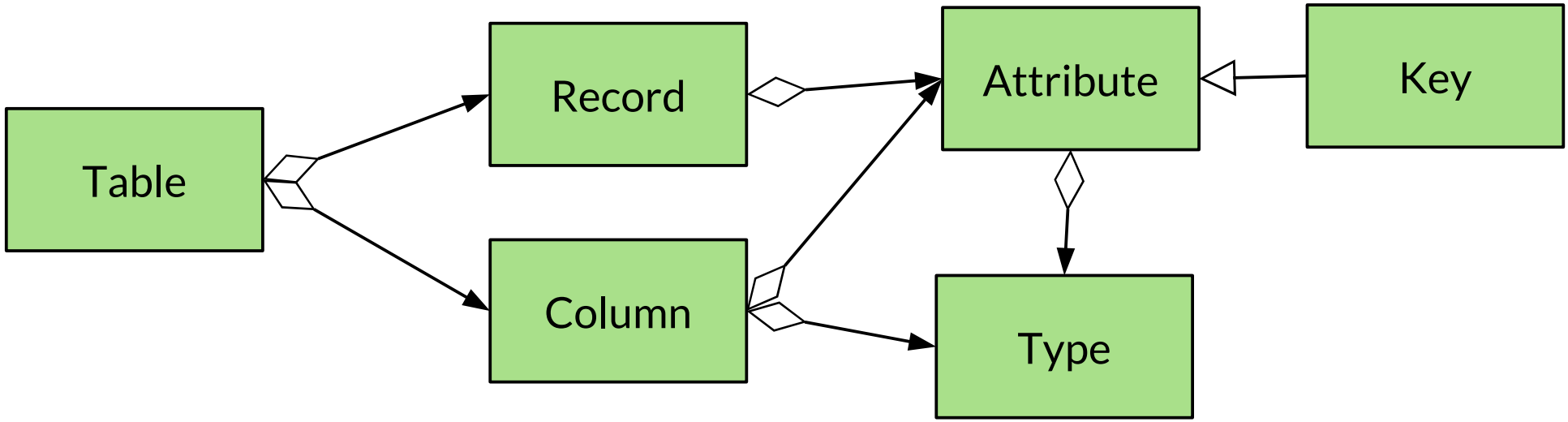
30.1 DDL in the Graph-Based Technical Spaces

30.1.1 Technical Space RelationWare with DDL Relational Schema

Relational Algebra works with *typed relations*

Technical Space Relational Algebra mit Metalanguage Relational Schema

- Relational Algebra (Codd) works on tables of tuples with attributes
  - See courses on databases



Relational Schema Metamodel

Key	FirstName	Surname	Street	Town
@1	Uwe	Aßmann	Bakerstreet 5	New York
@2	Frank	Miller	Northstreet 9	Pittsburgh
@3	Mary	Baker	Magdalenstreet	Oxford

30.1.2 Technical Space ER-Ware with DDL Entity-Relationship-Diagrams (ERD)

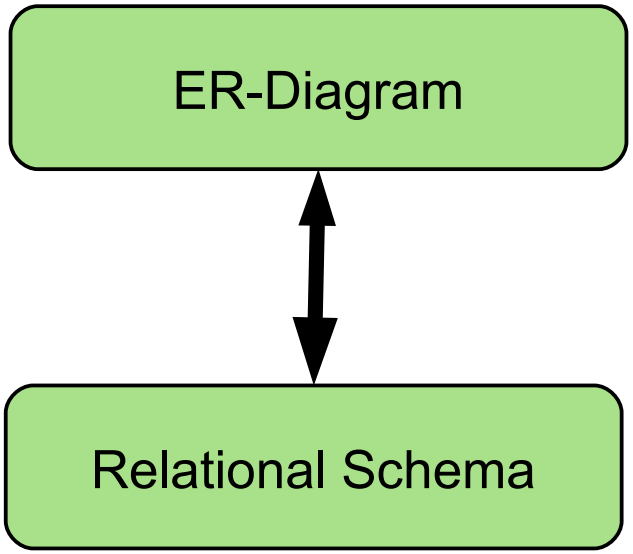
A Simple DDL/CDL with Mapping to the Relational Algebra

Relations and Entities (without inheritance)

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Modeling with Entity-Relationship-Diagrams (ERD)

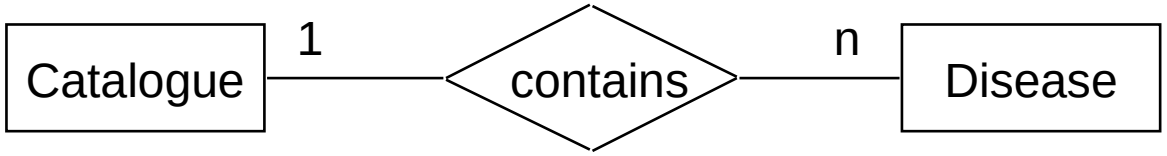
- ERD can be mapped easily to relational schema (with an invertible 1:n-mapping, **ER-RS-mapping**)
  - Entities form special relations with “identifer” (key, surrogate)
  - ER-diagrams can be stored easily in databases (simple persistence)
- ERD is often used as CDL in larger integrated development environments (simple persistence of code and models)



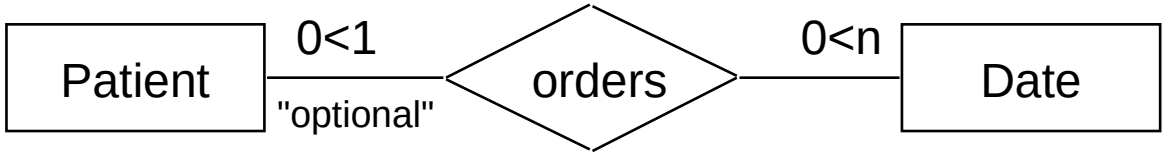
ERD-Relationships in Chen-Notation (unlike UML)

- All “entities” (classes) are represented as “entity-”tables

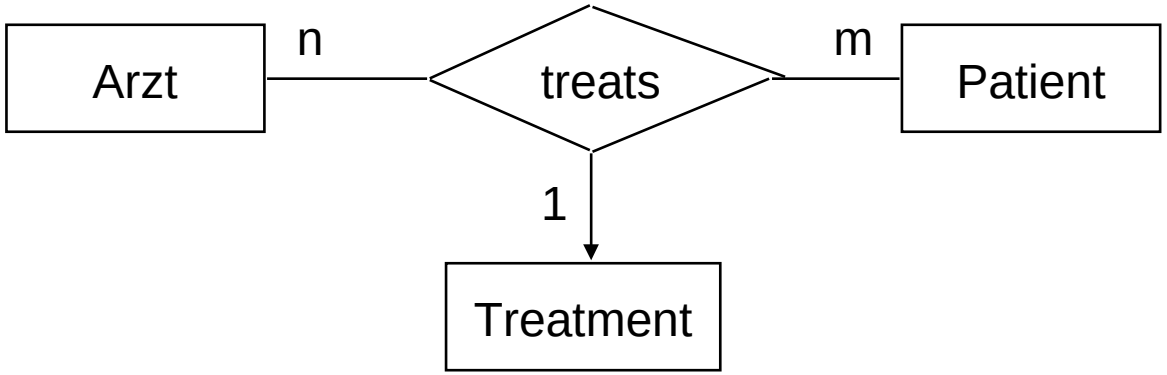
Cardinality



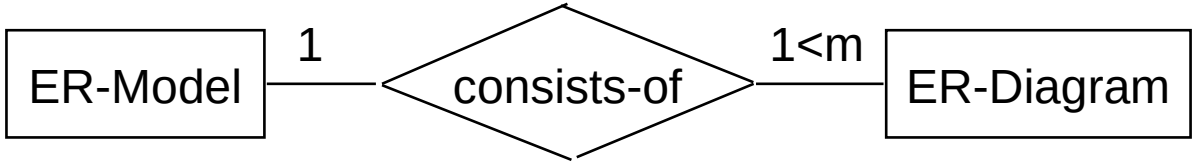
optional relationship



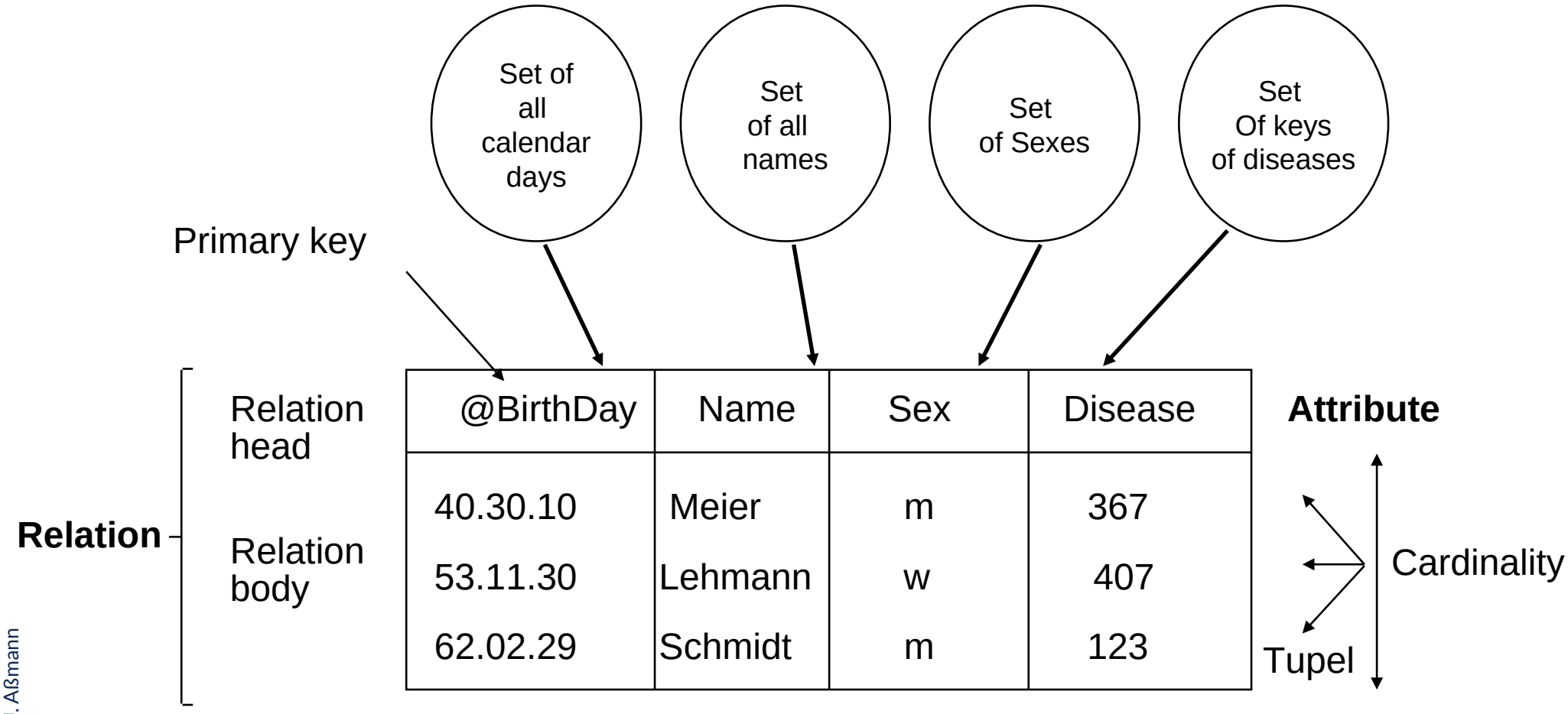
N-ary associations



Hierarchic Modeling

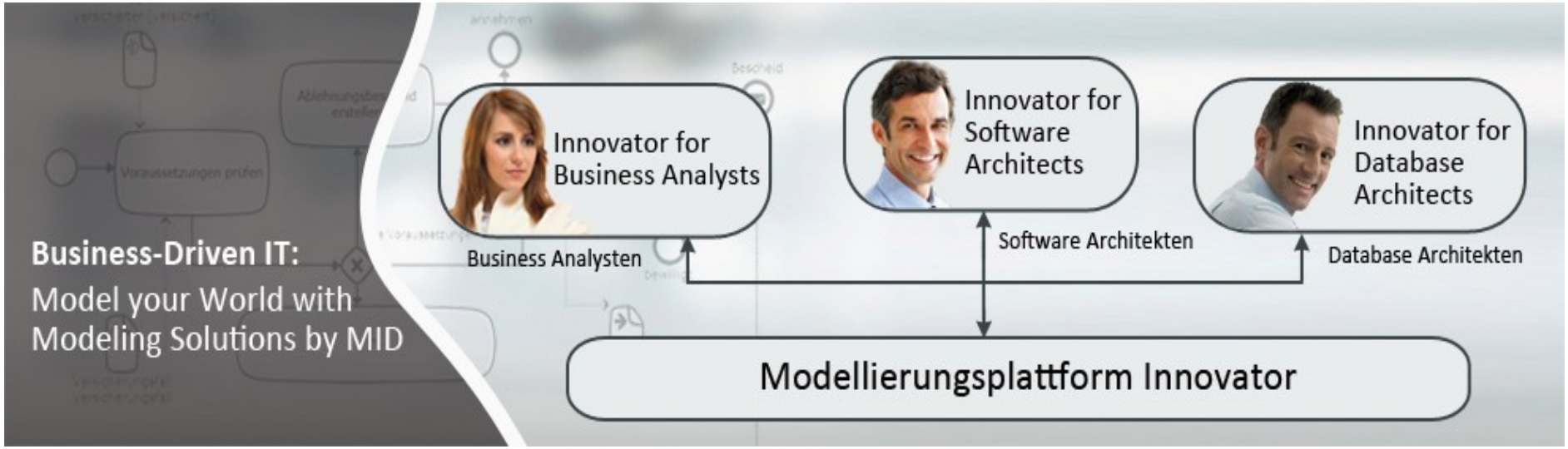


Mapping of Entity Type "Patient" to the Relational Schema



Importance of ERD

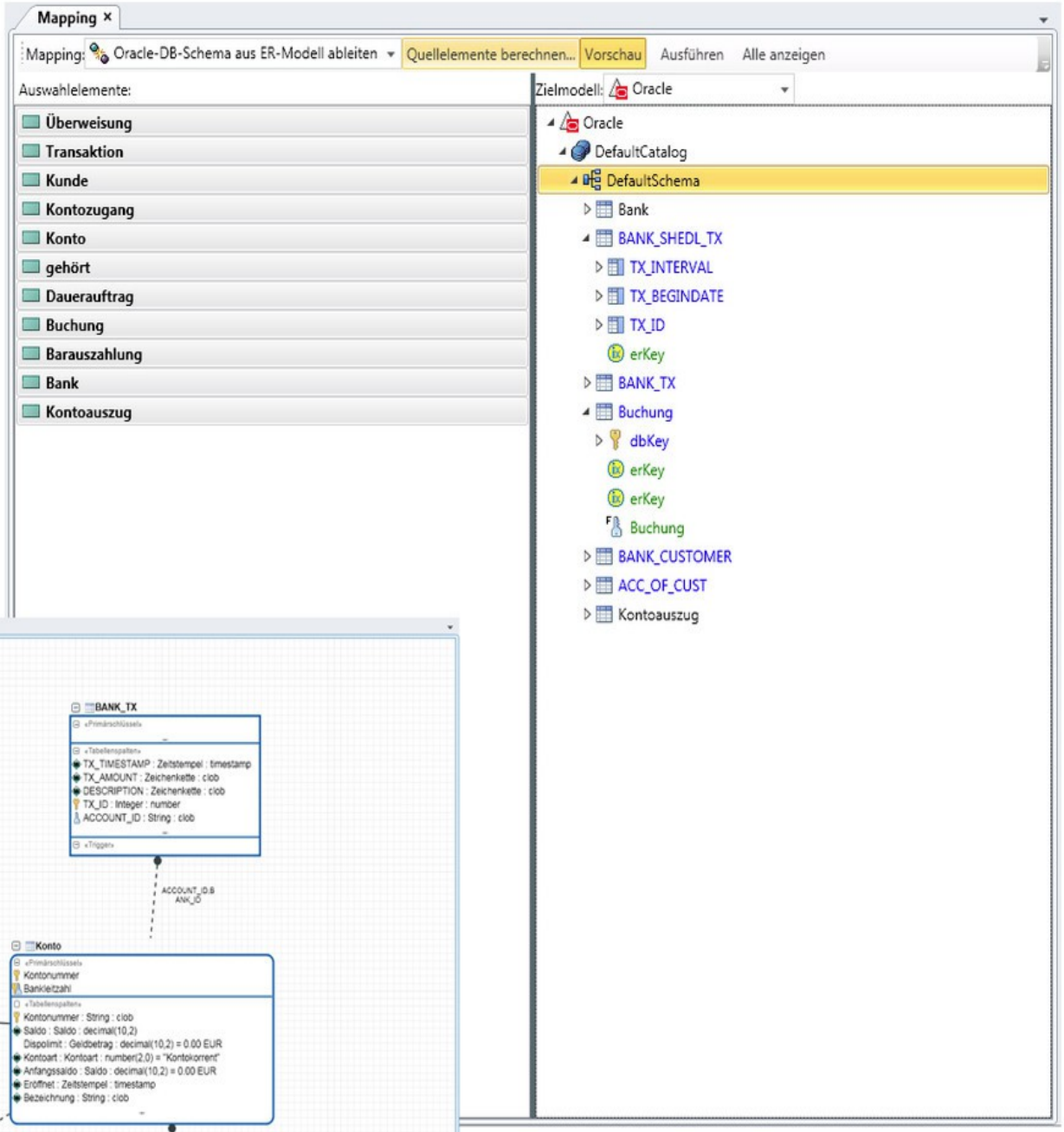
- ERD is the “better” relational schema, because it treats objects (entities)
  - Often used for data dictionaries in information systems
- ERD, however, does not support inheritance
  - Applications can easier be verified, e.g., for embedded or safety-critical systems
- Typical Tool: MID Innovator for database architects:

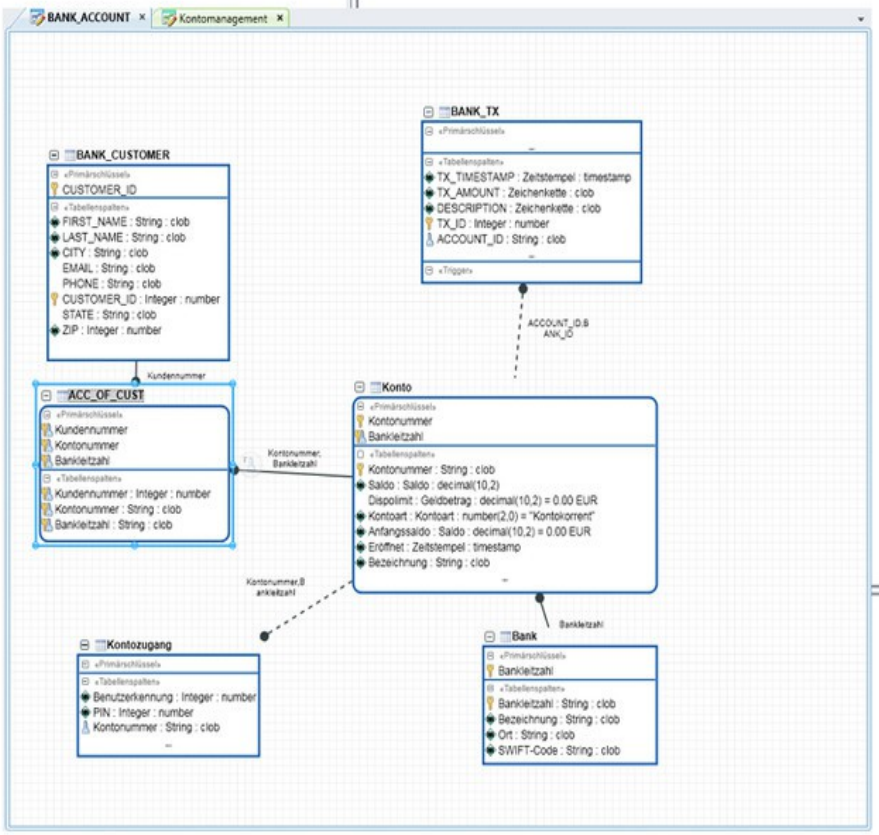


http://www.mid.de/index.php?id=541
http://www.mid.de/uploads/pics/Banner_Modellierungsplattform_03.jpg

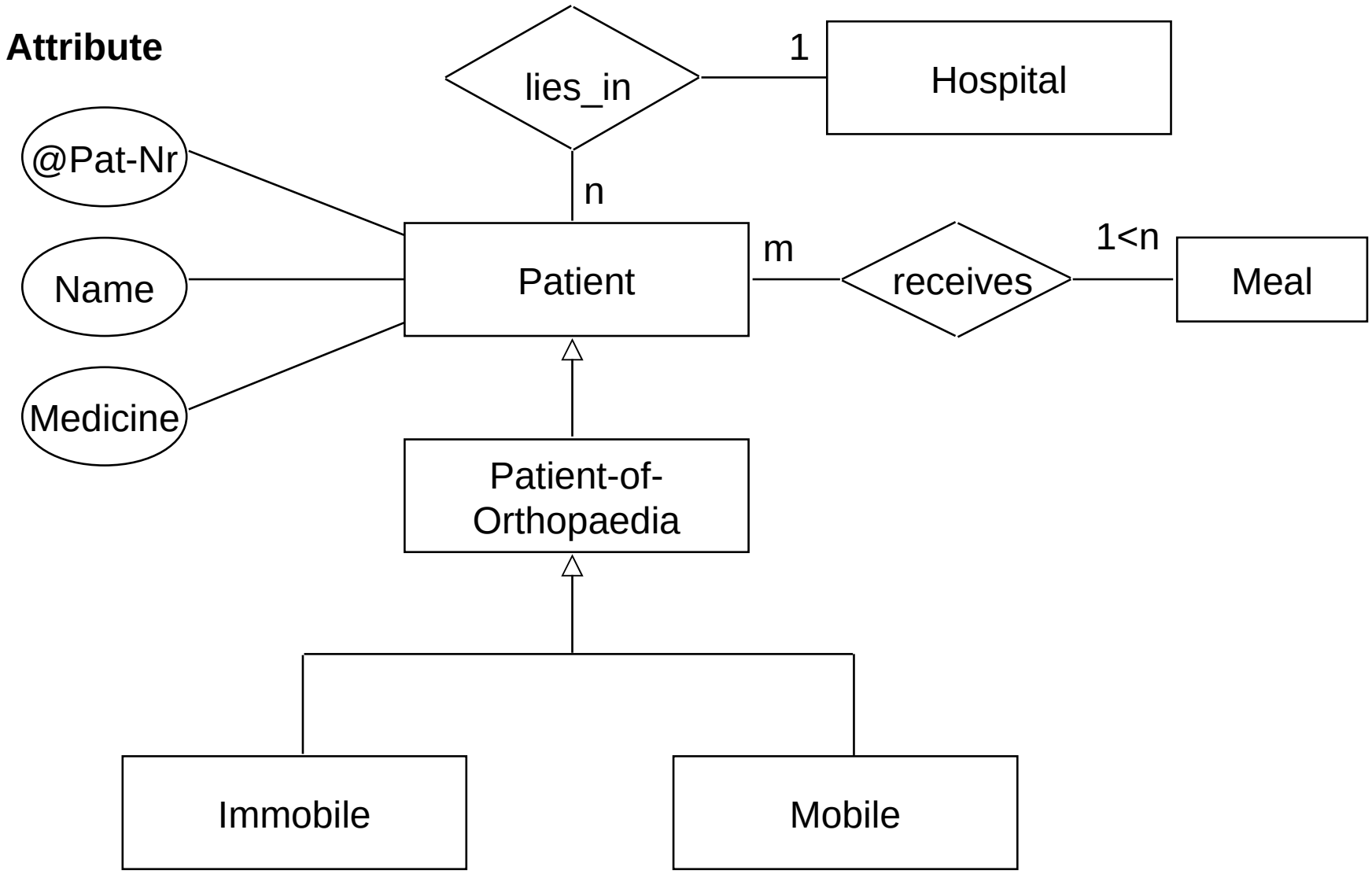
Mapping ERD to RS in MID

http://www.mid.de/typo3temp/pics/f0df65b8a2.jpg

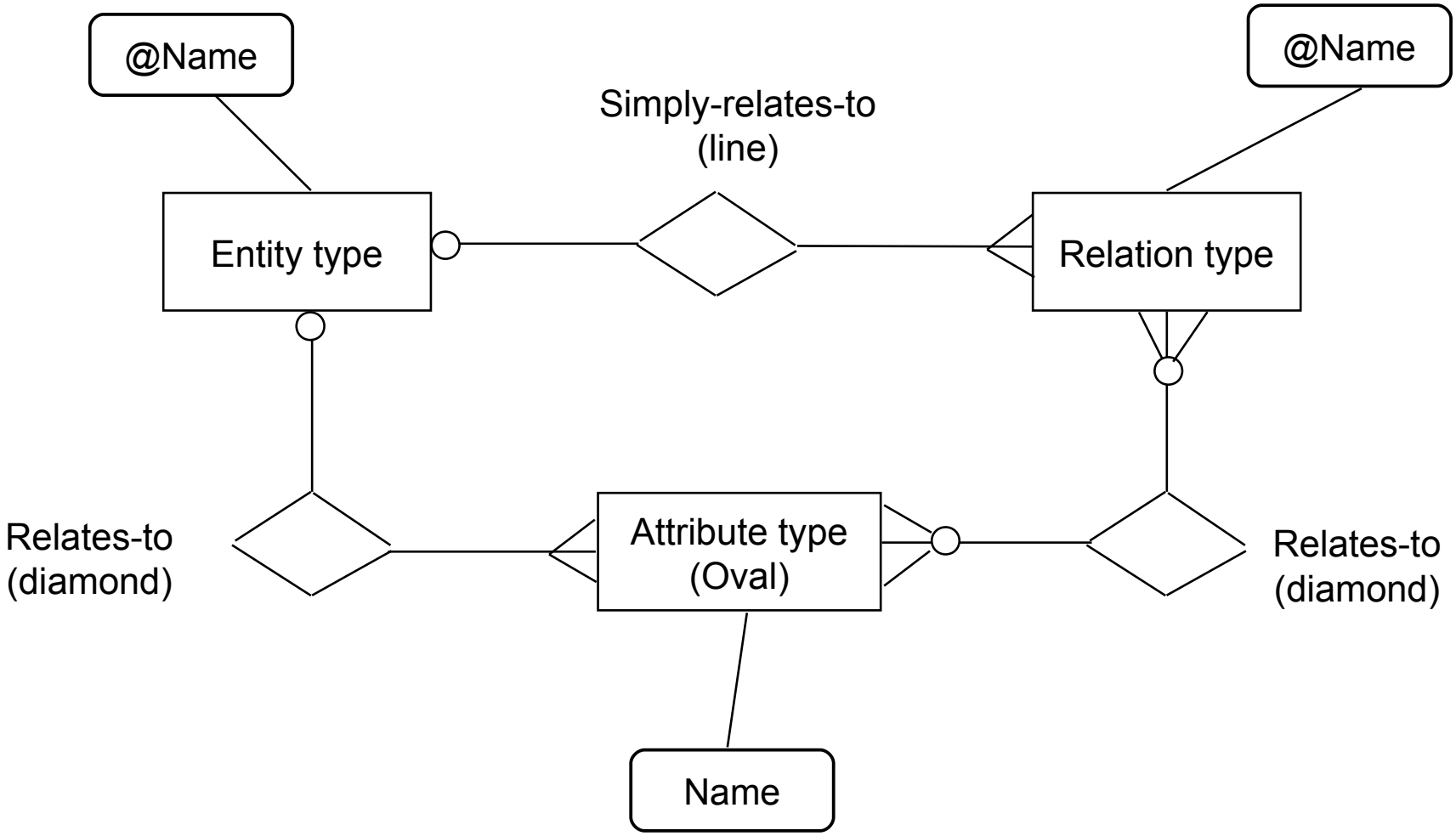




Extended ERD (EERD) Uses Inheritance
Example: Patient Record

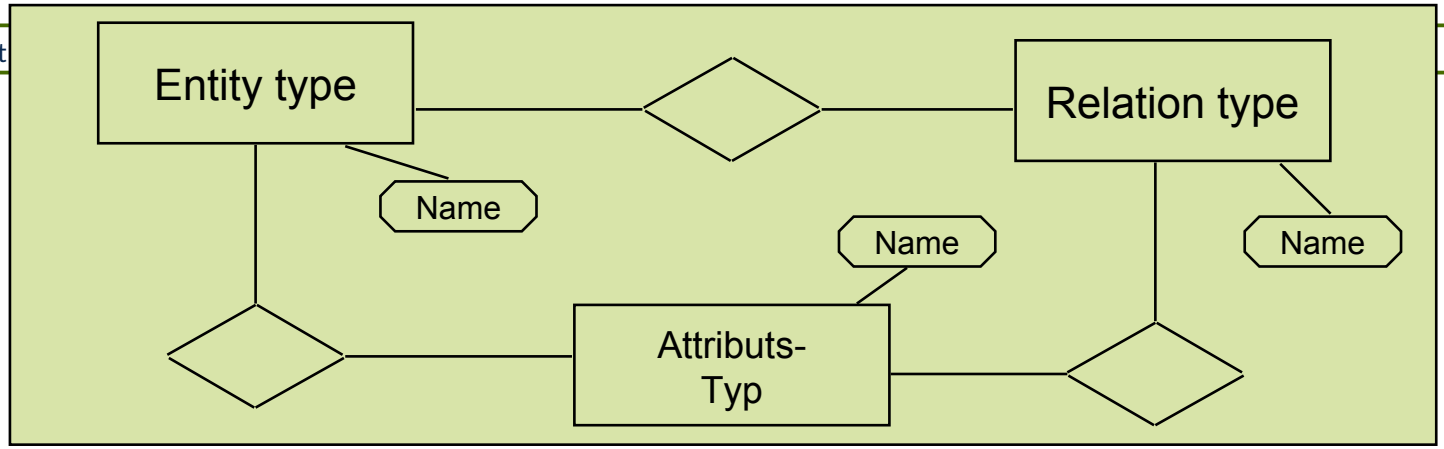


The Metamodel of ERD in ERD (lifted ERD Metamodel)

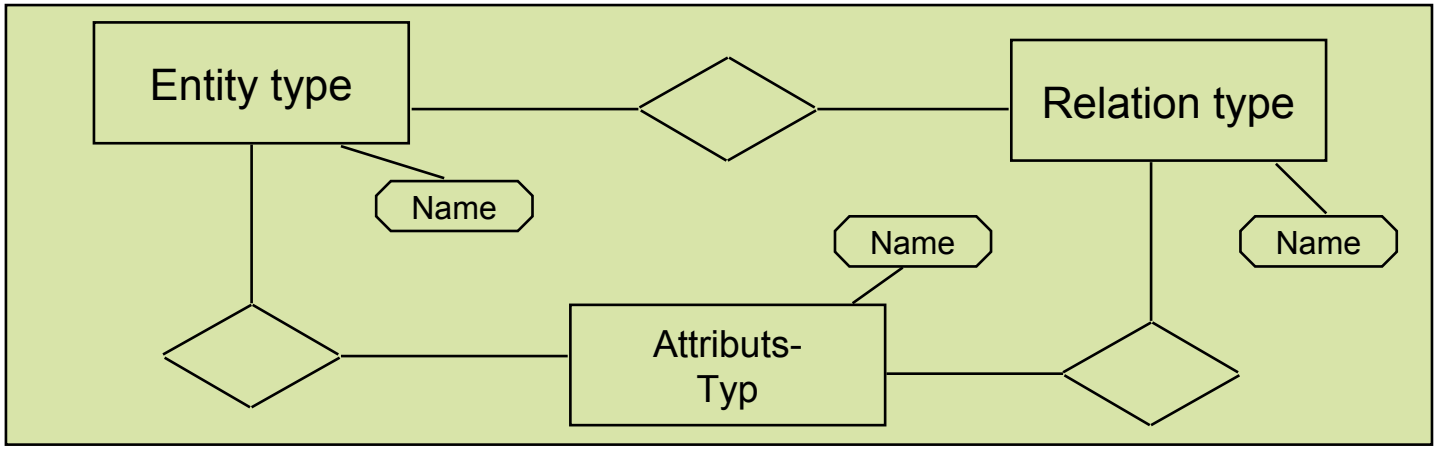


Metahierarchy with ERD as Metalanguage (lifted metamodel)

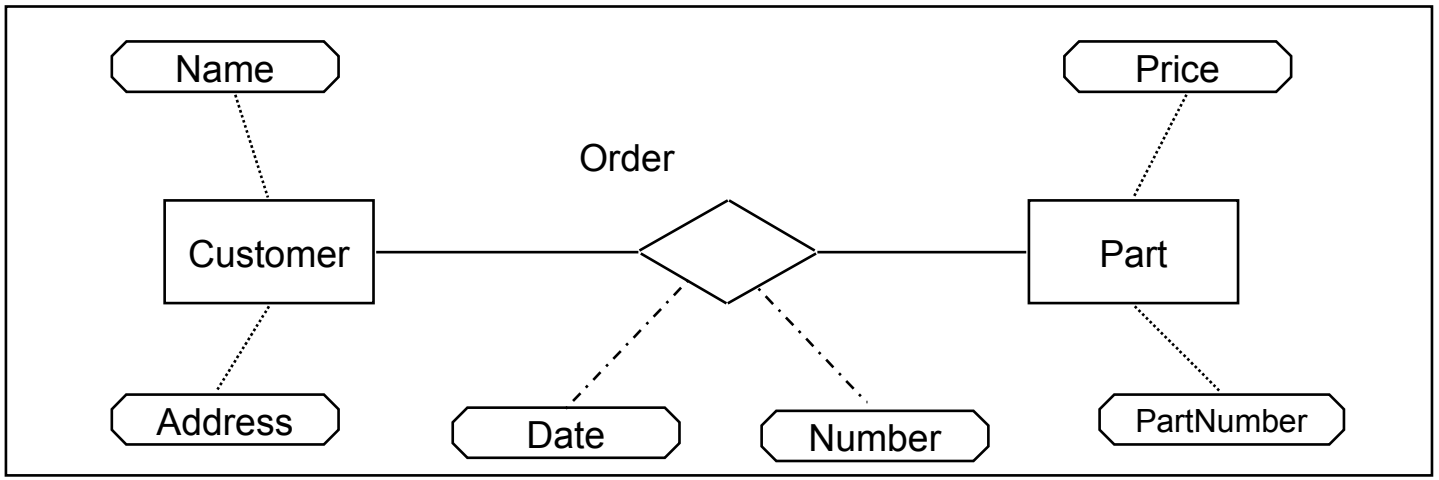
M3 **Metametamodel**



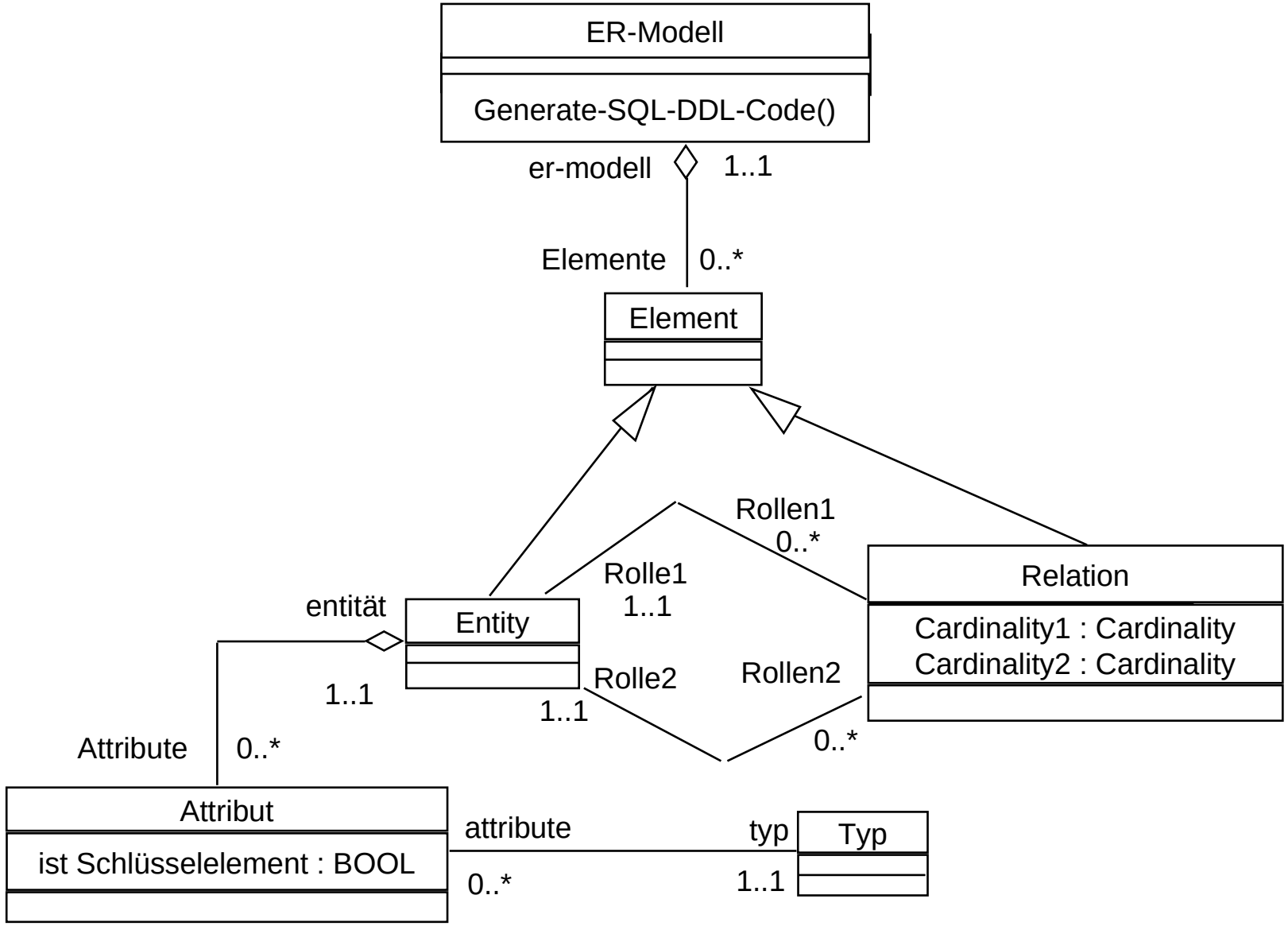
M2 **Metamodels**



M1 **Models**

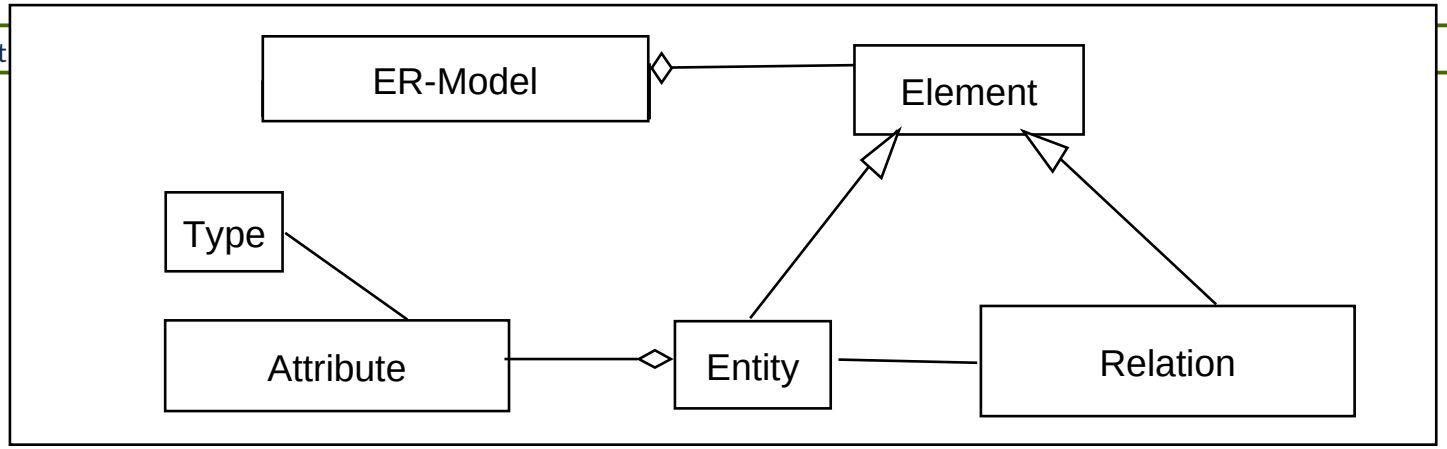


MOF is ERD with Inheritance
Meta-Modell of Entity-Relationship-Diagramms (in MOF)

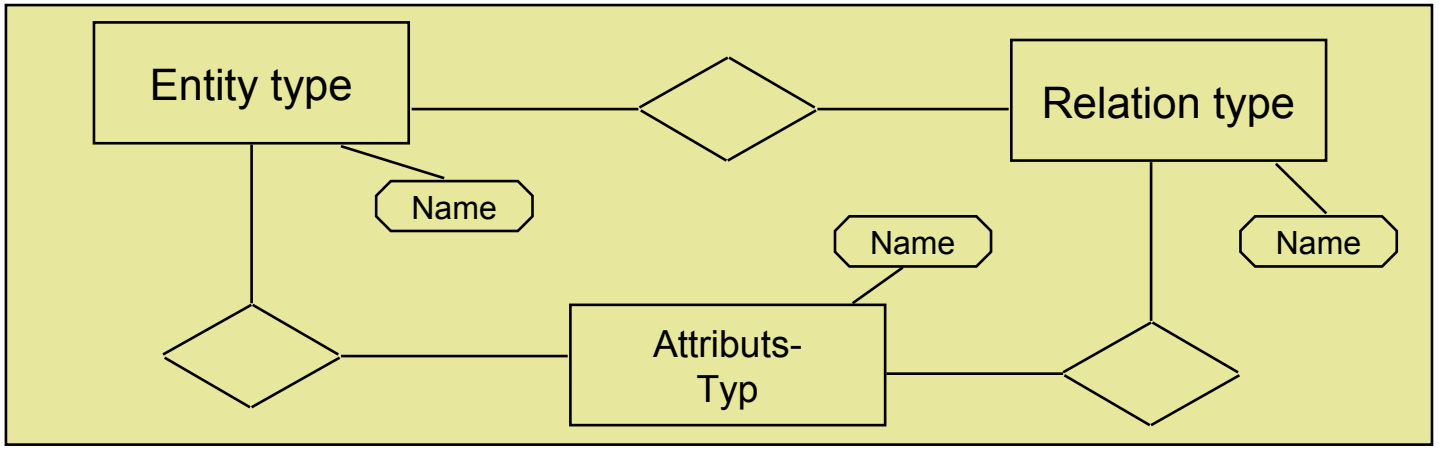


Metahierarchy with MOF as Metalanguage (non-lifted)

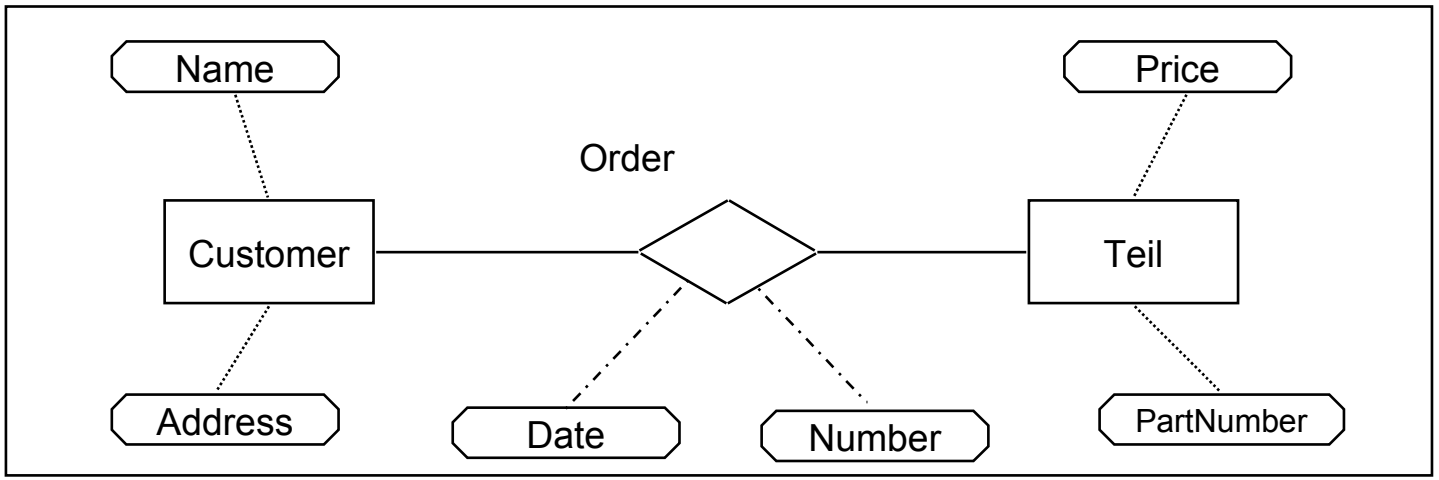
M3 **Metametamodel**



M2 **Metamodels**

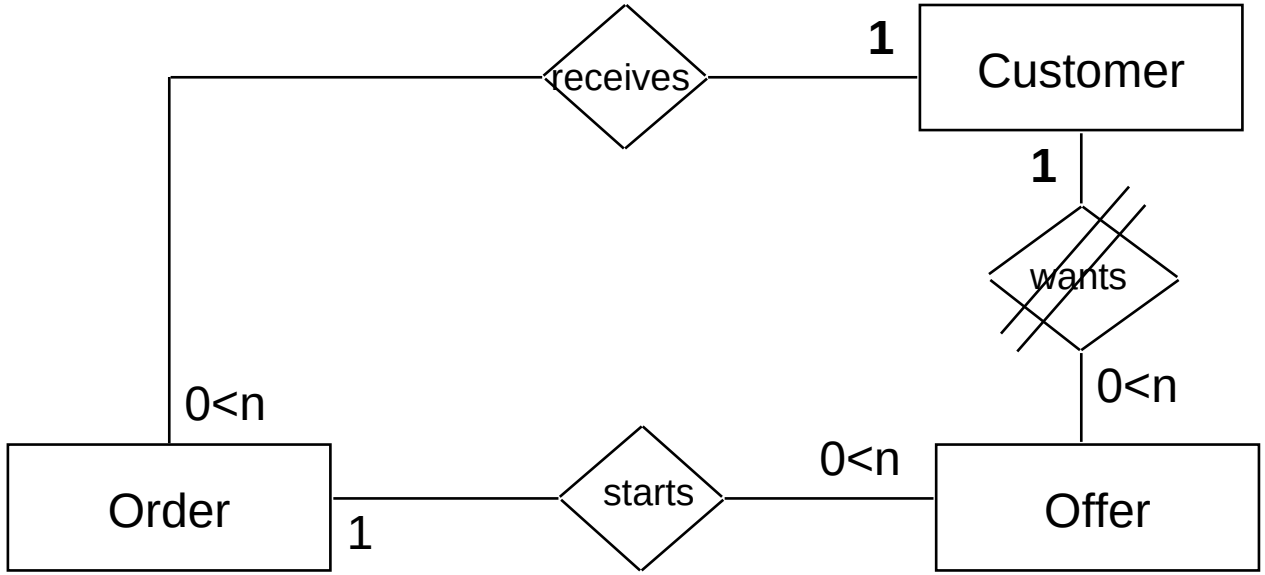


M1 **Models**



Consistency Constraints in ERD Models

- An ERD can contain integrity constraints (consistency constraints)
- Ex.: **Cycle-freedom constraint:** Check: find cycles in the graph of a ER diagram
- Correct by
  - cutting a cycle at the least important position (human intervention)
  - Finding a spanning tree and cutting all other edges
- Instead of cutting, edges can be made secondary links (then we have link trees)



after: [Raasch]

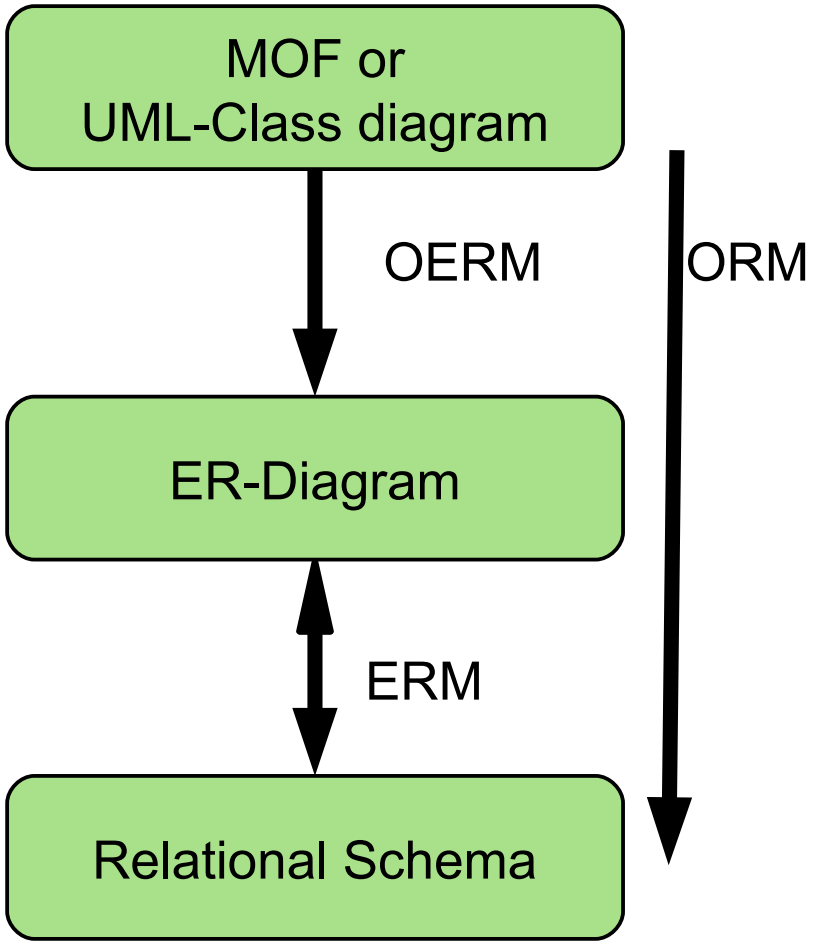
Other Consistency Constraints of ER-Models

- **Range checks** for attributes
- **Key dependencies (functional dependencies):**
  - Uniqueness of attribute values: An attribute K of a relation R is a key candidate, if only one tuple has the same value of K
  - Key minimality: Is the attribute K compound, no component can be removed to loose the key condition.
  - Primary key serves for identification of a tuple (“entity check”)
  - Secondary keys: other keys
  - Foreign key reference (primary key reference): A foreign key (link) is referencing a tuple in another relation by its primary key
- **Referential Integrity**
  - The model does not contain undefined foreign keys (links)
  - i.e., all names (links) can be resolved by name analysis

30.1.3 MOF and ERD

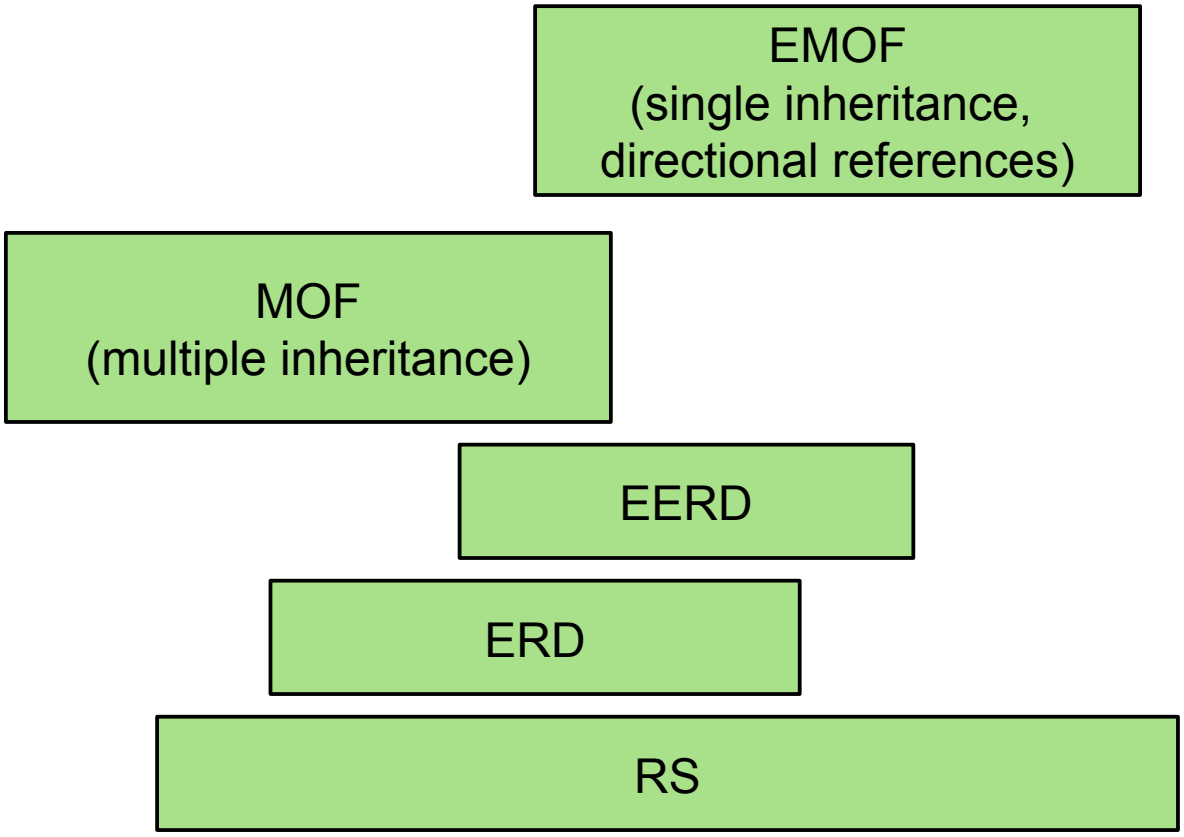
Data Modeling for Information Systems (Object-Relational Mapping, ORM) with UML-CD, ERD and RS

- For persistence, objects should be stored with an object-relational mapping to a database (OR-Mapping)
- (Indeterministic) OERM-Mapping of class diagrams to ERD
  - Inheritance mapping
  - Identification of keys (primary, secondary, foreign)
  - Resolution of multiple inheritance by copying
  - Cannot be inverted automatically
- Between ERD und RS exists a bidirectional mapping (ER-Mapping) by which the data models can be synchronized (restored without information loss)



The Difference of ERD, MOF and EMOF

- MOF extends ERD with multiple inheritance and method signatures
- However, MOF must be mapped down to Java
  - Inheritance
  - Bidirectional associations
- EMOF has only directed references, no bidirectional associations
  - Only simple inheritance
- EMOF can directly be mapped down to Java, C++, or C#



30.2 Flat Model Analysis with Graph Query Languages (Graph QL)

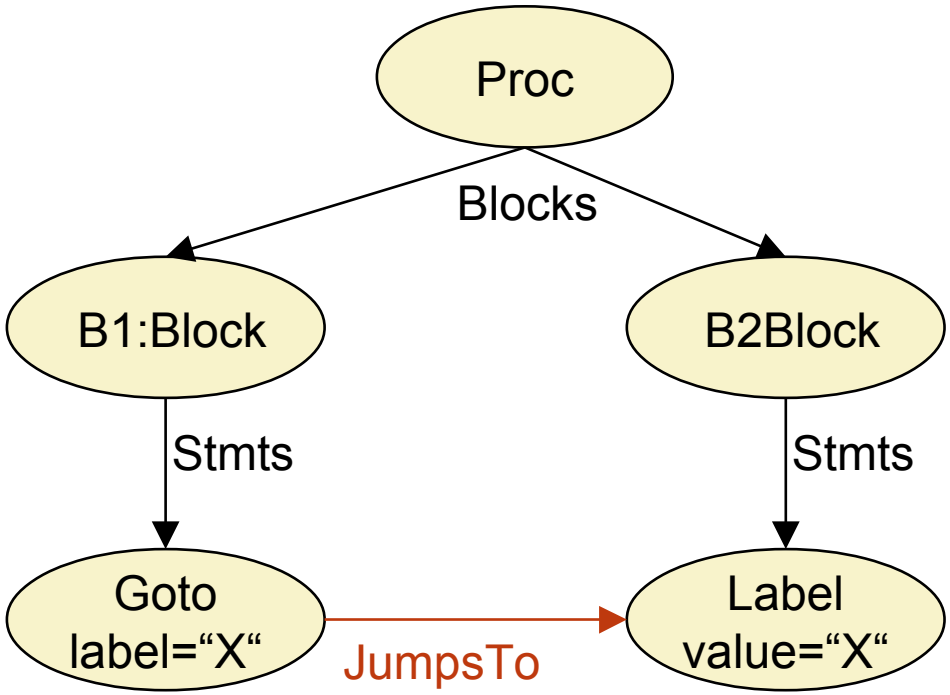
DQL – Data Query Languages

CQL – Code Query Languages

Graph Pattern Matching of Non-Tree Patterns

- **Graph pattern matching** works by mapping a graph pattern (graphlet) to the manipulated graph.
- Ex.: Linking gotos and Block-entry statements to build up the control-flow graph

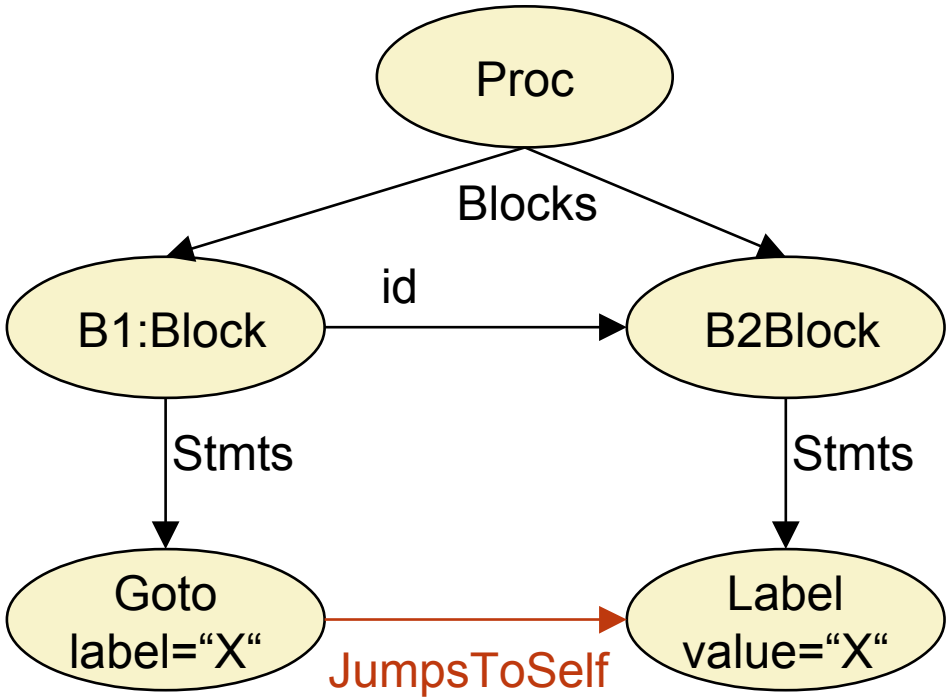
```
-- Datalog notation:
JumpsTo(Goto,Label) :-
    Blocks(Proc,B1:Block),
    Blocks(Proc,B2:Block),
    Stmts(B1,Goto),Stmts(B2,Label),
    Goto.label==X, Label.value==X.
-- if-then rules:
If  Blocks(Proc,B1:Block),
    Blocks(Proc,B2:Block),
    Stmts(B1,Goto),Stmts(B2,Label),
    Goto.label==X, Label.value==X
Then
    JumpsTo(Goto,Label).
– regular expression notation (TGreQL):
JumpsTo := Proc.Blocks.Stmts.Goto.label(X)
   AND Prod.Blocks.Stmts.Label.value(X)
```



Pattern Matching of Non-Tree Patterns

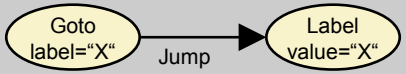
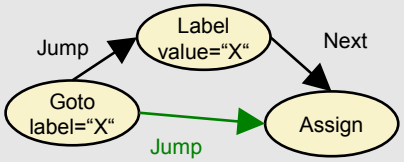
- Block self edges point back on their own block

```
-- Datalog notation:
JumpsToSelf(Goto,Label) :-
    Blocks(Proc,B1:Block),
    Blocks(Proc,B2:Block),id(B1,B2)
    Stmts(B1,Goto),Stmts(B2,Label),
    Goto.label==X, Label.value==X.
```



Different Notations for Node-Edge Patterns

- For notation of edges (and predicates), textual as well as graphical notations exist

	Datalog Prolog	Graphic (Optimix, EARS)	Textual graphics (TgreQL, GrGen)	Juxtaposition	Object-oriented (.QL)
edges	e(N,M)		-N-e-M-> N -e-> M	N e M	N.e(M)
recursion	r(N,M) :- e(N,Z), r(Z,M)		N -e*⟶ M	N e* M	N.e*(M)

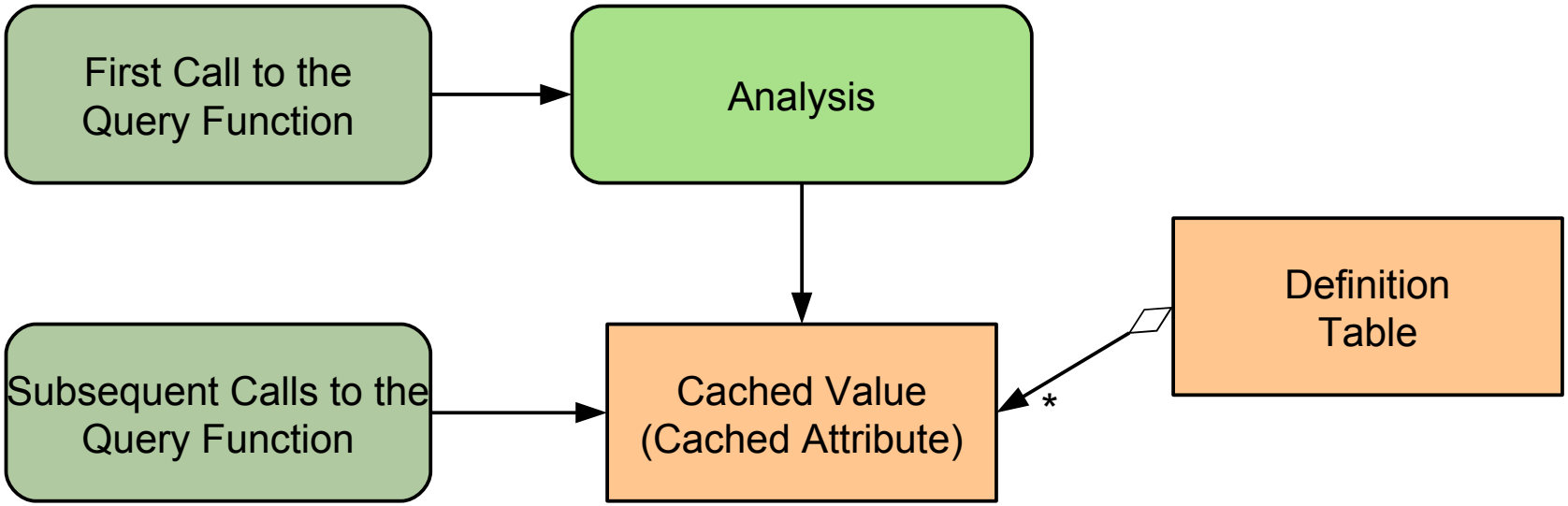
Definition of Attribution, Access and Query Functions

From the metamodel, we can define **access, query** and **attribution functions,** functions to access, query **attributes** or **neighbors:**

- **(Local) Attribute access functions:**
  - ModelElement.hasName()
  - ModelElement.getDeclaringType()
- **Neighbor access functions** (via references):
  - Class.getPackage(): for neighbor Package
  - Class.getUpperClass(): get the direct upper class
  - Class.getDeclaresMethod(): for contained Method
- **Query functions** looking up information in the abstract syntax graph (ASG) or model:
  - Expr.getUsedTypes(): search all types which are used in Expr (type analysis, type resolution)
  - Name.getType(): search the type object to the Name
  - Name.getMeaning(): search the definition of the Name
  - Stmt.getProcedure(): search out to find the procedure of the Stmt
- **Pattern match functions** assemble all matching redexes of a pattern
  - findRedexes (Pattern) Redexes

Name and Type Analysis: Caching a Query Function

- Some values of query functions change never, once they have been determined
  - The values can be cached
- **Attribute caching** is a mechanism to cache semantic attributes in an ASG or model for faster access
- A **definition table (often called symbol table)** is a set of cached attributes.



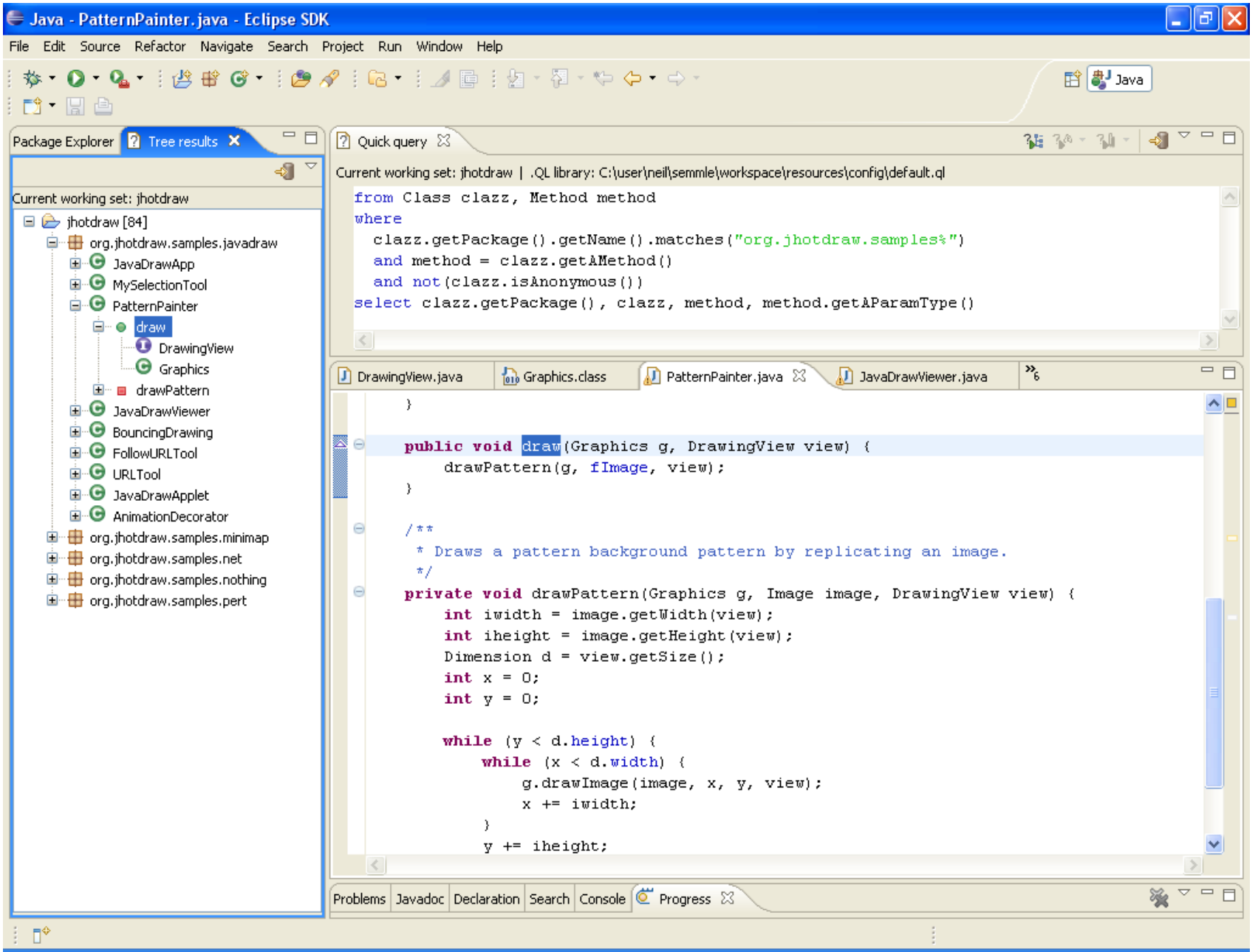
30.2.1 .QL – Relational Queries on Source Code in Technical Space Java

Courtesy to Florian Heidenreich and
http://semmle.com

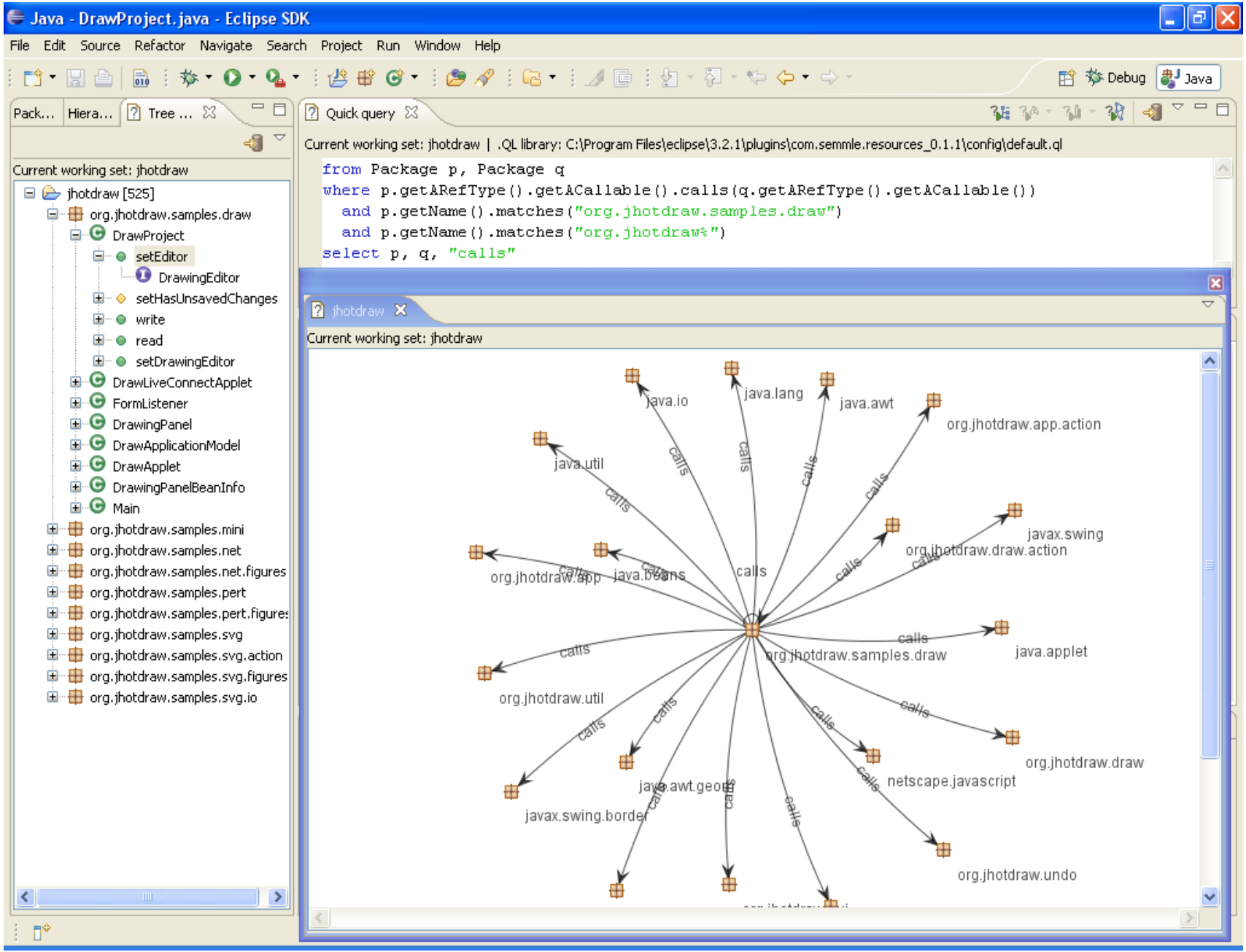
SQL-Like Code Query Language .QL

- **.QL** is an object-oriented query language in the spirit of SQL and Datalog
  - Developed in the group of Prof. Oege de Moor (Oxford)
  - Marketed by the startup Semmle.com
- Queries, metrics, visualizations are supported
  - Repositories with Java and Objective-C code
  - Works also now on C/C++
- Metamodel is EMOF-like (single inheritance, references)
  - Classes are interpreted as **Relations** (sets of tuples over member entries) resp. **Predicates** (telling whether a tuple exists)
  - Definition of access functions:
    - Class.getDeclaresMethod(): for neighbor Method
    - Class.getPackage(): for neighbor Package
    - ModelElement.hasName(): get the Name
    - ModelElement.getDeclaringType(): get the Type

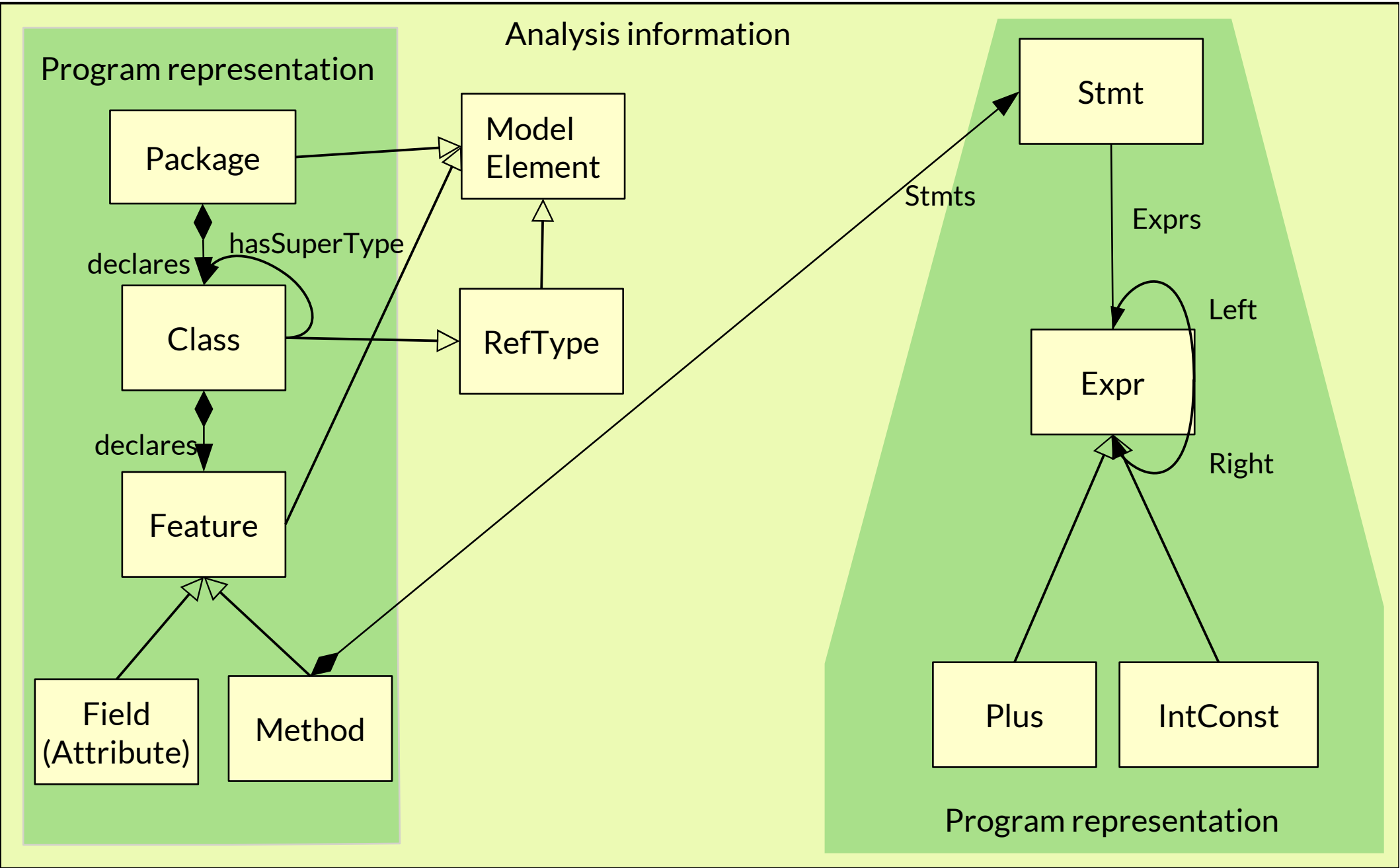
Code Display



Graph Visualization of the Resulting Structures



A Simple Model (Schema) of Semmle-DDL in EMOF



SemmleCode – SQL-Like Query Language on Semmle-DDL

- Query examples:
  - Select Statements on classes, methods, statements, expressions
- Language features:
  - Local Variables in queries
  - Non-deterministic methods returning sets and streams
  - Casts
  - Chaining
  - User defined query classes
- Metric examples:
  - Aggregation functions
  - SLOC
  - #Methods
- Expressions:
  - FROM <classes> WHERE <conditions> SELECT <variables>

Select Statements (1)

- Find all classes c implementing **`compareTo`**, but do not overwrite **`equals`**
- Find their packages

```
from Class c
where
    c.declaresMethod("compareTo")
    and not (c.declaresMethod("equals"))
select
    c.getPackage(), c
```

Select Statements (2)

- Find all **`main`**-methods declared in a package ending with „demo“
- Also called **pattern matching**

```
from Method m
where
    m.hasName(“main")
    and m.getDeclaringType().getPackage().getName().matches("%demo")
select
    m.getDeclaringType().getPackage(),
    m.getDeclaringType(),
    m
```

Definition of New Functions and Predicates

- Definition of new query functions by declaring query functions/methods in a class
- Methods may be indeterministic, i.e., return collections of objects

```
class Classinfo {
  Method findMethod(Class c) {
     c.declaresMethod("sumUpBill")
  }
}
```

- Definition of new predicates as methods in a class, using a domain-specific language
  language extension of Java
- Testing on or-conditions:

```
predicate isJDKMethod (Method m) {
   m.hasName("equals")
   or m.hasName("hashCode")
   or m.hasName("toString")
   or  m.hasName("clone")
}
```

Definition of New Predicates

- Use of Kleene Star for transitive closure on prediates/edges:

```
predicate upperClass(RefType down, RefType up) {
    down.hasSupertype+ (up)
}
```

- Complicated path expressions

```
predicate inTheMiddle(RefType down, RefType middle, RefType up) {
    down.hasSupertype+ (middle) and
    middle.hasSupertype+ (up)
}
```

Local Variables in Queries

Find all methods calling **`System.exit(...)`**

Sysexit is a local variable

```
from Method m, Method sysexit, Class system
where
    system.hasQualifiedName("java.lang", "System")
    and sysexit.hasName("exit")
    and sysexit.getDeclaringType() = system
    and m.getACall() = sysexit
select m
```

The Use of Non-deterministic Methods

- Synthesize a call graph between the methods of two packages
  - Call graph is retured as a set of tuples of (caller, callee)
- getARefType and getACallable are indeterminstic, i.e., return collections of objects

```
from Package caller, Package callee
where caller.getARefType().getACallable().calls(
          callee.getARefType().getACallable())
      and caller.fromSource()
      and callee.fromSource()
      and caller != callee
select caller, callee
```

Casts

- Find all dependencies between packages, also their using types

```
from MetricPackage p
select p, p.getADependencySrc().getARefType()
```

Chaining (Multiple Source - Multiple Target Graph Reachability Problem, MSMT)

Find all Pairs (s,t) such that

- t is a direct superclass of s
- s and t are superclasses of `org.jfree.data.gantt.TaskSeriesCollection`
- and t is not **`java.lang.Object`**

```
from RefType tsc, RefType s, RefType t
where
    tsc.hasQualifiedName("org.jfree.data.gantt","TaskSeriesCollection")
    and s.hasSubtype*(tsc)
    and t.hasSubtype(s)
    and not(t.hasName("Object"))
select s,t
```

.QL-Query Classes

- ***Query classes*** in .QL are special predicates and may nest other predicates
  - They do not define objects, but "truths" about the model
  - Their constructors define restrictions of metaclasses

```
// definition of a query class as subclass of a metaclass
class VisibleInstanceField extends Field {
  VisibleInstanceField() {
    not (this.hasModifier("private")) and
    not (this.hasModifier("static"))
  }
  predicate readExternally() {
    exists (FieldRead fr |
          fr.getField()=this and
          fr.getSite().getDeclaringType()
               != this.getDeclaringType())
  }
}
```

```
// use of a query class
from VisibleInstanceField vif
where vif.fromSource() and not (vif.readExternally())
select vif.getDeclaringType().getPackage(),
               vif.getDeclaringType(),
               vif
```

30.2.2 Metrics with .QL

Aggregation Functions for Computing Metrics

- Compute the average number of methods per type and package
  - Other aggregation functions: count, sum, max, min, avg
- Employs „Eindhoven Quantifier Notation“ (Dijkstra et al.)
  - C | <predicate>

- Query: „Compute the average number of methods in all type c of a package p”

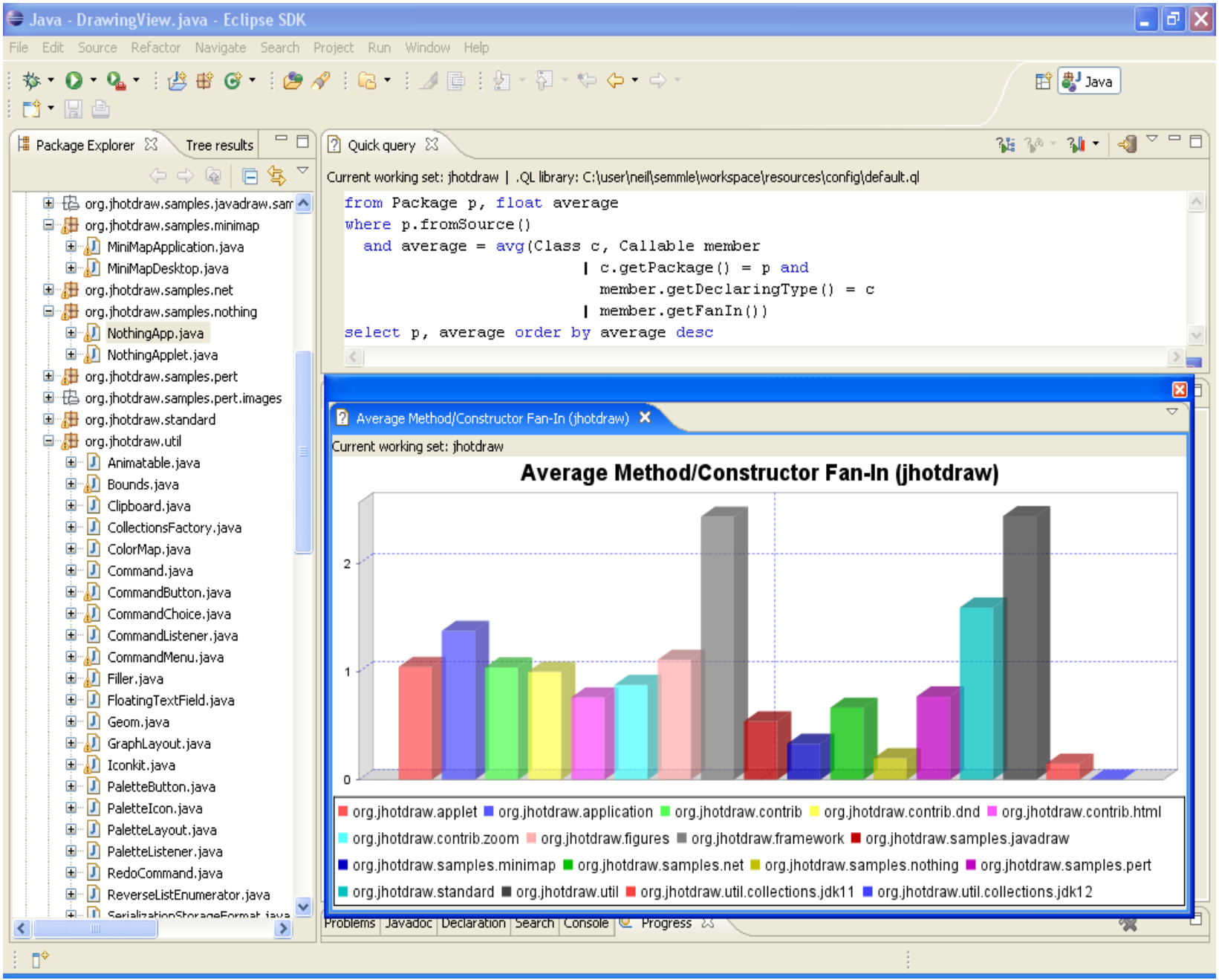
```
from Package p
where p.fromSource()
select p, avg(RefType c |
              c.getPackage() =p |
                        c.getNumberOfMethods())
```

Aggregation Functions for Computing SLOC Metrics

- Calculating a SLOC metrics on package “Billing” in the current compilation unit
- Grammar rules:
- Aggr ::= aggregationFunction '('
  localvars // FROM
  '|' condition // WHERE
  '|' aggregatedValue ')' // SELECT
- AggregationFunction ::= 'sum' | 'count' | 'avg' | 'max' | 'min'

```
from Package pkg
where pkg.hasName(”Billing”)
select sum(CompilationUnit comp | //FROM
          comp.getPackage()=pkg |    // WHERE
             comp.getNumberOfLines()) // SELECT
```

Statistics (Metrics) Uses Aggregation Functions



30.2.3. Graph Querying with GReQL

- Open source, from University of Koblenz-Landau, Prof. Ebert
- Applicable to a subset of UML (GrUML)

TGreQL is similar to .QL

- But uses a relational notation, from-with-report clauses

.QL

```
from RefType tsc, RefType s, RefType t
where
    tsc.hasQualifiedName("org.jfree.data.gantt","TaskSeriesCollection")
    and s.hasSubtype*(tsc)
    and t.hasSubtype(s)
    and not(t.hasName("Object"))
select s,t
```

TGreQL

```
from RefType tsc, RefType s, RefType t
with
    s hasSubtype*->tsc,
    tsc.hasQualifiedName("org.jfree.data.gantt","TaskSeriesCollection"),
    t hasSubtype->s,
    not t.hasName("Object")
report s,t
```

The Query Language TGreQL

- TgreQL style is very similar to Xcerpt
- Implements F-Datalog incl. Transitive closure operator
- Prof. J. Ebert U Koblenz

```
// construct a call graph
From caller, callee: V{Method}
With caller (
    ← {isStatementIn}
  [ ← {isReturnValueOf} ]
    ← {isActualParameterOf} *
    ← {isCalleeOf}
 ) + callee
Report
   caller.name as „Caller“
   callee.name as „Callee“
```

Operators:

- * Transitive closure operator
- + positive transitive closure
- □ □ navigation direction
- [] optional path
- ( ) sequence of paths or edges
- | alternative path

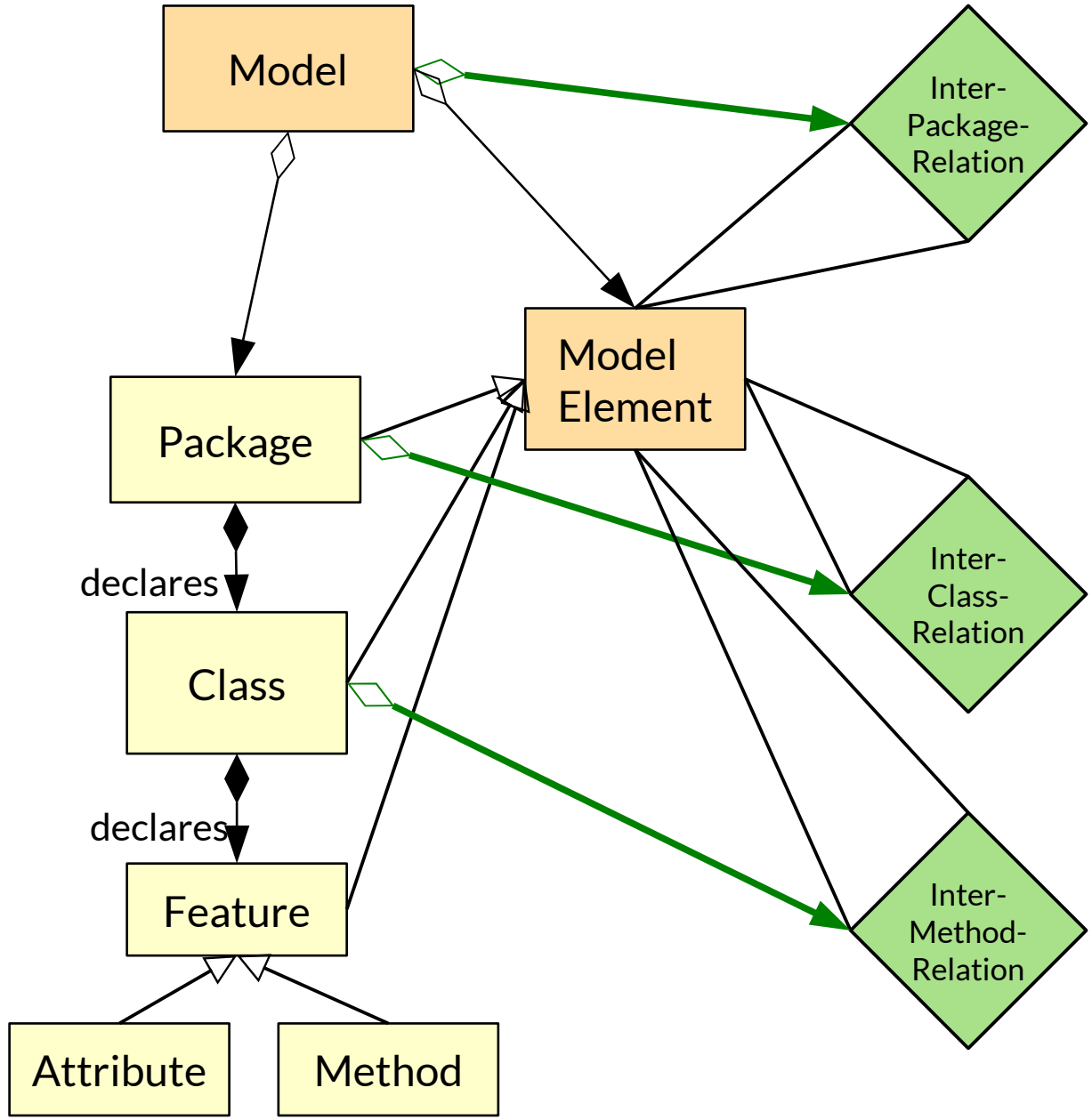
Result (example):

Caller	Callee
main	System.out.println
main	compute
main	twice
main	add
compute	twice
compute	add

30.2.4. Lifting Information Up the Containment Hierarchy

Lifting Information Along the Block Containment Structure (Scope Structure)

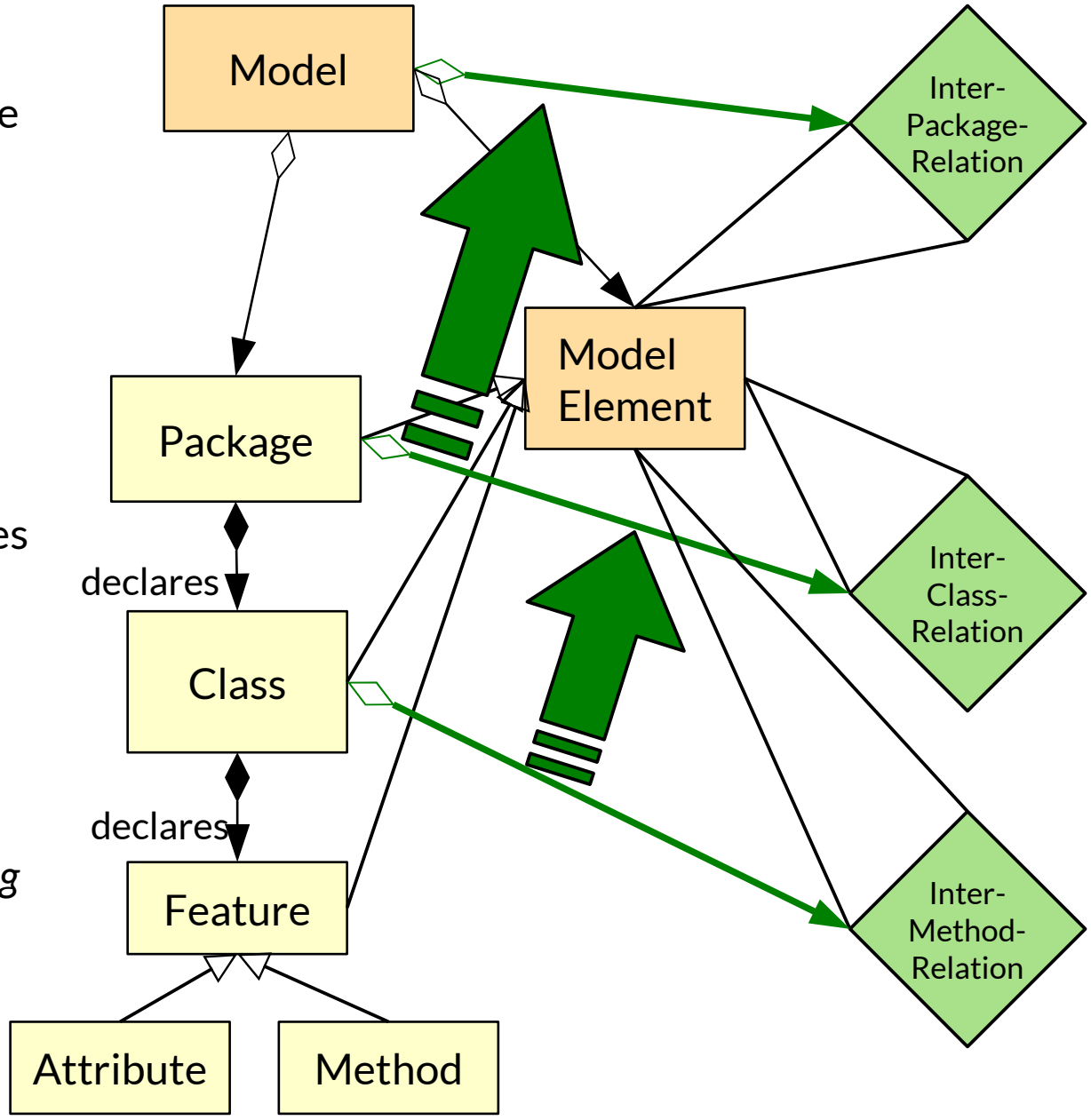
- Languages are block-structured, i.e., live in a **containment hierarchy.**
- A model has **model elements**
- A class has **inter-method relationship** (e.g., the call graph)
- A package has **inter-class relationships** between these model elements
- A model has **inter-package relationships** between these model elements



A megamodel builds on graphs, at least on link trees, no longer on trees

Lifting Information Along the Block Containment Structure

- **Dependency lifting** means to lift information **up** in along the containment hierarchy
  - from an inter-method relationship to a inter-class relationship
  - from an inter-class relationship to a inter-package relationship
- Dependency lifting propagates information **up** the abstract syntax tree and the containment tree
- Dependency lifting is an important process to *summarize dependencies among siblings in containment hierarchies in models*



Dependency Lifting Information Along the Block Containment Structure

- **Dependency lifting** lifts dependency information up the containment structure, thereby summarizing the dependencies
- **result** is implicitly defined default return parameter

```
// Lifting a pair of method dependencies
// on a pair of classes
class Method {
   Class getDependentClass() {
         exists (Method m |
               depends(this.getClass(),m)
               and result = m.getClass()
         )
         and result != this
   }
}
```

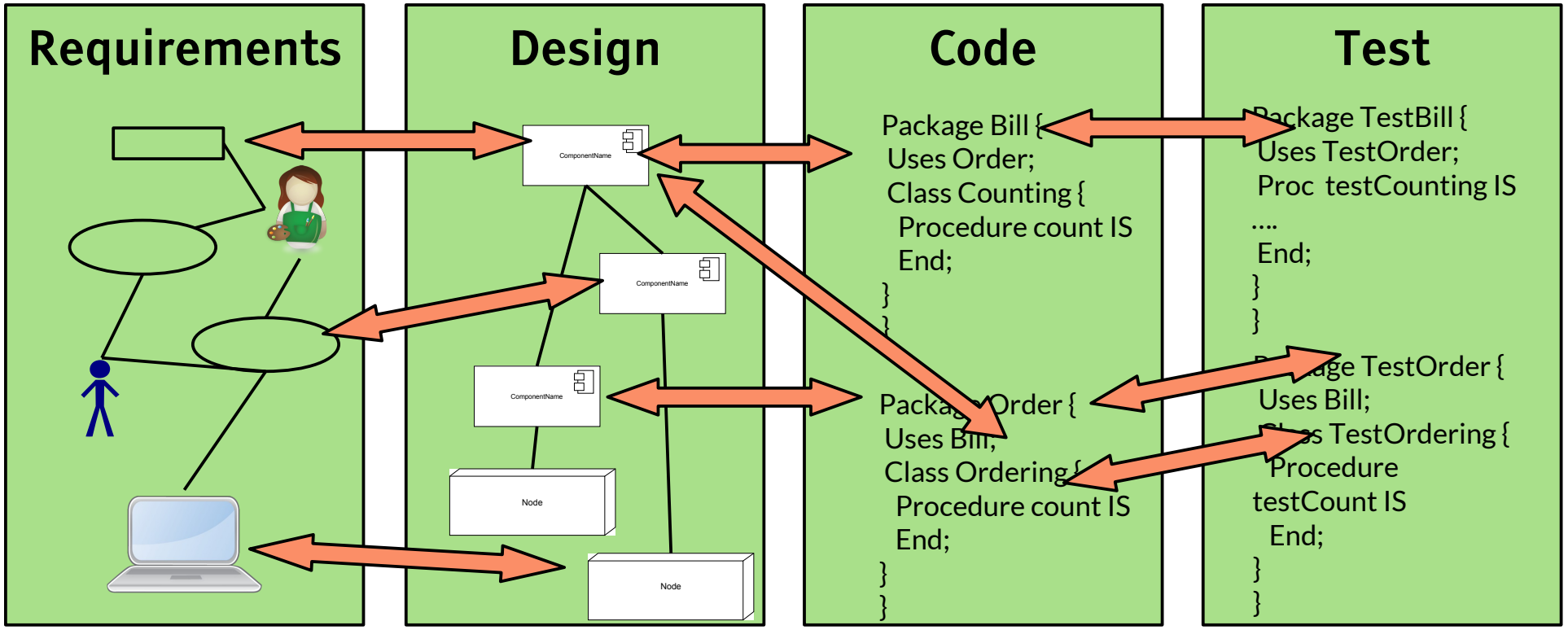
```
// Lifting a pair of class dependencies to
// a pair of packages
class Class {
   Package getDependentPackage() {
     exists (Class cl |
       depends(this.getPackage(),cl)
       and result = cl.getPackage()
     )
     and result != this
   }
}
```

30.3 Macromodel Dependency Analysis

- Remember: A **macromodel** is a megamodel with consistent dependencies

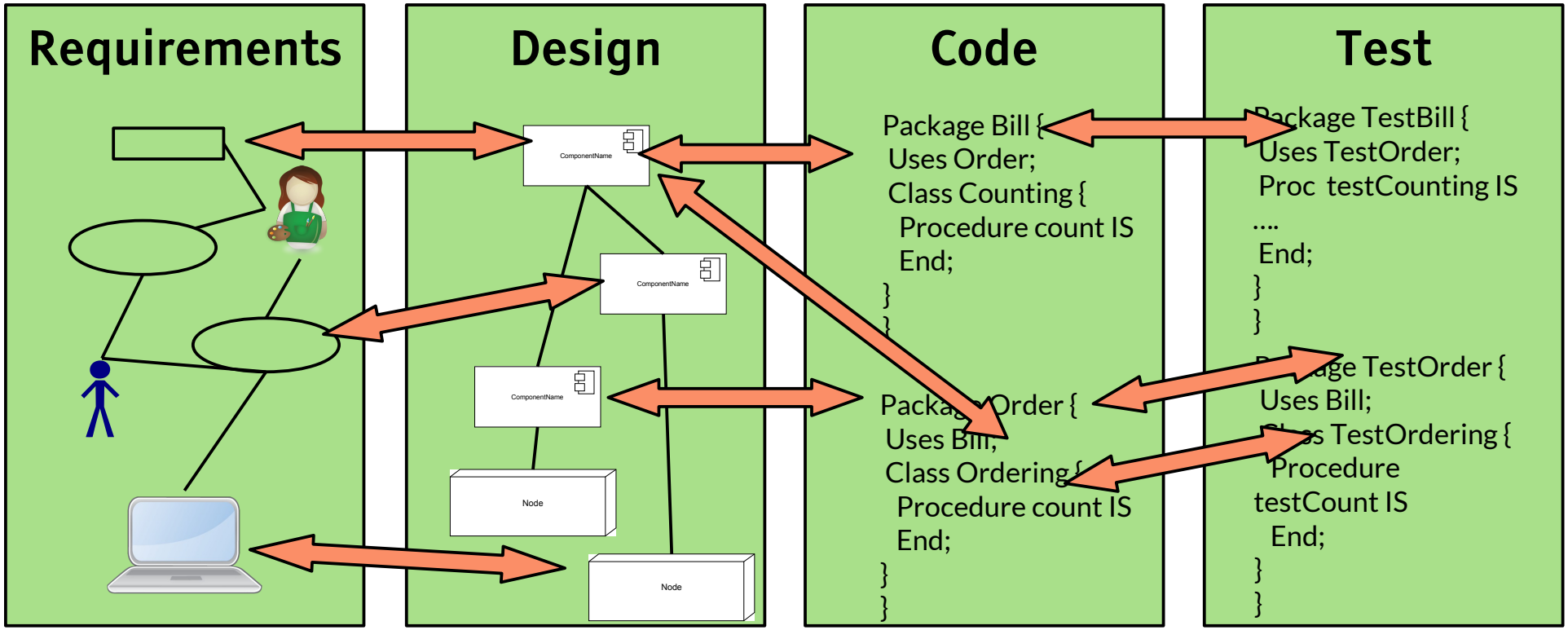
Q12: The ReDeCT Problem and its Macromodel

- The **ReDeCT problem** is the problem how requirements, design, code and tests are related (⍰ V model)
- Mappings between the Requirements model, Design model, Code, Test cases
- A **ReDeCT macromodel** has maintained mappings between all 4 models



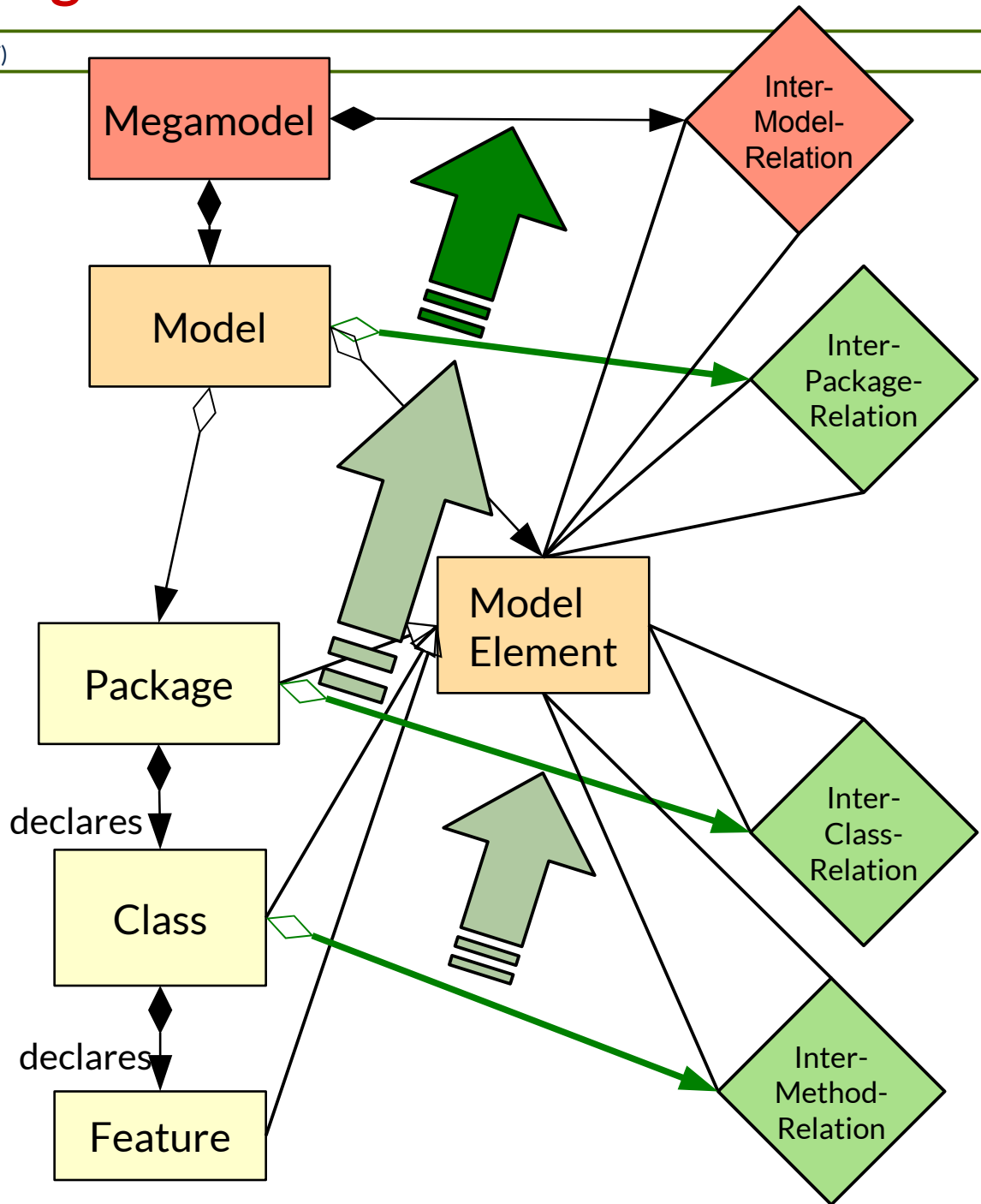
Inter-Model Relationships in The ReDeCT Macromodel

- An **inter-model relationship** is a relationship between model elements of different models (usually link or graph relationship)
  - Here: expresses mapping between the Requirements model, Design model, Code, Test cases
- The **ReDeCT macromodel relies on inter-model relationships** between all 4 models



Lifting Information Along the Block Containment Structure
Between Models in the Megamodel

- **Megamodel-Dependency Lifting** means to lift information **up** in along the containment hierarchy **from between the packages of a model to between the models of the megamodel**
  - from an intra-model relationships to a inter-model relationship
- Megamodel-Dependency-Lifting propagates information **up** into the megamodel
- Megamodel-Dependency-Lifting is an important process to *summarize dependencies among models*
- Result: a **macromodel**



Megamodel Dependency Lifting in Semmle .QL

- The lifting procedure also works for lifting package dependencies within a model to model dependencies.
  - Consider models as "normal" objects in the repository
  - Formulate queries about model-element relationships and lift them to model relationships

```
// Lifting a pair of class dependencies to
// a pair of packages
class Class {
   Package getDependentPackage() {
     exists (Class cl |
       depends(this.getPackage(),cl)
       and result = cl.getPackage()
     )
     and result != this
   }
}
```

```
// Lifting a pair of package dependencies to
// a pair of models
class Package {
   Model getDependentModel() {
     exists (Model mod |
       depends(this.getModel(),mod)
       and result = mod.getModel()
     )
     and result != this
   }
}
```

How to Discover Dependencies Between Models in a Megamodel

- After analysis of all models, **lift the information up the containment hierarchy into the megamodel**
  - Construct inter-model relationships by lifting from inter-package relationships
- This turns the megamodel into a ***macromodel***, because a megamodel with model-element constraints is called a macromodel

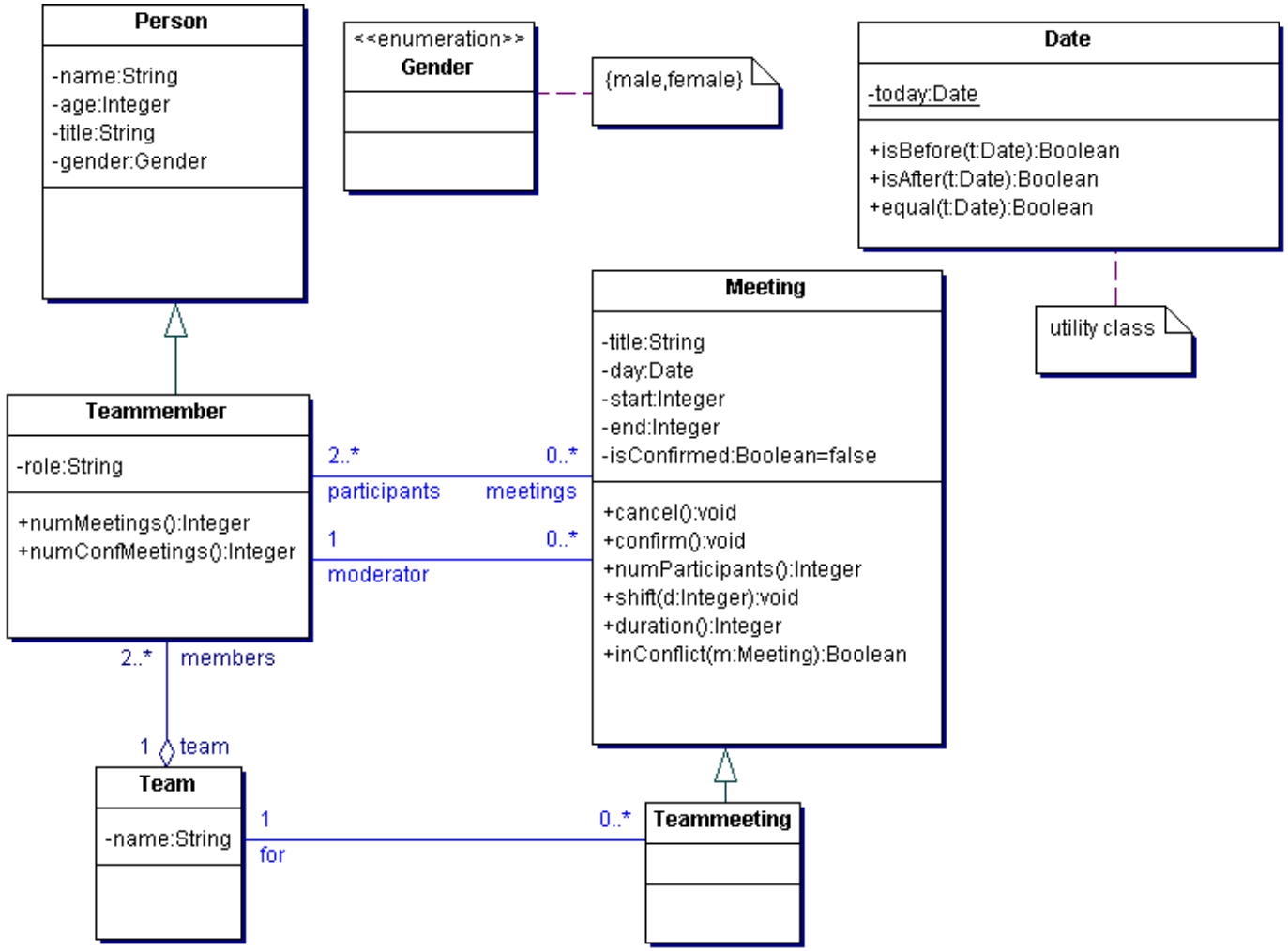
Megamodel dependency analysis consists of
lifting model-level dependency analysis to inter-model relationships

30.4. Writing Model Constraints by Graph Querying with OCL

- The DDL of OCL is MOF

OCL for Invariants in UML-Class Diagrams

- course Softwaretechnologie-II



Examples OCL Invariants

- OCL queries usually start at a specific class; their results define *invariants* on the objects of the class
  - All attributes of a class are visible by default in OCL.
  - Relations between classes define functions
- Query language uses expressions over these functions

Example of Invariant:

```
context Meeting inv: self.end > self.start
```

Equivalent:

```
context Meeting inv: end > start
    -- self is the context of the query, from which processing starts
```

Equivalent named constraint:

```
context Meeting inv startEndConstraint:
self.end > self.start
    -- Constraints can constrain attribute values
```

- FROM and SELECT clauses are modeled via functions:

Selection constraint:

```
context Person inv searchForPerson:
allInstances()->select(p:Person|p.name.StartsWith(„Uwe"))
    -- FROM clause is modeled via allInstances() function
    -- SELECT clause is modeled via select() function
```

Examples OCL Invariants

- **Selection constraint:**

```
context Person inv searchNames:
allInstances()->collect(name)
context Person inv countNames:
allInstances()->collect(name)->size()
```

- **Multiplicity constraint:**

```
context Person inv countNames:
allInstances()->collect(name)->size() < 15
```

- More on OCL: Course Softwaretechnologie-II, Ch. “Konsistenzprüfung mit OCL”, Dr. Birgit Demuth
- Www.dresden-ocl.de

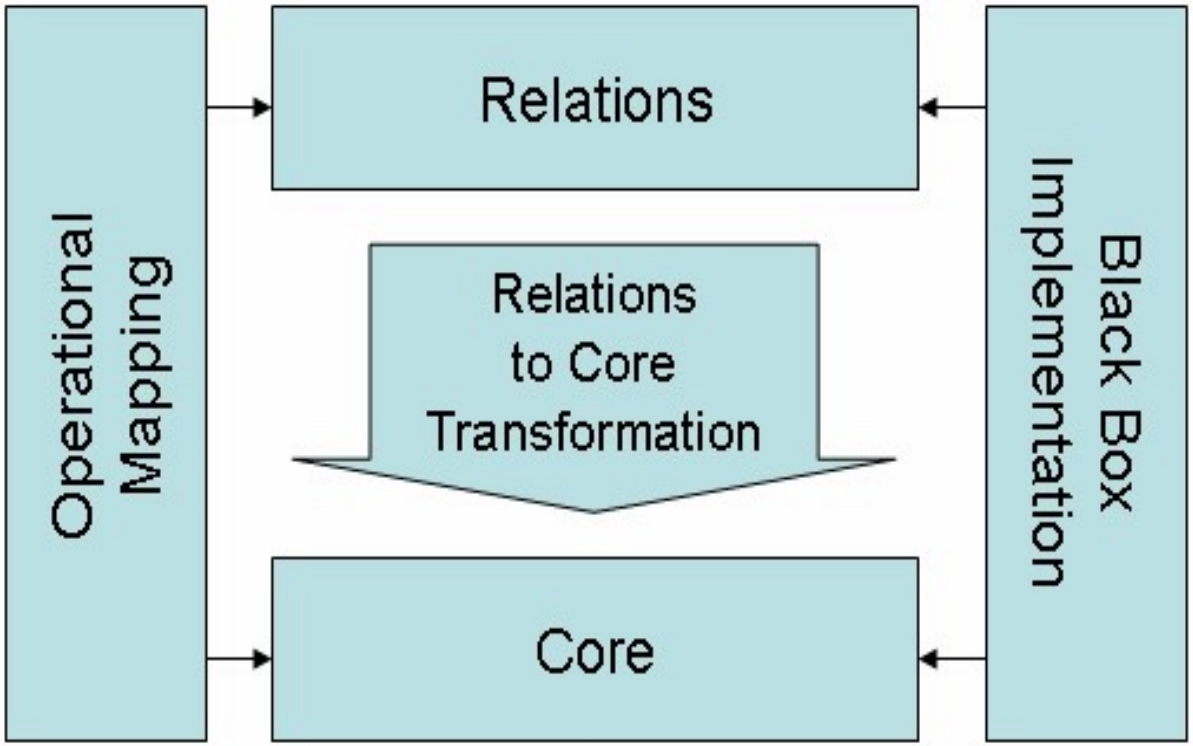
30.4.2 Model Mappings with Query-View-Transformations (QVT)

The language of the OMG for model transformations within MDA

OMG: MOF 2.0 Query / Views / Transformations RFP. ad/2002-04-10. Needham, MA: Object Management Group, April 2002.

http://www.omg.org/cgi-bin/doc?ad/2002-4-10

QVT Dialects



From: [https://de.wikipedia.org/wiki/Datei:QVT-Language-Architecture_591x387.jpg]

Transitive Closure with QVT Relations

- **QVT relations** uses logic expressions on base and derived relations (graph-logic isomorphism)

```
// Transitive Closure in QVT relations,
// Modeled with recursive relation "transitiverelation"
relation transitiverelation {
  domain node:Node {
    // matching attributes
    name = sameName;
  }
  domain node2:Node {
    // node2 must have the
    // same name as node
    name = sameName;
  }
  domain node3:Node {
    // node3 must also
    // have the same name
    name = sameName;
  }
```

```
when {
    // conditions: base relation must exist
    baserelation(node,node2) or
    // or a transitive relation to a base relation
    (transitiverelation(node,neighbor)
    and baserelation(neighbor,node2));
  }
  where { // Aufruf einer Transformation
    makeNodeSound(node);
  }
}
```

QVT Tools

Tool			
Eclipse M2M Project	Operational	http://www.eclipse.org/m2m/	
Magic Draw	Operational		
MediniQVT	Relational	http://projects.ikv.de/qvt/wiki	

QVT-R uses OCL for Model Search, Query, and Mapping

- OCL can be called within QVT scripts
  - Two different DQL are combined within a single language

```
// this is QVT
rule checkNoDoubleFeatureInSuperClasses(name:String) {
  from node: Class (
    -- OCL query
    node->TransitiveClosure()->collect.().exists(s | s.name()
= name);
  )
  to
    System.out.println("Error: super class has doubly defined
feature: "+s.name());
}
```

30.4.3. Graph Invariant Specification with Spider Diagrams

Spider Diagrams

- http://en.wikipedia.org/wiki/Spider_diagram
- S. Kent. Constraint Diagrams: Visualizing Invariants in OO Modelling. Proceedings of OOPSA 97, ACM Press, Oct. 97, pp. 327-341.
- S. Kent and J. Howse. Mixing Visual and Textual Constraint Languages, UML 99, IEEE press, Oct 1999.

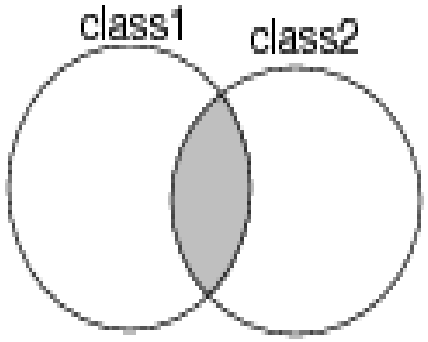
- Spider-Diagramme are equivalent to monadic second-order logic 2. Stufe (MSOL).
  - They include OCL (first-order logic)
- Source of diagrams: J. Lövdahl, Towards a Visual Editing Environment for the Semantic Web. Linköpings universitet, 2002.

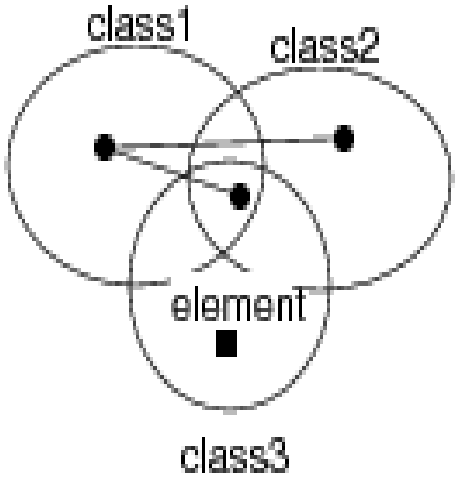
Simple Spider Diagrams are Extended Venn Diagrams

- Classes are visualized as venn ellipsoids
- Set algebra is expressed by intersection of ellipsoids
- Existential Logic (propositional logic with existential quantifiers) is expressed by **spiders** (hyperedges)

Result = class1^class2

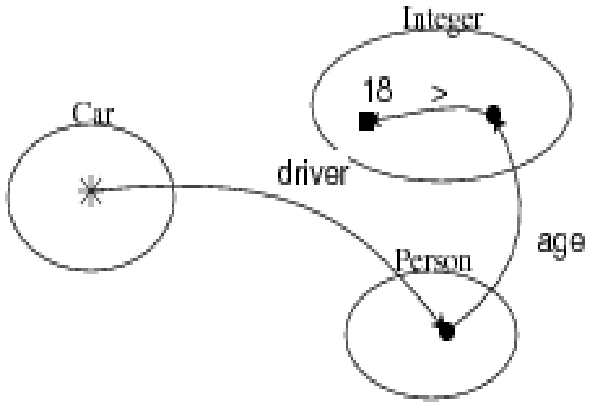
An object of class1 has an object of class2 and an object in class1^class2^class3 and class3\class1\class2 is not empty



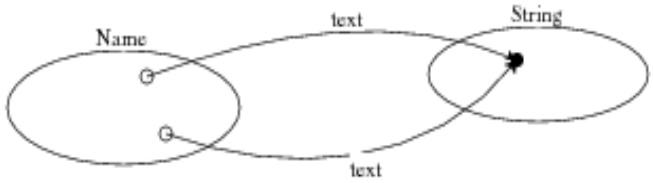


- All quantifiers are possible (star symbol)

All cars must be driven
by a person older than 18

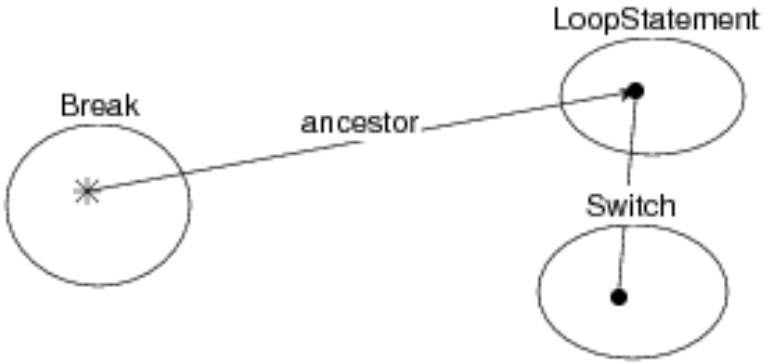


There are no two names that have the same string

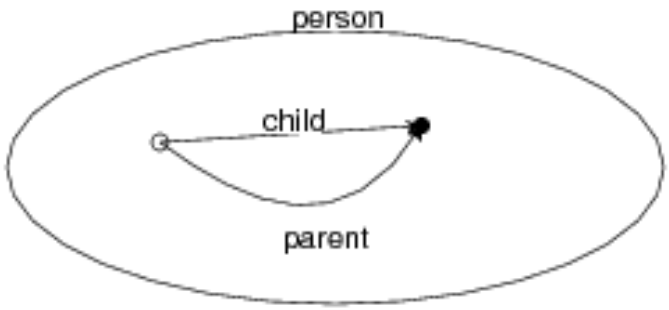


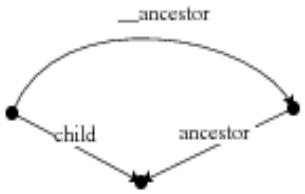
Other constraints

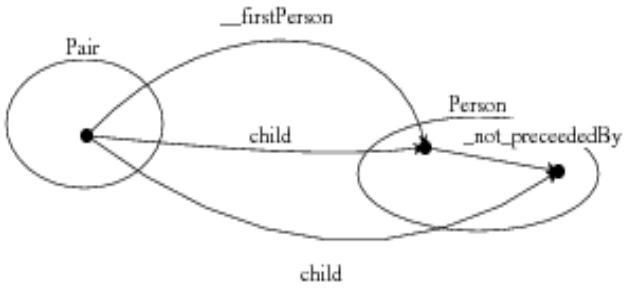
All Break statements must have a LoopStatement as ancestor, which is related to a Switch state

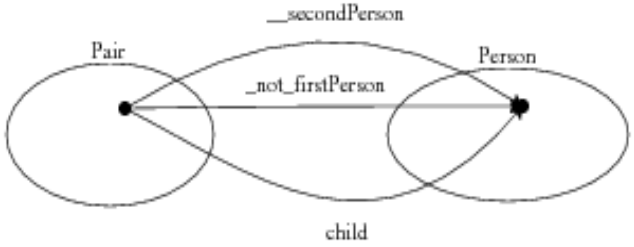


For every person, there is no child that has no parent



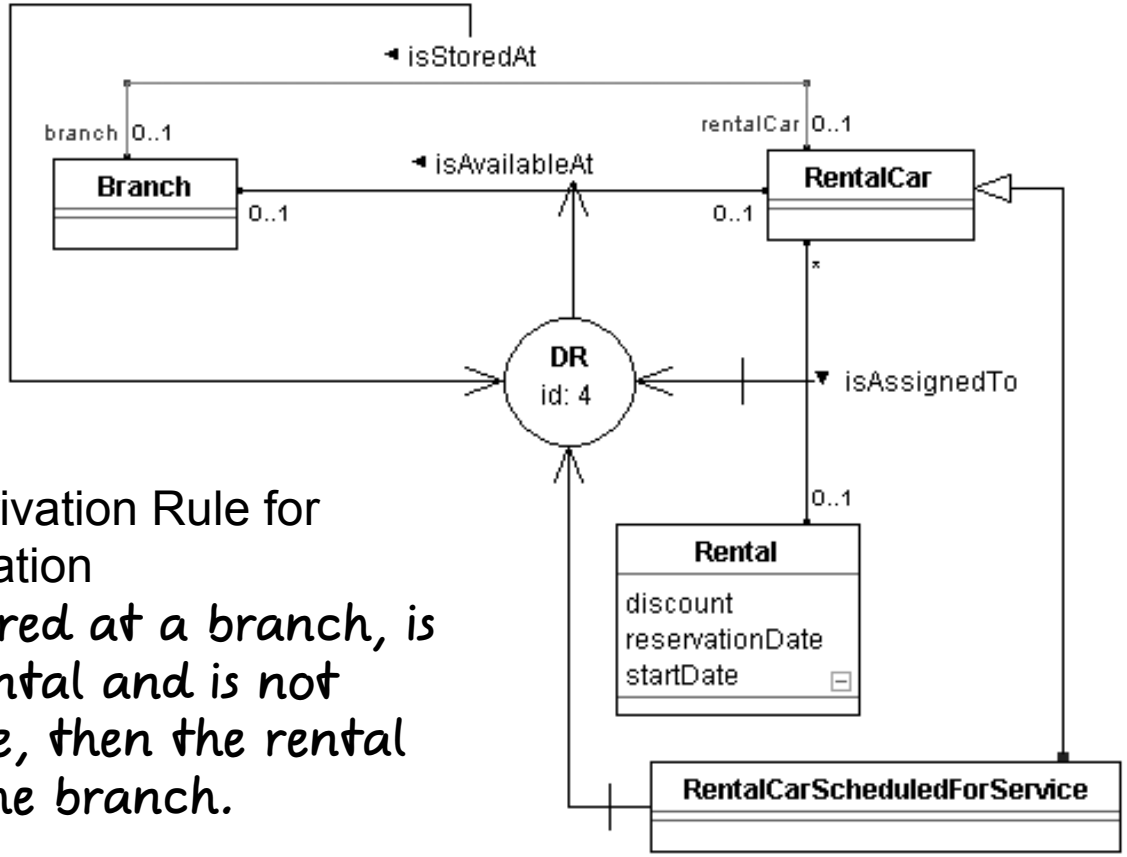






30.4.4. URML – A UML-like Spider Notation

- URML http://oxygen.informatik.tu-cottbus.de/rewerse-i1/?q=URML
- Emilian Pascalau and Adrian Giurca. Can URML model successfully Drools rules? Proceedings of the 2nd East European Workshop on Rule-Based Applications (RuleApps 2008) at the 18th European Conference on Artificial Intelligence. Patras, Greece, July 23, 2008.
  - http://ceur-ws.org/Vol-428/paper5.pdf

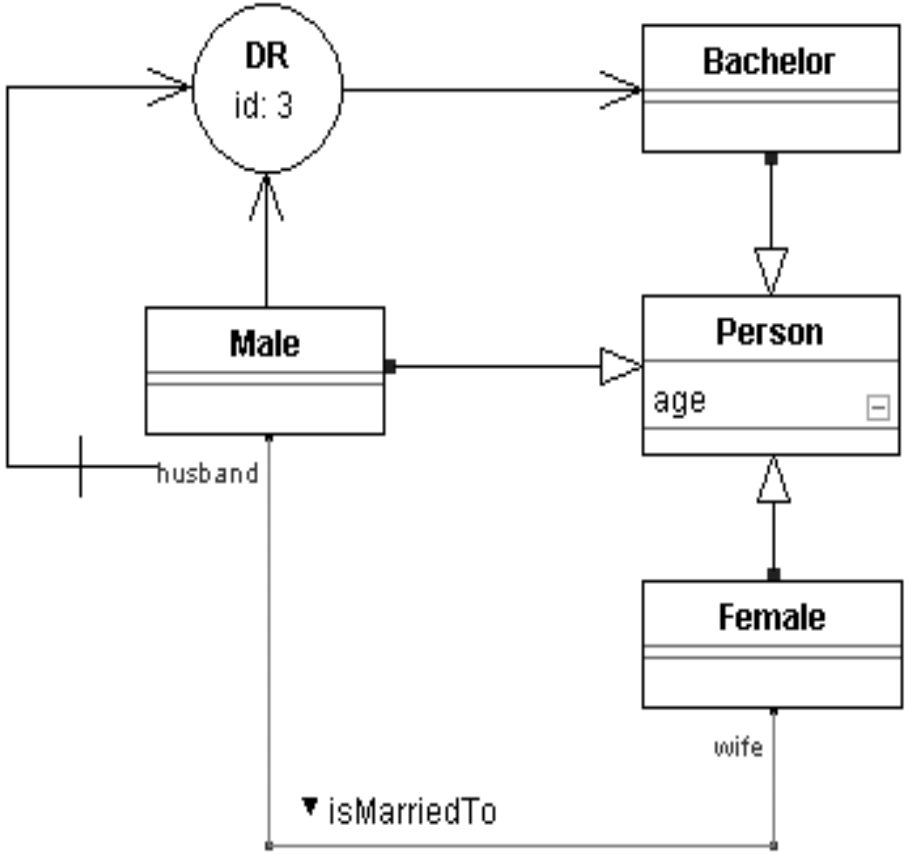


- Ex: Modeling a Derivation Rule for Defining an Association

If a rental car is stored at a branch, is not assigned to a rental and is not scheduled for service, then the rental car is available at the branch.

Modeling a Derivation Rule with a Role Condition

A bachelor is a male that is not a husband.



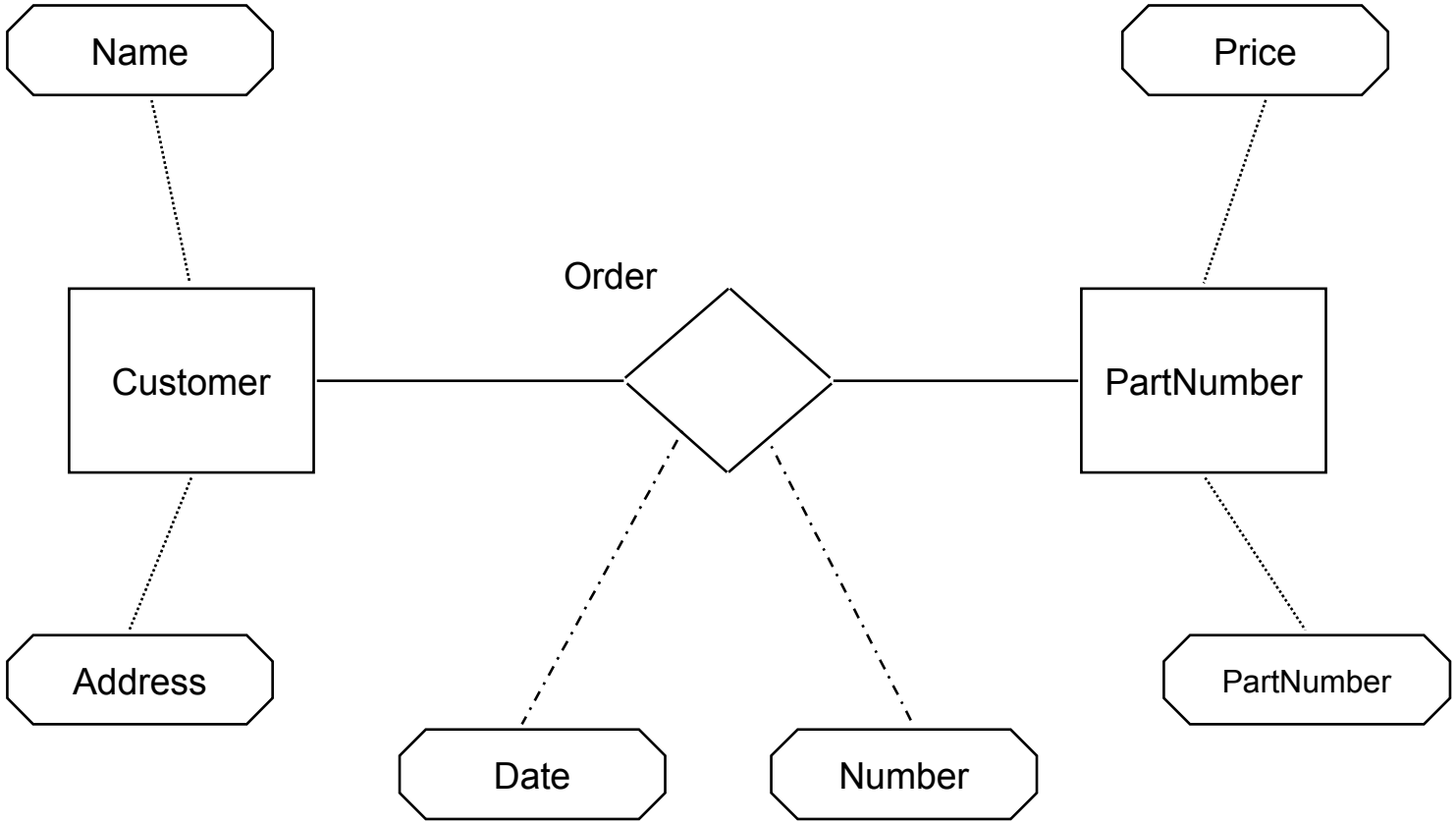
The End

- Why does ERD and MOF help to define link-consistent link trees?
- Explain why TgreQL and Xcerpt have similar query styles
- Why does a megamodel usually build on graphs, not on trees?
- Why do we need graph query and transformation languages?

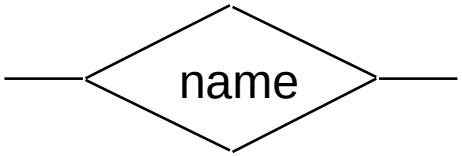
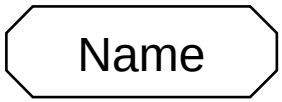
Appendix

A Simple ER-Model

- All “entities” (classes) are represented as “entity-”tables



ERD Model Elements [Chen]

Notation	Meaning
	**Entity type:** Set of objects
	**Relationship type:** Set of relations between entity types
	**Attribute:** Describes a function or a predicate over an entity
1, n 0 < n	**Cardinality** of a relationship type**:** minimum and maximum amout of neighbors in a relation

Praktische Vorgehensweise bei der Erstellung eines ERD

- Ähnlich wie strukturgetriebene Vorgehensweise in der ST-1-Vorlesung
- 1) Festlegen der Entitytypen
- 2) Ableitung der Beziehungstypen
- 3) Zuordnung der Attribute
  - zu den Entitytypen unter dem Gesichtspunkt der natürlichsten Zugehörigkeit, d. h. sie sind "angeborene" Eigenschaften unabhängig von ihrer Nutzung.
  - Kardinalitäten festlegen
- 4) Konsistenzprüfung
  - 5a) Fremdschlüssel definieren für die Herstellung notwendiger Verbindungen zwischen Entitytypen und Eintrag ins DD
  - 5b) Fremdschlüssel-Regeln spezifizieren, nach Rücksprache mit dem Anwender
- 5) Eintrag ins DD

Beispiel “Arztpraxis”

Aufgabenstellung:

“Es sind in einer **Arztpraxis** die organisatorischen Abläufe für das Bestellwesen der **Patienten**, den Aufruf aus dem Wartezimmer, die **Arztbehandlung** und die Abrechnung unter Einsatz von PCs weitgehend zu rationalisieren. Spätere Erweiterungen sollen leicht möglich sein.”

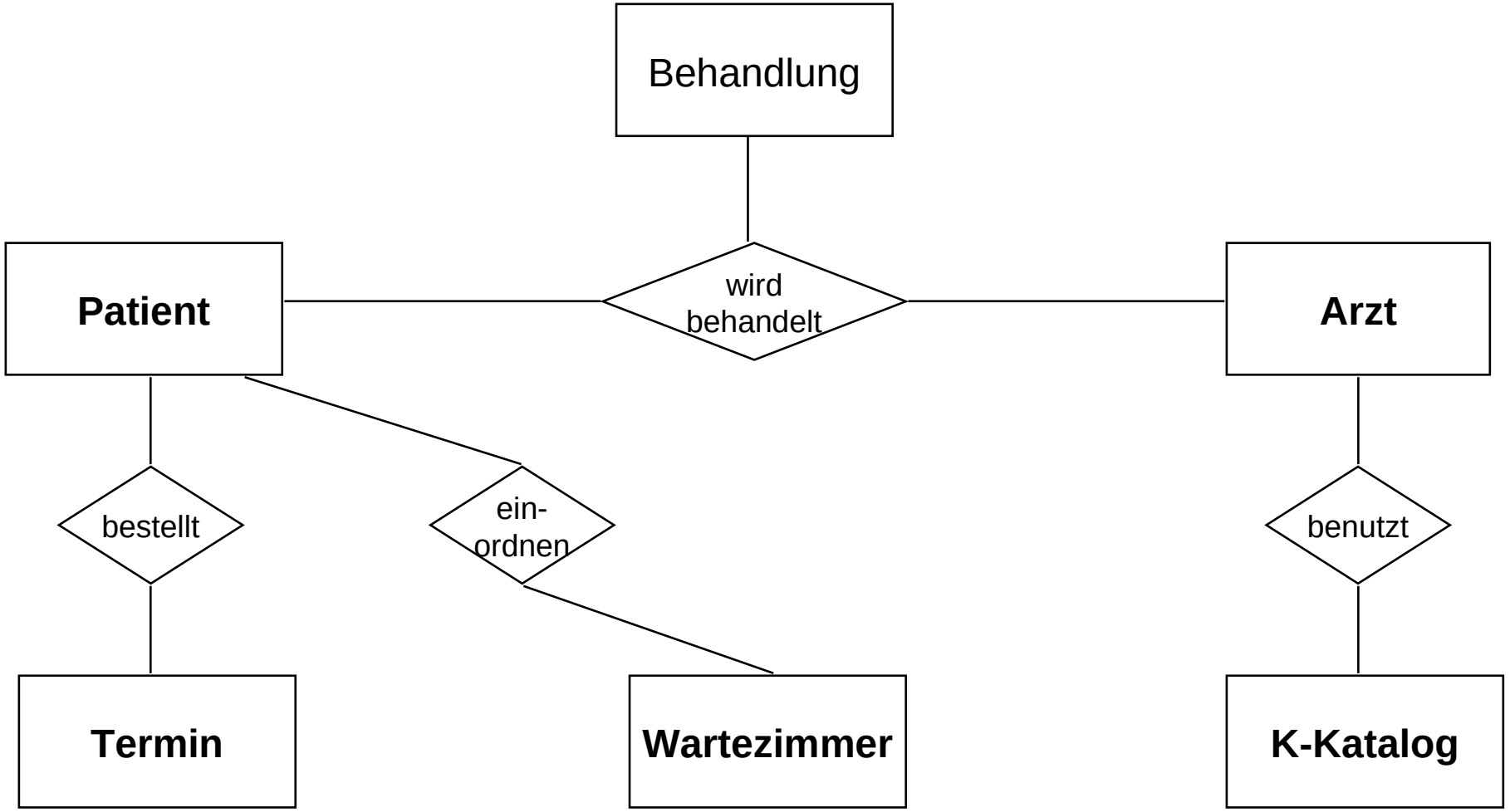
Analyse mit Verb-Substantiv-Analyse

ERD “Arztpraxis” (1)

Schritt (1)

ERD “Arztpraxis” (2)

Schritt (2)



ERD “Arztpraxis” (3)

Schritt (4,5)