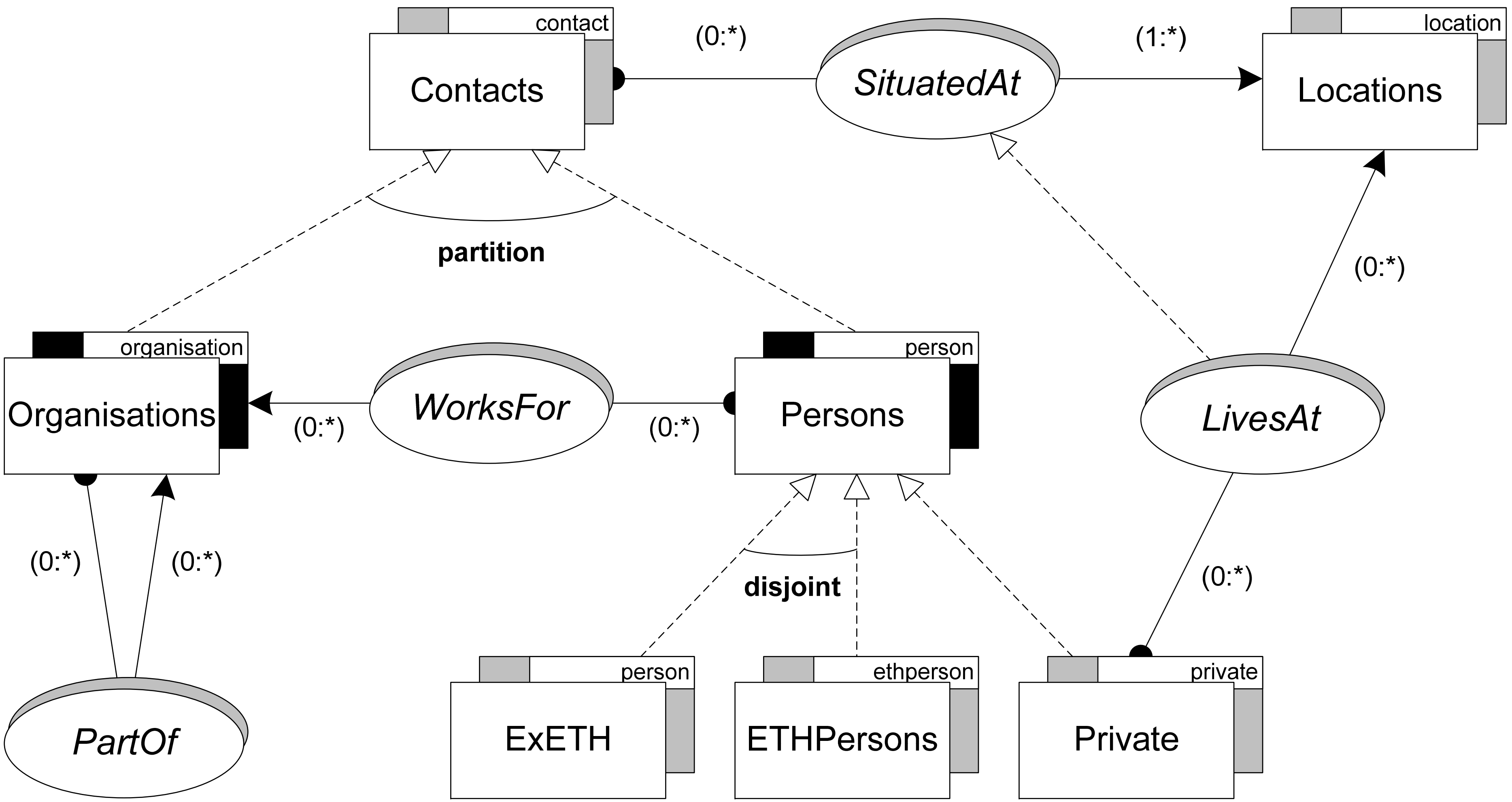
Object-Oriented Databases
The OM Data Model

- Multiple Inheritance, Instantiation and Classification
- Collections and Associations
- Cardinality, Classification and Evolution Constraints

OM Data Model

- Extended Entity-Relationship model for object-oriented data management
- Distinguishing features
  - distinguishes typing and classification
  - data represented as objects, i.e. attributes and methods
  - multiple inheritance, multiple instantiation, multiple classification
  - collections and binary associations as first-order concept
  - constraints for integrity, classification and evolution
  - data definition, manipulation and query language OML
- Implementations
  - OMS Pro, OMS/Java, eOMS, OMS Avon

OM Data Model



Typing and Classification

Typing

- representation of entities
- defines format of data values
- defines operations
- defines inheritance properties

```
public class Person {
   String name;
   Date birthdate;

   public Person(String name) {
      this.name = name;
   }
}
```

Classification

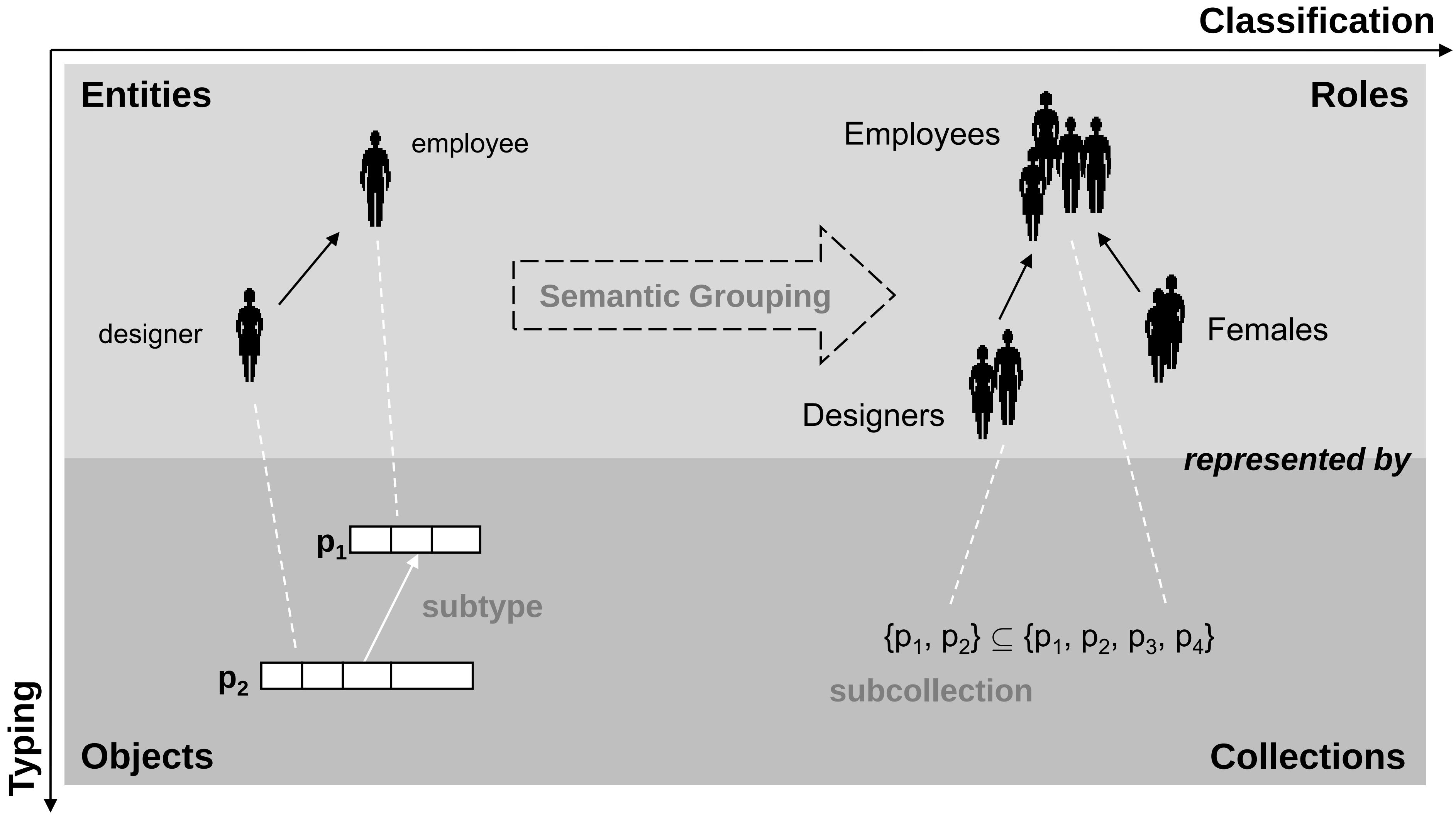
- roles of entities
- defines semantic groupings as collections of values
- defines constraints among collections

```
Person alex =
   new Person("Alex de Spindler");
Collection<Person> friends =
   new HashSet<Person>();
Collection<Perons> coWorkers =
   new HashSet<Person>();
friends.add(alex);
coWorkers.add(alex);
```

Typing and Classification

- Better understanding of issues
  - important to recognise the two concepts even if they are somehow merged together in a particular model or system
- Reduces complexity of type graphs
  - no need to introduce subtypes to represent each classification
- Rich classification structures
- Support for relationships between objects
  - associations over collections rather than embedded in objects
- Integration of database and programming languages

Typing and Classification



Typing and Classification

- Collections
  - semantic groupings of objects
- Member types of collections
  - constrain membership in a collection
  - can define a view of objects accessed in context of collection
- Object evolution
  - objects can gain and lose roles by being added to and deleted from collections
  - type change only required if an object is not an instance of member type of collection

OM Data Model Layers

- OM distinguishes typing from classification based on a two-layered Entity-Relationship model
- Type layer
  - defines object representation
  - multiple inheritance
  - multiple instantiation
- Classification layer
  - defines semantic groupings
  - multiple classification
  - collections and associations

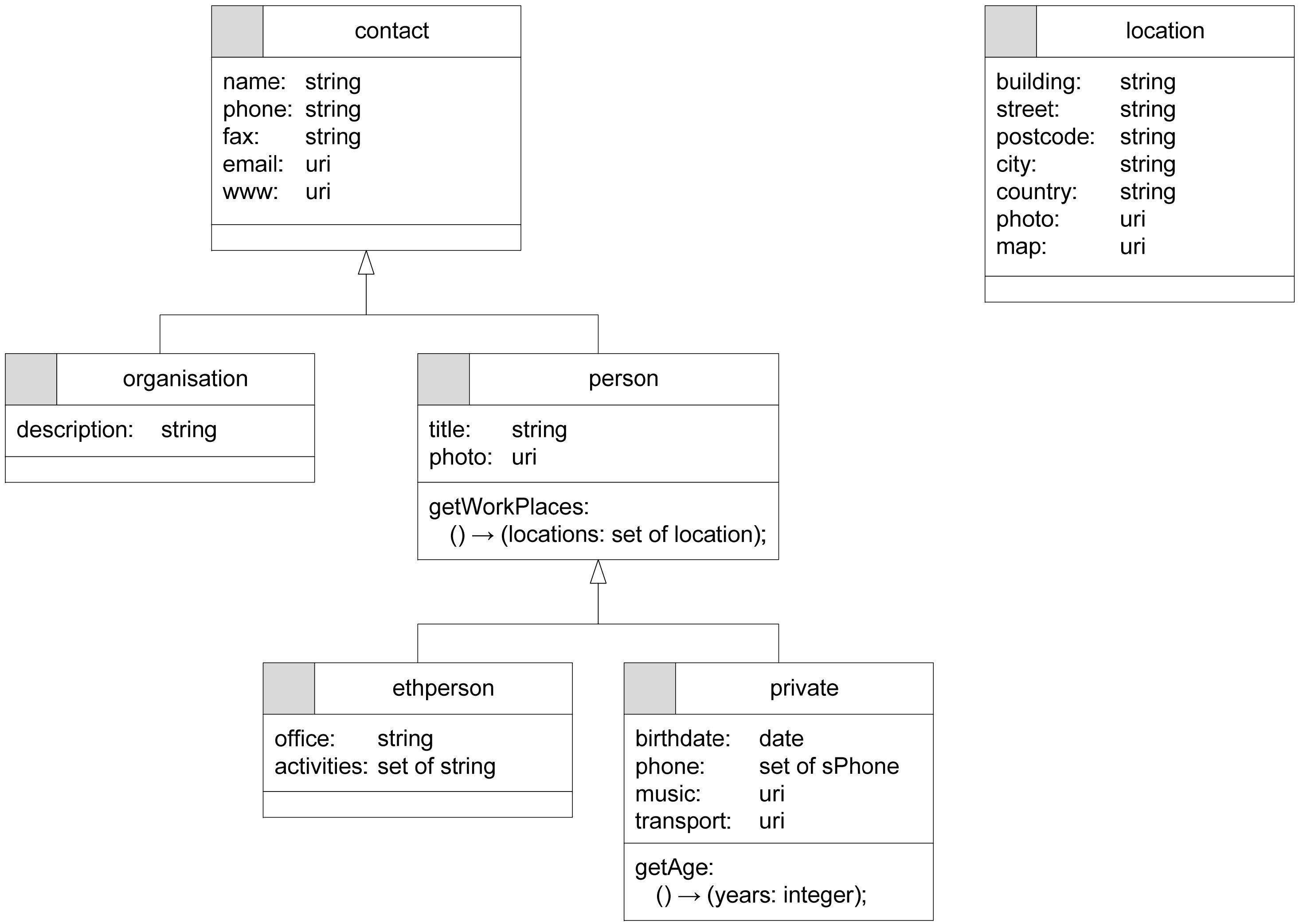
OM Type Layer

- Objects are represented by object types
  - object types define type units
  - instances of object types have corresponding information units
- Objects can gain and lose types dynamically
  - dress operation adds a type to an object
  - strip operation removes a type from an object
- Multiple inheritance
  - an object type can have multiple supertypes
  - conflicts and name clashes must be handled by developer
- Multiple instantiation
  - objects can have types from parallel inheritance hierarchies
  - objects can have types that are completely unrelated

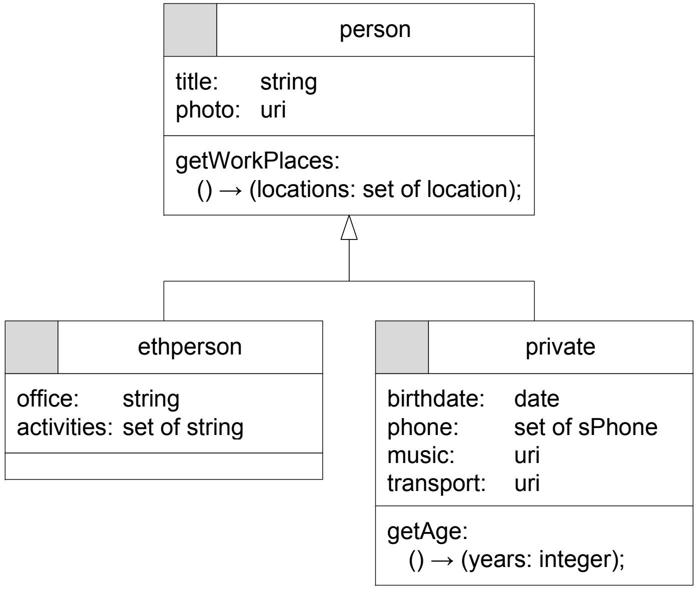
OM Type Layer

- Values of different types of types are supported in the OM data model
- Base types
  - define basic built-in values without identity
  - string, integer, real, boolean, date, uri, ...
- Object types
  - define representations of objects with identity
- Structured types
  - define structure or record values without identity
- Bulk types
  - define collection values of given member type without identity

Object Types



Type Units



- Each type defines a type unit
  - direct correspondence to type
  - no inherited fields
- Attributes have a name, a type and a bulk
  - uni
  - set, bag, sequence, ranking
- Methods are managed separately and linked to types

person	(title, string, uni), (photo, uri, uni)

ethperson	(office, string, uni), (activities, uri, set)

private	(birthdate, date, uni), (phone, sPhone, set), (music, uri, uni), (transport, uri, uni)

Information Units

Object

o327

contact
name: "Moira C. Norrie" phone: "+41 44 632 72 42" ...

person
title: "Prof." ...

ethperson
office: "IFW D 45.1" ...

private
birthdate: null phone: { ("mobile", "+4179...") } ...

Information Units

o327	contact	"Moira C. Norrie", "+41 44 632 72 42", ...
o327	person	"Prof.", ...
o327	ethperson	"IFW D 45.1", ...
o327	private	null, {("mobile", "+4179...")}, ...

Browsing Objects

Information Units

o327	contact	"Moira C. Norrie", "+41 44 632 72 42", ...
o327	person	"Prof.", ...
o327	ethperson	"IFW D 45.1", ...
o327	private	null, {("mobile", "+4179...")}, ...

Instance person

person(o327)
name: "Moira C. Norrie" phone: "+41 44 632 72 42" ... title: "Prof" ...

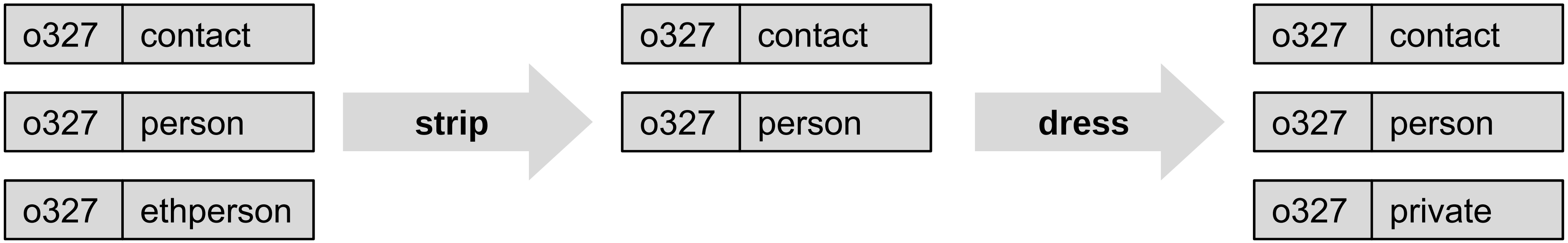
Instance ethperson

ethperson(o327)
name: "Moira C. Norrie" phone: "+41 44 632 72 42" ... title: "Prof" ... office: "IFW D 45.1" ...

Instance private

private(o327)
name: "Moira C. Norrie" ... title: "Prof" ... birthdate: null phone: {("mobile", "+4176...")}

Dressing and Stripping Objects

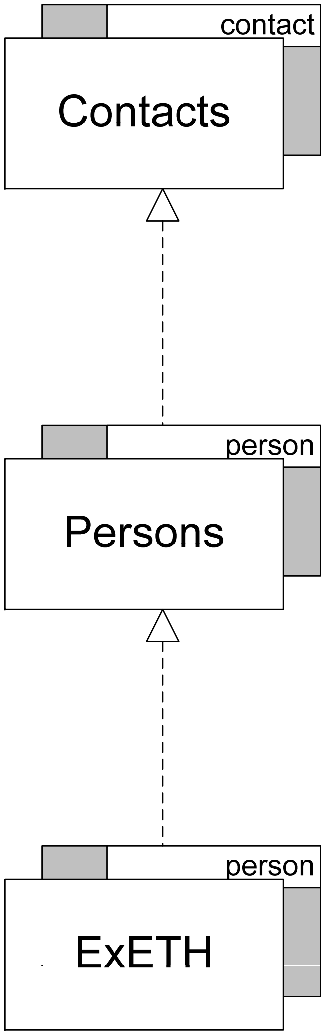


- Objects can gain and lose type instances dynamically
- Dress operation creates an information unit of given type, initialised it with null values, and adds it to object
- Strip operation removes an information unit of given type and discards values stored in it

OM Classification Layer

- Classification is defined based on types from type layer
- Collections as a concept for semantic groupings
  - collection membership constrained by type
  - multiple collections can share the same member type
  - different types of collection behaviour
  - kinds and roles
- Constraints to raise semantic expressiveness
  - subcollections and subcollection constraints
  - classification structures and classification constraints
  - associations to link objects together
  - cardinality constraints to describe associations
  - evolution constraints that govern object lifecycle

Collections and Subcollections



Contacts
contact(o212) contact(o213) contact(o214) contact(o215)

subset

Persons
person(o212) person(o213) person(o215)

subset

ExETH
person(o212)

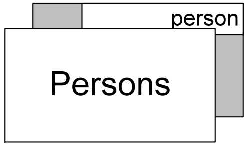
ext(Contacts) =
{ contact(o212), contact(o213), contact(o214), contact(o215) }

ext(Persons) $\subseteq$ ext(Contacts)

ext(ExETH) $\subseteq$ ext(Persons)

Collection Behaviour

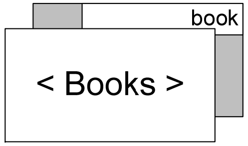
Set



Persons
person(o111)
person(o112)
person(o113)
person(o114)

no duplicates
no order

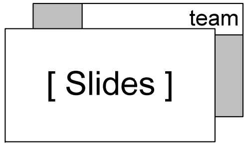
Bag



Books
book(211)
book(212)
book(212)
book(212)
book(213)
book(213)

duplicates
no order

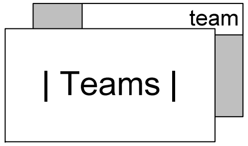
Sequence



Slides
slide(311)
slide(312)
slide(313)
slide(314)
slide(315)
slide(311)

duplicates
order

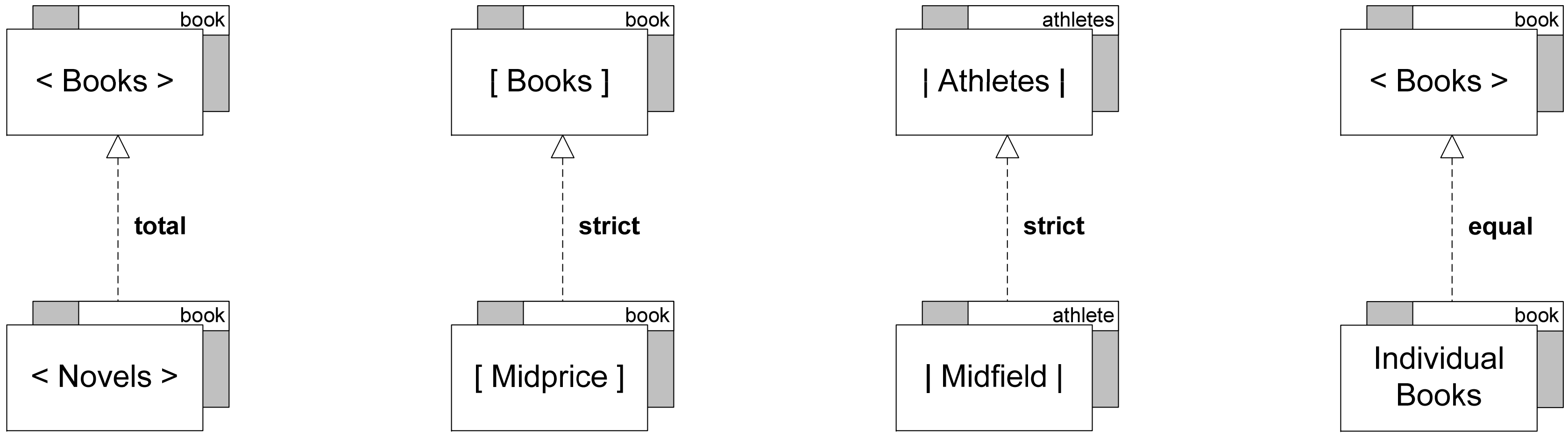
Ranking



Teams
team(411)
team(415)
team(413)
team(412)
team(416)
team(414)

no duplicates
order

Subcollection Behaviour



control duplicates

all copies of a novel that are in Books are also in Novels

$\{(b_1,2), (b_2,3), (b_3,1)\}$
$\{(b_1,2), (b_3,1)\}$

control order

subcollection is a strict subsequence of supercollection

$[b_1, b_1, b_2, b_2, b_2, b_3]$
$[b_1, b_2, b_2, b_2]$

control order

subcollection is a strict subranking of supercollection

$|a_1, a_2, a_3, a_4, a_5, a_6|$
$|a_3, a_4|$

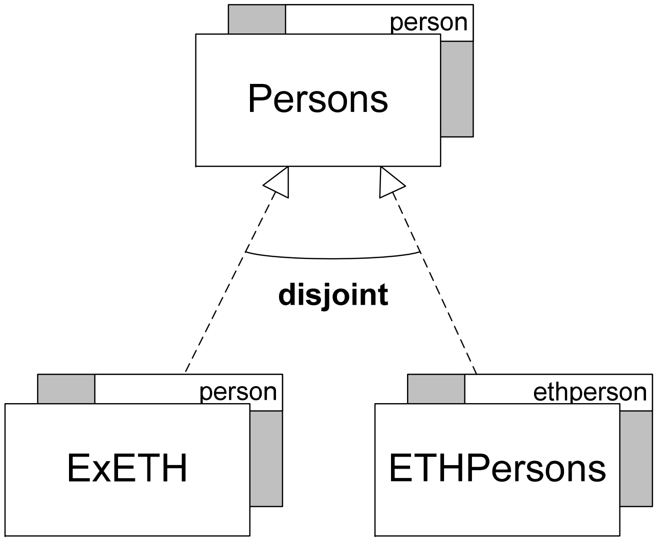
control membership

collection behaviour is different, elements are the same

$\{(b_1,2), (b_2,3), (b_3,1)\}$
$\{b_1, b_2, b_3\}$

Classification Structures

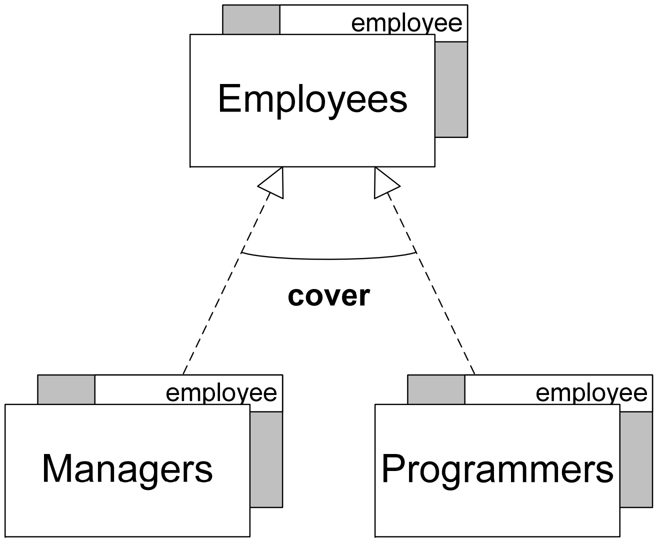
Disjoint



No person can be employed by ETH and, at the same time, have left ETH

ext(ExETH) $\cap$ **ext(ETHPersons)** $= \emptyset$

Cover

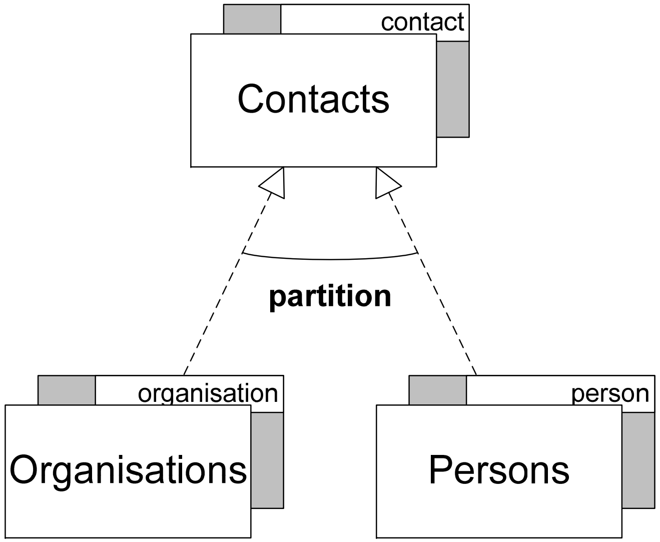


Every employee is either a manager, a programmer or both

ext(Managers) $\cup$ **ext(Programmers)** $=$ **ext(Employees)**

Classification Structures

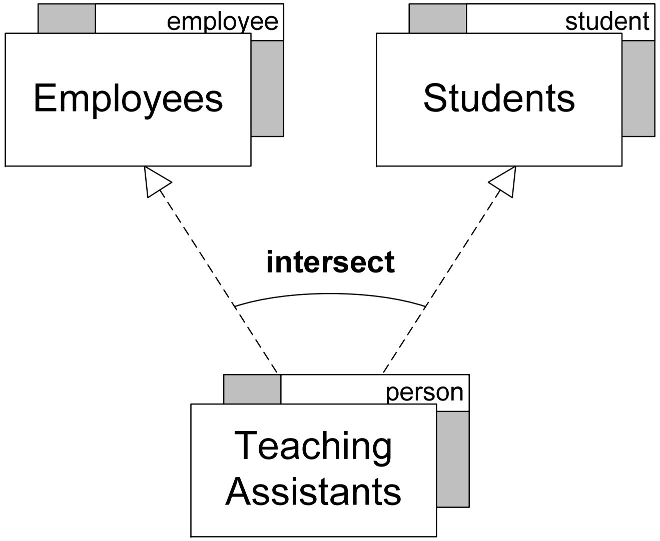
Partition



A contact is either an organisation or a person, but not both

ext(Organisations) $\cap$ ext(Persons) $=\emptyset$
$\wedge$ ext(Organisations) $\cup$ ext(Persons)
$=$ ext(Contacts)

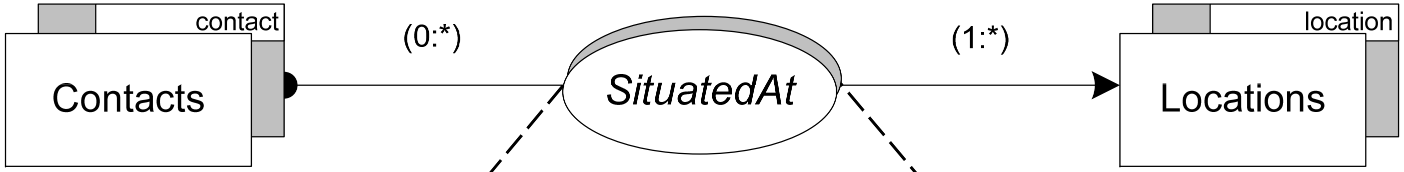
Intersection



Every person that is an employee and a student is a teaching assistant

ext(Employees) $\cap$ ext(Students) $=$
ext(TeachingAssistants)

Associations



Contacts
contact(o212)
contact(o213)
contact(o214)
contact(o215)

SituatedAt	
contact(o212)	location(o311)
contact(o213)	location(o311)
contact(o214)	location(o315)

Locations
location(o311)
location(o315)

Source or Domain Collection

Relation Collection (Binary Collection)

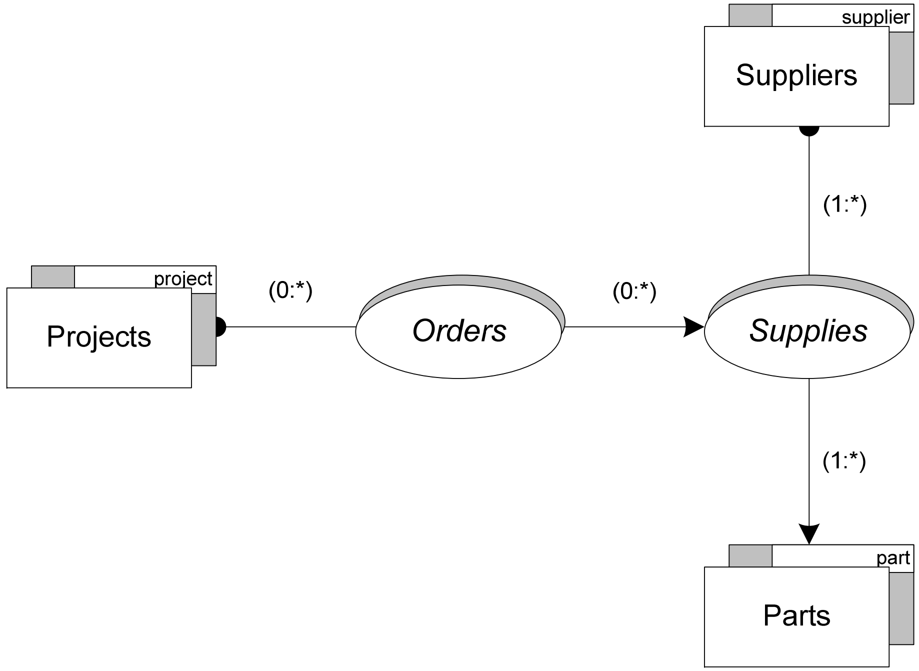
Target or Range Collection

Associations

- Cardinality constraints
  - (0:*) constraint on domain expresses that an organisation can be situated at any number of locations
  - (1:*) constraint on range expresses that each location has to be associated with at least one organisation
  - notation differs from the one commonly used in E/R models
- Behaviour
  - relation collection of an association is a normal collection
  - can be set, bag, sequence or ranking
- No ternary association and no relationship attributes
  - OM does not support ternary or n-ary associations
  - OM does not support attributes for associations

Nested Associations

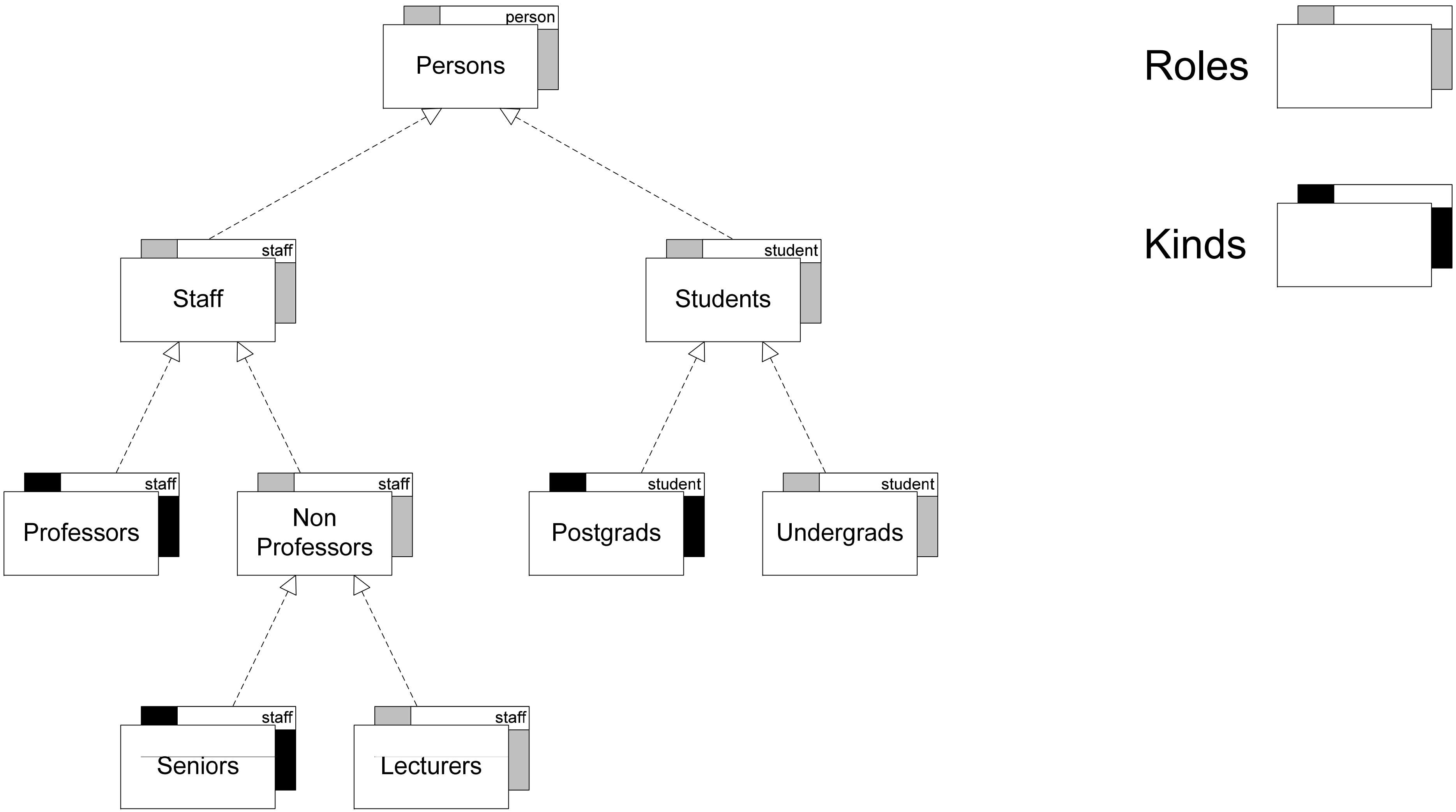
- Domain and range of an association can be associations
- Can be used to model
  - n-ary relationships
  - relationship attributes
- Advantages
  - decomposition of ternary relationship into primary and secondary association
  - clearer semantics of cardinality constraints
  - allows uniform query language constructs to be used



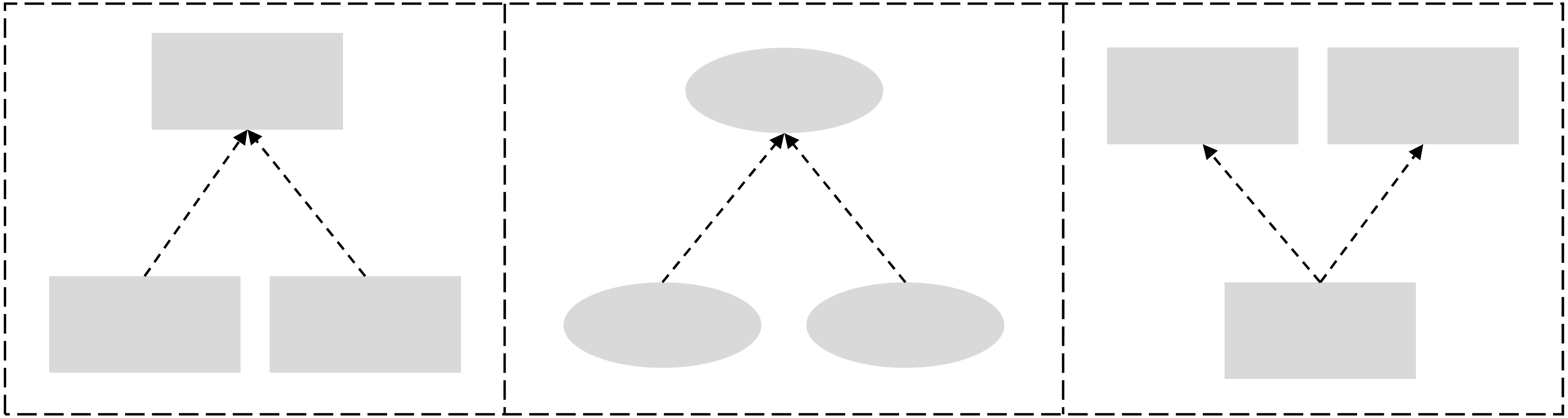
Kinds and Roles

- Kinds
  - fundamental fixed classification
  - similar to Stan Zdonik's notion of essential types but he does not distinguish typing and classification and only has types to deal with both representation and classification
  - kinds can change if certain conditions fulfilled
- Roles
  - roles change during entity lifecycles
- Kinds and roles also control the evolution of a database

Example


person
Persons
staff
Staff
student
Students
staff
Professors
staff
Non Professors
student
Postgrads
student
Undergrads
staff
Seniors
staff
Lecturers
Roles
Kinds

Classification Graphs



- $C_2 \preccurlyeq C_1$ denotes that C_2 is a subcollection of C_1
- For a collection C
  - kinds C $=$ { K | K is a kind and $C \preccurlyeq K$ }
  - roles C $=$ { R | R is a role and $C \preccurlyeq R$ }
    $=$ { R | $C \preccurlyeq R$ and R is not a kind }

Controlling Evolution

- Assumptions
  - each classification structure has a single root
  - a root is a kind
  - if $C \preccurlyeq C_1$ and there is no C_2 with $C_1 \preccurlyeq C_2$ then C_1 is the maximal collection of C
  - each collection has a single maximal collection
- Migration $x :: C_1 \rightarrow C_2$ valid if
  a) x does not belong to a subcollection of C_1
  b) x can lose a kind only if it loses the contextual role of that kind
  $\forall K \in (\text{kinds } C_1 - \text{kinds } C_2): \exists R \in \text{roles } K \Rightarrow R \notin \text{roles } C_2$

Migration Example

- $x :: \text{Postgrads} \rightarrow \text{Lectures}$
  - no x can belong to a subcollection of Postgrads
  - kinds Postgrads $-$ kinds Lecturers
    $= \{\text{Postgrads, Persons}\} - \{\text{Persons}\} = \{\text{Postgrads}\}$
  - $\forall\, K \in \{\text{Postgrads}\}: \exists\, R \in \text{roles } K \Rightarrow R \notin \text{roles Lecturers}$
  - $K = \text{Postgrads}$
    $\exists\, R \in \text{roles Postgrads} \Rightarrow R \notin \text{roles Lecturers}$
    $\exists\, R \in \{\text{Students}\} \Rightarrow R \notin \{\text{Lecturers, NonProfessors, Staff}\}$
- Migration is valid

Migration Example

- $x :: \text{Postgrads} \rightarrow \text{Undergrads}$
  - no x can belong to a subcollection of Postgrads
  - kinds Postgrads $-$ kinds Undergrads
    $= \{\text{Postgrads, Persons}\} - \{\text{Persons}\} = \{\text{Postgrads}\}$
  - $\forall K \in \{\text{Postgrads}\}: \exists R \in \text{roles } K \Rightarrow R \notin \text{roles Lecturers}$
  - $K = \text{Postgrads}$
    $\exists R \in \text{roles Postgrads} \Rightarrow R \notin \text{roles Undergrads}$
    $\exists R \in \{\text{Students}\} \Rightarrow R \notin \{\text{Undergrads, Students}\}$
- Migration is invalid

Literature

- Moira C. Norrie: **An Extended Entity-Relationship Approach to Data Management in Object-Oriented Systems**, In: *Proceedings of ER, 390-401, 1993*
- Moira C. Norrie: **Distinguishing Typing and Classification in Object Data Models**, In: *Information Modelling and Knowledge Bases VI, H. Kangassalo, H. Jaakkola, K. Hori and T. Kitahashi, eds, IOS Press, 1995*
- Alain P. Würgler: **OMS Development Framework: Rapid Prototyping for Object-Oriented Databases**, *PhD Thesis, ETH No. 13512, 2000*

Next Week

Object Model Language: OML

- Collection Algebra
- Language Design
- Data Definition, Manipulation and Query Language