Object Database Standards, Languages, and Design

Chapter 21

Announcement

- HW 3:
  - 10%
  - Due 2nd of June.

- Quiz 3
  - 3%
  - On Saturday May 11
  - Chapter 21

Chapter Objectives

- Discuss the importance of standards (e.g., portability, interoperability)
- Introduce Object Data Management Group (ODMG):
- Present Object Database Conceptual Design

Chapter Outline

- Advantages of Standards
- Overview of the Object Model ODMG
- The Object Definition Language DDL
- The Object Query Language OQL
- Object Database Conceptual Model

- The Object Model of ODMG ...

- One of the main reasons for the success of RDBMS is the SQL standard.
- Standards are essential for:
  - Portability (ability to be executed in different systems) and
  - Interoperability (ability to access multiple systems)
- As a result a consortium of ODBMS vendors formed a standard known as ODMG (Object Data Management Group)

... The Object Model of ODMG

- The ODMG standard is made up of several parts
  - Object module
  - Object definition Language (ODL)
  - Object Query Language (OQL)
  - Bindings to O-O programming languages (OOPLs)

ODMG Object Model

- ODMG object model:
  - Is the data model upon which the ODL and the OQL are based
  - Provides the data types, type constructors, and other concepts that can be utilized in the ODL to specify object database schemas
  - Provide a standard terminology

ODMG Basic Building Blocks

- The basic building blocks of the object model are
  - Objects
  - Literlas

- An object has four characteristics

1. Identifier: unique system-wide identifier
2. Name: unique within a particular database and/or program; it is optional
3. Lifetime: persistent vs transient
4. Structure: specifies how object is constructed by the type constructor and whether it is a collection or an *atomic* object

ODMG Literals

- A literal has a current value but not an identifier
- Three types of literals

1. Atomic literal: predefined; basic data type values (e.g., `short, float, boolean, char`)
2. structured: values that are constructed by tuple constructors. (e.g., Date, Time, Interval, Timestamp, etc)
3. collection: a collection (e.g., set, list, array, bag, dictionary) of values or objects

ODMG Interface and Class Definition

- ODMG supports two concepts for specifying object types:
  - Interface
  - Class
- There are similarities and differences between interfaces and classes
- Both have behaviors (operations) and state (attributes and relationships)

ODMG Interface

- An interface is a specification of the abstract behavior of an object type
- State properties of an interface (i.e., its attributes and relationships) cannot be inherited from
- Objects cannot be instantiated from an interface
- There are many built-in object interfaces (e.g., Object, Date, Time, Collection, Array, List);

ODMG Interface Definition

- Example

```
interface Object {
    …
    boolean     same_as(in object  other_object);
    Object      copy();
    Void        delete();
 };
```

- Note: interface is ODMG's keyword for class/type

Built-in Interfaces for Date Objects

- <u>Example</u>

```
interface Date:Object {
      enum weekday{sun,mon,tue,wed,thu,fri,sat};
      enum Month{jan,feb,mar,…,dec};
      unsigned short year();
      unsigned short month();
      unsigned short day();
      …
      boolean is_equal(in Date other_date);
 };
```

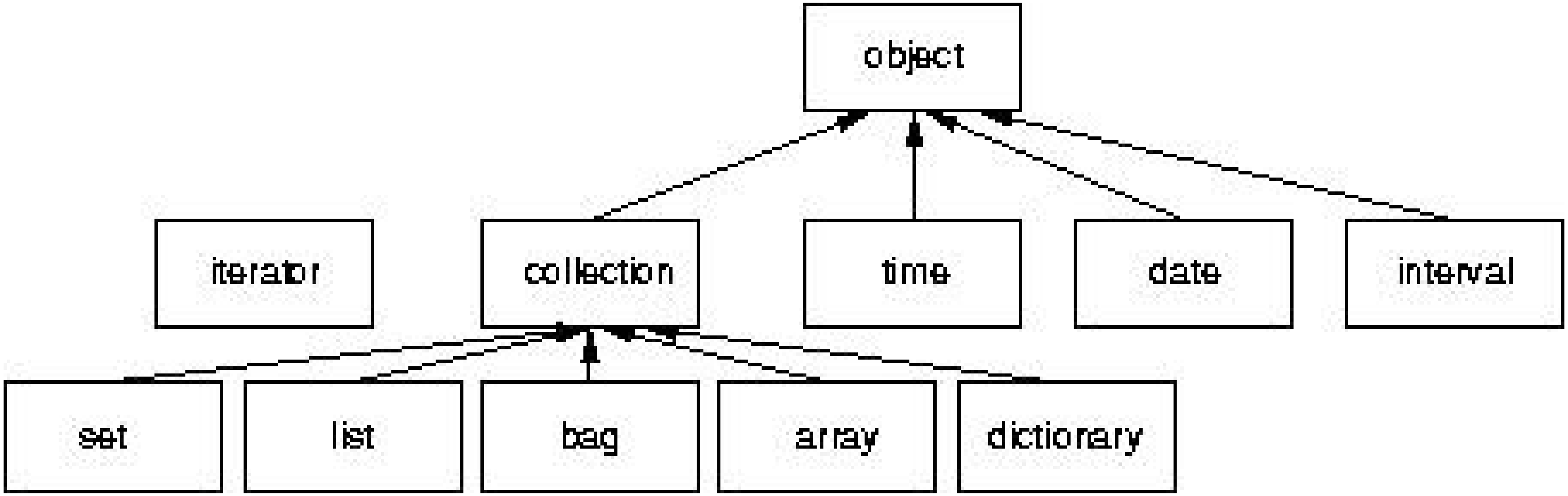
Built-in Interfaces for Collection Objects

- A `collection` object inherits the basic `collection` interface, for example:
  - **cardinality()**
  - **is_empty()**
  - **insert_element()**
  - **remove_element()**
  - **contains_element()**
  - **create_iterator()**

Collection Types

- Collection objects are further specialized into types like a set, list, bag, array, and dictionary
- Each collection type may provide additional interfaces, for example, a set provides:
  - create_union()
  - create_difference()
  - is_subst_of()
  - is_superset_of()
  - is_proper_subset_of()

Object Inheritance Hierarchy



Built-in interfaces of the object module

ODMG Class

- A class is a specification of abstract behavior and state of an object type
- A class is Instantiable
- Supports “extends” inheritance to allow both state and behavior inheritance among classes. Unlike interface in which only behavior is inherited.
- Multiple inheritance via “extends” is not allowed

Atomic Objects

- Atomic objects are user-defined objects and are defined via keyword `class`
- An example:

```
class Employee (extent all_emplyees key ssn) {
  attribute string name;
  attribute string ssn;
  attribute short age;
  relationship Dept works_for;
  void reassign(in string new_name);
}
```

Class Extents

- An ODMG object can have an `extent` defined via a class declaration
- Each `extent` is given a name and will contain all persistent objects of that class
- For `Employee` class, for example, the extent is called `all_employees`
- This is similar to creating an object of type `Set<Employee>` and making it persistent

Class Key

- A class key consists of one or more unique attributes
- For the `Employee` class, the key is `ssn.` Thus each employee is expected to have a unique `ssn`
- Keys can be composite, e.g.,
  `(`**`key`**` dnumber, dname)`

Object Factory

- An object factory is used to generate individual objects via its operations
- An example:

```
interface ObjectFactory {
  Object new ();
};
```

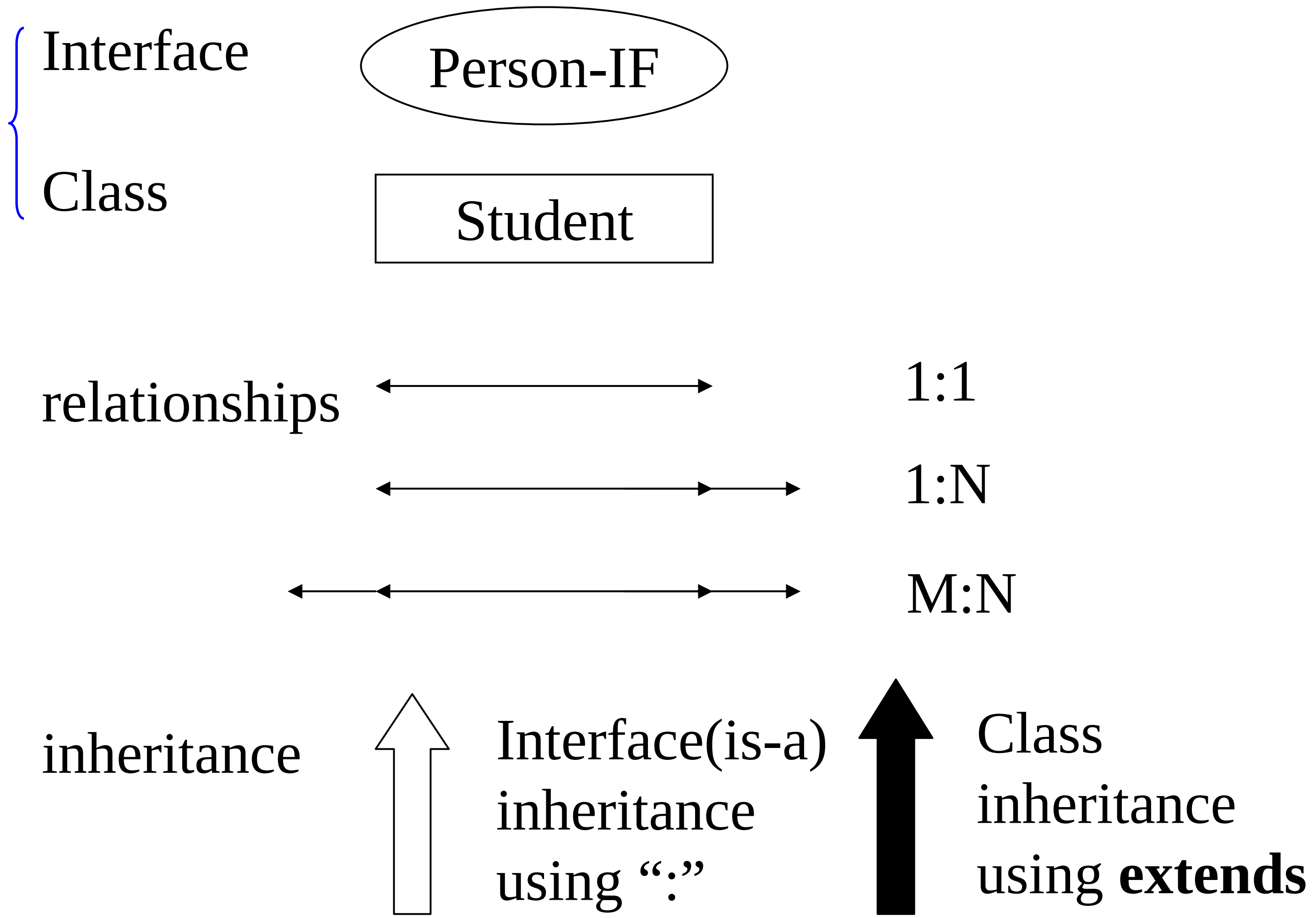
- `new()` returns new objects with an `object_id`
- One can create their own factory interface by inheriting the above interface

Object Definition Language (ODL)

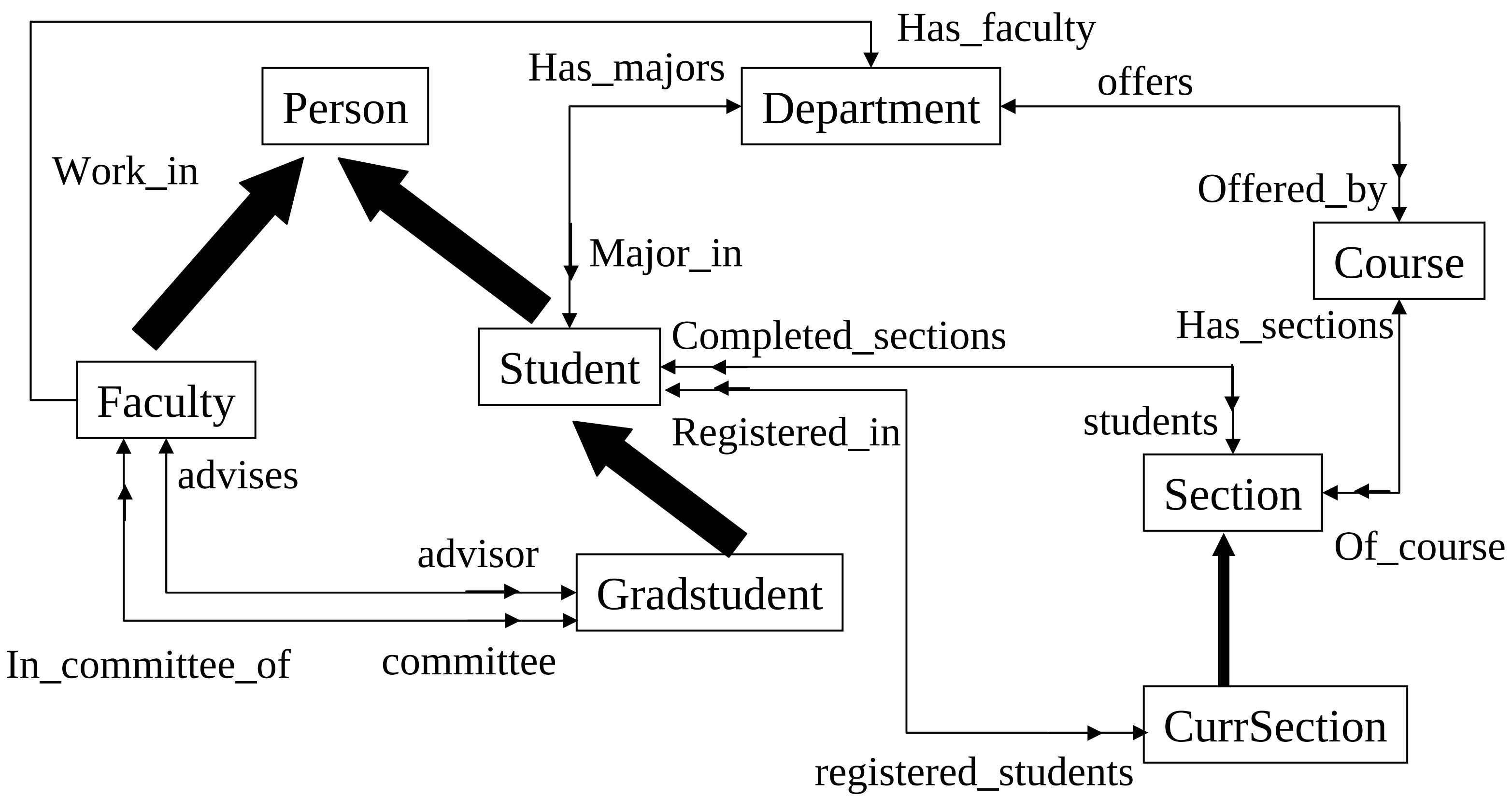
- ODL supports semantics constructs of ODMG
- ODL is independent of any programming language
- ODL is used to create object specification (classes and interfaces)
- ODL is not used for database manipulation, OQL is.

Graphical notation for representing ODL schemas

object specification



A graphical ODB schema for UNIVERSITY database



ODL Examples (1): A Very Simple Class

```
class Degree {
    attribute string college;
    attribute string degree;
    attribute string year;
};
```

- *(all examples are based on the university schema presented in Chapter 4 and graphically shown on page 680):*

ODL Examples (2): A Class With Key and Extent

- A class definition with “extent”, “key”, and more elaborate attributes; still relatively straightforward

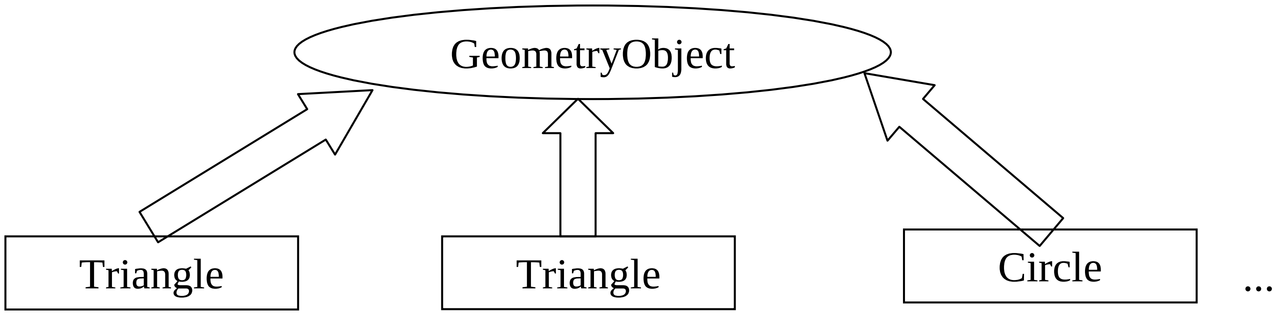
```
class Person (extent persons key ssn) {
    attribute struct Pname {string fname …} name;
    attribute string ssn;
    attribute date birthdate;
    …
    short age();
}
```

ODL Examples (3): A Class With Relationships

- Note extends (inheritance) relationship
- Also note “inverse” relationship

```
Class Faculty extends Person (extent faculty) {
   attribute string rank;
   attribute float  salary;
   attribute string phone;
   …
   relationship Dept works_in inverse Dept::has_faculty;
   relationship set<GradStu> advises inverse GradStu::advisor;
   void give_raise (in float raise);
   void promote (in string new_rank);
};
```

Graphical schema for geometric objects




```
interface GeometryObject
{
 attribute enum Shape{Rectangle,Triangle, Circle,…}shape;
  attribute struct Point {short x, short y}   reference_point;
  float   perimeter();
  float   area();
  void   translate(in short x_translation; in short y_translation);
  void   rotate(in float angle_of_rotation);
};
```

only operations are inherited, not properties as a result noninstantiable

Inheritance via ":" – An Example

```
interface GeometryObject {
    attribute struct point {…} reference_point;
    float perimeter ();
    …
};

class Triangle : GeometryObject (extent triangles) {
    attribute short side_1;
    attribute short side_2;
    …
};
```

Object Query Language

- OQL is DMG's query language
- OQL works closely with programming languages such as C++
- Embedded OQL statements return objects that are compatible with the type system of the host language
- OQL's syntax is similar to SQL with additional features for objects

Object Query Language (OQL)

- basic OQL syntax
  - select ... from ... where ...
  - Retrieve the names of all departments in the college of 'Engineering'

How to refer to a persistent object?
Entry point (named persistent object; or name of the extent of a class)

```
Q0: SELECT   d.dname
    FROM     d in departments
    WHERE    d.college = 'Engineering';
```

extent name

iterator variable

d in departments
departments d
departments as d

Data Type of Query Results

- The data type of a query result can be any type defined in the ODMG model
- A query does not have to follow the `select…from…where…` format
- A persistent name on its own can serve as a query whose result is a reference to the persistent object
  - Example

    departments; whose output is `set<Departments>`

Path Expressions

- A *path expression* is used to specify a path to attributes and objects in an entry point
- A path expression starts at a persistent object name (or its iterator variable)
- The name will be followed by zero or more dot connected relationship or attribute names, e.g.,

  departments.chair;

Views as Named Objects

- The *define* keyword in OQL is used to specify an identifier for a *named query*
- The name should be unique; if not, the results will replace an existing named query
- Once a query definition is created, it will persist until deleted or redefined
- A view definition can include parameters

An Example of OQL View

- A view to include students in a department who have a minor:

```
define has_minor(dept_name) as
select s
from s in students
where s.minor_in.dname=dept_name
```

- `has_minor` can now be used in queries

Single Elements from Collections

- An OQL query returns a collection
- OQL's `element` operator can be used to return a single element from a singleton collection that contains one element:

```
element (select d
from d in departments
where d.dname = 'Software Engineering');
```

- If d is empty or has more than one elements, an *exception* is raised

Collection Operators

- OQL supports a number of aggregate operators that can be applied to query results
- The aggregate operators include `min, max, count, sum`, and `avg` and operate over a collection
- `count` returns an integer; others return the same type as the collection type

An Example of an OQL: Aggregate Operator

- To compute the average GPA of all seniors majoring in Business:

```
avg ( select s.gpa
      from s in students
      where s.class = 'senior'
      and s.majors_in.dname ='Business');
```

Membership and Quantification

- OQL provides membership and quantification operators:
  - `(e in c)` is true if e is in the collection c
  - `(for all e in c: b)` is true if all e elements of collection c satisfy b
  - `(exists e in c: b)` is true if at least one e in collection c satisfies b

An Example of Membership

- To retrieve the names of all students who completed ICS102:

```
select s.name.fname s.name.lname
from s in students
where 'ICS102' in
   (select c.name
    from c in s.completed_sections.section.of_course);
```

Ordered Collections

- Collections that are lists or arrays allow retrieving their `first, last`, and `ith` elements
- OQL provides additional operators for extracting a sub-collection and concatenating two lists
- OQL also provides operators for ordering the results

An Example of Ordered Operation

- To retrieve the last name of the faculty member who earns the highest salary:

```
first (select struct
(faculty: f.name.lastname,salary f.salary)
from f in faculty
ordered by f.salary desc);
```

Grouping Operator

- OQL also supports a grouping operator called `group by`
- To retrieve average GPA of majors in each department having >100 majors:

```
select deptname, avg_gpa:
avg (select p.s.gpa from p in partition)
from s in students
group by deptname: s.majors_in.dname
having count (partition) > 100
```

Object Database Conceptual Design

- Object Database (ODB) vs Relational Database (RDB)
  - Relationships are handled differently
  - Inheritance is handled differently
  - Operations in OBD are expressed early on since they are a part of the class specificaiton

Relationships: ODB vs RDB (1)

- Relationships in ODB:
  - relationships are handled by reference attributes that include OIDs of related objects
  - single and collection of references are allowed
  - references for binary relationships can be expressed in single direction or both directions via `inverse` operator

Relationships: ODB vs RDB (2)

- Relationships in RDB:
  - Relationships among tuples are specified by attributes with matching values (via *foreign keys*)
  - Foreign keys are single-valued
  - *M:N* relationships must be presented via a separate relation (table)

Inheritance Relationship in ODB vs RDB

- Inheritance structures are built in ODB (and achieved via ":" and `extends` operators)

- RDB has no built-in support for inheritance relationships; there are several options for mapping inheritance relationships in an RDB (see Chapter 7)

Early Specification of Operations

- Another major difference between ODB and RDB is the specification of operations
  - ODB: operations specified during design (as part of class specification)
  - RDB: may be delayed until implementation

Mapping EER Schemas to ODB Schemas

- Mapping EER schemas into ODB schemas is relatively simple especially since ODB schemas provide support for inheritance relationships
- Once mapping has been completed, operations must be added to ODB schemas since EER schemas do not include an specification of operations

Mapping EER to ODB Schemas

- Step 1:
  - Create an ODL class for each EER entity type or subclass
    - Multi-valued attributes are declared by sets, bags or lists constructors
    - Composite attributes are mapped into tuple constructors

Mapping EER to ODB Schemas

- Step 2:
  - Add relationship properties or reference attributes for each binary relationship into the ODL classes participating in the relationship
    - Relationship cardinality: single-valued for 1:1 and N:1 directions; set-valued for 1:N and M:N directions
    - Relationship attributes: create via tuple constructors

Mapping EER to ODB Schemas

- Step 3:
  - Add appropriate operations for each class
    - Operations are not available from the EER schemas; original requirements must be reviewed
    - Corresponding *constructor* and *destructor* operations must also be added

Mapping EER to ODB Schemas

- Step 4:
  - Specify inheritance relationships via `extends` clause
    - An ODL class that corresponds to a sub-class in the EER schema inherits the types and methods of its super-class in the ODL schemas
    - Other attributes of a sub-class are added by following Steps 1-3

Mapping EER to ODB Schemas

- Step 5:
  - Map weak entity types in the same way as regular entities
    - Weak entities that do not participate in any relationships may alternatively be presented as *composite multi-valued attribute* of the owner entity type

Mapping EER to ODB Schemas

- Step 6:
  - Map categories (union types) to ODL
    - The process is not straightforward
    - May follow the same mapping used for EER-to-relational mapping:
      - Declare a class to represent the category
      - Define 1:1 relationships between the category and each of its super-classes

Mapping EER to ODB Schemas

- Step 7:
  - Map *n*-ary relationships whose degree is greater than 2
    - Each relationship is mapped into a separate class with appropriate reference to each participating class

END