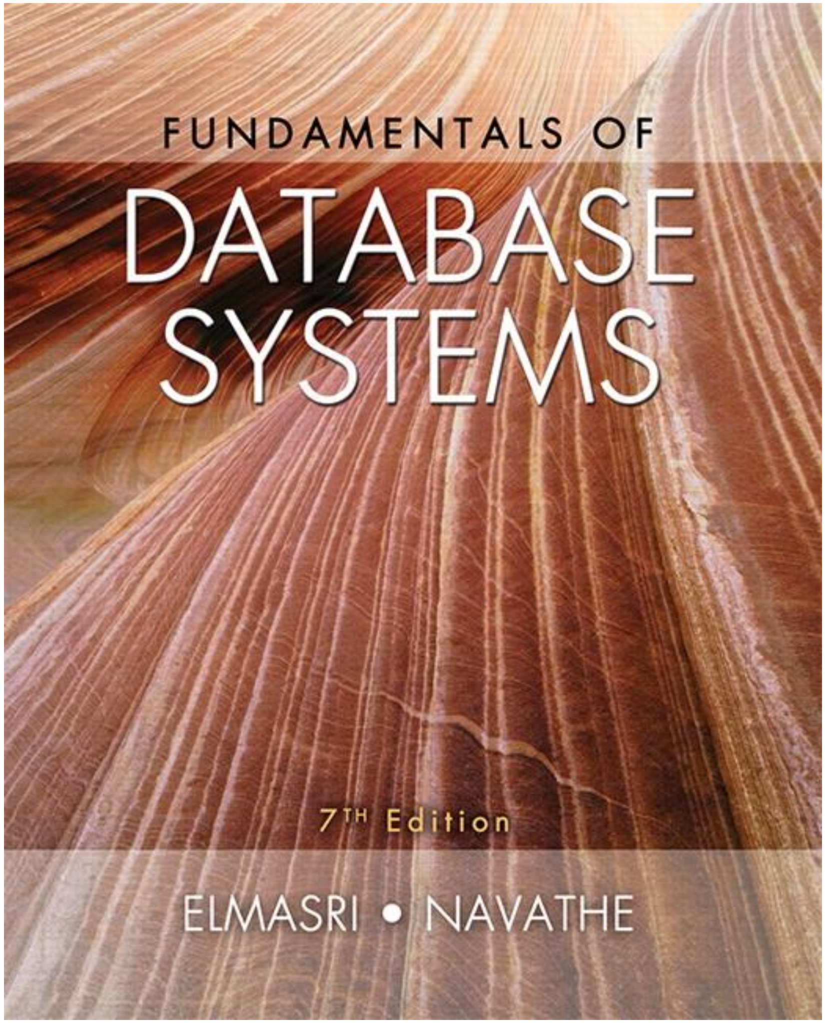

FUNDAMENTALS OF
DATABASE
SYSTEMS
7TH Edition
ELMASRI • NAVATHE

Chapter 12 Outline

- Overview of Object Database Concepts
- Object-Relational Features
- Object Database Extensions to SQL
- ODMG Object Model and the Object Definition Language ODL
- Object Database Conceptual Design
- The Object Query Language OQL
- Overview of the C++ Language Binding

Object and Object-Relational Databases

- **Object databases (ODB)**
  - **Object data management systems (ODMS)**
  - Meet some of the needs of more complex applications
  - Specify:
    - Structure of complex objects
    - Operations that can be applied to these objects

Overview of Object Database Concepts

- Introduction to object-oriented concepts and features
  - Origins in OO programming languages
  - Object has two components:
    - State (value) and behavior (operations)
  - Instance variables (attributes)
    - Hold values that define internal state of object
  - Operation is defined in two parts:
    - Signature (interface) and implementation (method)

Overview of Object Database Concepts (cont'd.)

- Inheritance
  - Permits specification of new types or classes that inherit much of their structure and/or operations from previously defined types or classes
- Operator overloading
  - Operation's ability to be applied to different types of objects
  - Operation name may refer to several distinct implementations

Object Identity, and Objects versus Literals

- Object has Unique identity
  - Implemented via a unique, system-generated object identifier (OID)
  - **Immutable**
- Most OO database systems allow for the representation of both objects and literals (simple or complex values)

Complex Type Structures for Objects and Literals

- Structure of arbitrary complexity
  - Contain all necessary information that describes object or literal
- Nesting **type constructors**
  - Generate complex type from other types
- Type constructors (type generators):
  - **Atom (basic data type – int, string, etc.)**
  - **Struct (or tuple)**
  - **Collection**

Complex Type Structures for Objects and Literals (cont'd.)

- Collection types:
  - **Set**
  - **Bag**
  - **List**
  - **Array**
  - **Dictionary**
- **Object definition language (ODL)**
  - Used to define object types for a particular database application

Figure 12.1 Specifying the object types EMPLOYEE, DATE, and DEPARTMENT using type construc

```
define type EMPLOYEE
    tuple  (  Fname:         string;
              Minit :        char;
              Lname:         string;
              Ssn:           string;
              Birth_date:    DATE;
              Address:       string;
              Sex:           char;
              Salary:        float;
              Supervisor:    EMPLOYEE;
              Dept:          DEPARTMENT;
define type DATE
    tuple  (  Year:          integer;
              Month:         integer;
              Day:           integer; );
define type DEPARTMENT
    tuple  (  Dname:         string;
              Dnumber:       integer;
              Mgr:           tuple  (  Manager:      EMPLOYEE;
                                       Start_date:   DATE; );
              Locations:     set(string);
              Employees:     set(EMPLOYEE);
              Projects:      set(PROJECT); );
```

Figure 12.2 Adding op … DEPARTMENT.

```
define class EMPLOYEE
    type tuple (  Fname:            string;
                  Minit:            char;
                  Lname:            string;
                  Ssn:              string;
                  Birth_date:       DATE;
                  Address:          string;
                  Sex:              char;
                  Salary:           float;
                  Supervisor:       EMPLOYEE;
                  Dept:             DEPARTMENT; );
    operations    age:              integer;
                  create_emp:       EMPLOYEE;
                  destroy_emp:      boolean;
end EMPLOYEE;
define class DEPARTMENT
    type tuple (  Dname:            string;
                  Dnumber:          integer;
                  Mgr:              tuple (  Manager:      EMPLOYEE;
                                             Start_date:   DATE; );
                  Locations:        set (string);
                  Employees:        set (EMPLOYEE);
                  Projects          set(PROJECT); );
    operations    no_of_emps:       integer;
                  create_dept:      DEPARTMENT;
                  destroy_dept:     boolean;
                  assign_emp(e: EMPLOYEE): boolean;
                  (* adds an employee to the department *)
                  remove_emp(e: EMPLOYEE): boolean;
                  (* removes an employee from the department *)
end DEPARTMENT;
```

Encapsulation of Operations

- Encapsulation
  - Related to abstract data types
  - Define **behavior** of a class of object based on operations that can be externally applied
  - External users only aware of interface of the operations
  - Can divide structure of object into visible and hidden attributes

Encapsulation of Operations

- **Constructor** operation
  - Used to create a new object
- **Destructor** operation
  - Used to destroy (delete) an object
- **Modifier** operations
  - Modify the state of an object
- **Retrieve** operation
- *Dot notation* to apply operations to object

Persistence of Objects

- **Transient objects**
  - Exist in executing program
  - Disappear once program terminates
- **Persistent objects**
  - Stored in database, persist after program termination
  - **Naming mechanism:** object assigned a unique name in object base, user finds object by its name
  - **Reachability:** object referenced from other persistent objects, object located through references

Figu

```
define class DEPARTMENT_SET
    type set (DEPARTMENT);
    operations add_dept(d: DEPARTMENT):   boolean;
        (* adds a department to the DEPARTMENT_SET object *)
            remove_dept(d: DEPARTMENT):  boolean;
        (* removes a department from the DEPARTMENT_SET object *)
            create_dept_set:        DEPARTMENT_SET;
            destroy_dept_set:       boolean;
end Department_Set;
...
persistent name ALL_DEPARTMENTS: DEPARTMENT_SET;
(* ALL_DEPARTMENTS is a persistent named object of type DEPARTMENT_SET *)
...
d:= create_dept;
(* create a new DEPARTMENT object in the variable d *)
...
b:= ALL_DEPARTMENTS.add_dept(d);
(* make d persistent by adding it to the persistent set ALL_DEPARTMENTS *)
```

Type (Class) Hierarchies and Inheritance

- Inheritance
  - Definition of new types based on other predefined types
  - Leads to **type** (or **class**) **hierarchy**
- Type: **type name** and list of visible (public) **functions** (attributes or operations)
  - Format:
    - `TYPE_NAME: function, function, ..., function`

Type (Class) Hierarchies and Inheritance (cont'd.)

- **Subtype**
  - Useful when creating a new type that is similar but not identical to an already defined type
  - Subtype inherits functions
  - Additional (local or specific) functions in subtype
  - Example:
    - `EMPLOYEE subtype-of PERSON: Salary, Hire_date, Seniority`
    - `STUDENT subtype-of PERSON: Major, Gpa`

Type (Class) Hierarchies and Inheritance (cont'd.)

- **Extent**
  - A *named persistent object* to hold collection of all persistent objects for a class
- **Persistent collection**
  - Stored permanently in the database
- **Transient collection**
  - Exists temporarily during the execution of a program (e.g. query result)

Other Object-Oriented Concepts

- **Polymorphism** of operations
  - Also known as **operator overloading**
  - Allows same operator name or symbol to be bound to two or more different implementations
  - Type of objects determines which operator is applied
- **Multiple inheritance**
  - Subtype inherits functions (attributes and operations) of more than one supertype

Summary of Object Database Concepts

- Object identity
- Type constructors (type generators)
- Encapsulation of operations
- Programming language compatibility
- Type (class) hierarchies and inheritance
- Extents
- Polymorphism and operator overloading

Object-Relational Features: Object DB Extensions to SQL

- **Type constructors (generators)**
  - Specify complex types using UDT
- Mechanism for specifying **object identity**
- **Encapsulation of operations**
  - Provided through user-defined types (UDTs)
- **Inheritance** mechanisms
  - Provided using keyword `UNDER`

User-Defined Types (UDTs) and Complex Structures for Objects

- **UDT** syntax:
  - `CREATE TYPE <type name> AS (<component declarations>);`
  - Can be used to create a complex type for an attribute (similar to *struct* – no operations)
  - Or: can be used to create a type as a basis for a table of objects (similar to *class* – can have operations)

User-Defined Types and Complex Structures for Objects (cont'd.)

- Array type – to specify collections
  - Reference array elements using []
- **`CARDINALITY`** function
  - Return the current number of elements in an array
- Early SQL had only array for collections
  - Later versions of SQL added other collection types (set, list, bag, array, etc.)

Object Identifiers Using Reference Types

- **Reference type**
  - Create unique object identifiers (OIDs)
  - Can specify system-generated object identifiers
  - Alternatively can use primary key as OID as in traditional relational model
  - Examples:
    - `REF IS SYSTEM GENERATED`
    - `REF IS <OID_ATTRIBUTE> <VALUE_GENERATION_METHOD> ;`

Creating Tables Based on the UDTs

- **INSTANTIABLE**
  - Specify that UDT is instantiable
  - The user can then create one or more tables based on the UDT
  - If keyword INSTANTIABLE is left out, can use UDT only as attribute data type – not as a basis for a table of objects

Encapsulation of Operations

- User-defined type
  - Specify methods (or operations) in addition to the attributes
  - Format:

```
CREATE TYPE <TYPE-NAME> (
<LIST OF COMPONENT ATTRIBUTES AND THEIR TYPES>
<DECLARATION OF FUNCTIONS (METHODS)>
);
```

Figure 12.4a Illustrating some of the object features of SQL. Using UDTs as types for attributes such as Address and Phone.

```
(a) CREATE TYPE STREET_ADDR_TYPE AS (
        NUMBER          VARCHAR (5),
        STREET          NAME VARCHAR (25),
        APT_NO          VARCHAR (5),
        SUITE_NO        VARCHAR (5)
    );
    CREATE TYPE USA_ADDR_TYPE AS (
        STREET_ADDR     STREET_ADDR_TYPE,
        CITY            VARCHAR (25),
        ZIP             VARCHAR (10)
    );
    CREATE TYPE USA_PHONE_TYPE AS (
        PHONE_TYPE      VARCHAR (5),
        AREA_CODE       CHAR (3),
        PHONE_NUM       CHAR (7)
    );
```

continued on next slide

Figure 12.4b Illustrating some of the object features of SQL. Specifying UDT for PERSON_TYPE.

```
(b) CREATE TYPE PERSON_TYPE AS (
        NAME            VARCHAR (35),
        SEX             CHAR,
        BIRTH_DATE      DATE,
        PHONES          USA_PHONE_TYPE ARRAY [4],
        ADDR            USA_ADDR_TYPE
    INSTANTIABLE
    NOT FINAL
    REF IS SYSTEM GENERATED
    INSTANCE METHOD AGE() RETURNS INTEGER;
    CREATE INSTANCE METHOD AGE() RETURNS INTEGER
        FOR PERSON_TYPE
        BEGIN
            RETURN /* CODE TO CALCULATE A PERSON'S AGE FROM
                      TODAY'S DATE AND SELF.BIRTH_DATE */
        END;
    );
```

continued on next slide

Specifying Type Inheritance

- NOT FINAL:
  - The keyword NOT FINAL indicates that subtypes can be created for that type
- UNDER
  - The keyword UNDER is used to create a subtype

Figure 12.4c Illustrating some of the object features of SQL. Specifying UDTs for STUDENT_TYPE and EMPLOYEE_TYPE as two subtypes of PERSON_TYPE.

```
(c) CREATE TYPE GRADE_TYPE AS (
        COURSENO      CHAR (8),
        SEMESTER      VARCHAR (8),
        YEAR          CHAR (4),
        GRADE         CHAR
    );
    CREATE TYPE STUDENT_TYPE UNDER PERSON_TYPE AS (
        MAJOR_CODE    CHAR (4),
        STUDENT_ID    CHAR (12),
        DEGREE        VARCHAR (5),
        TRANSCRIPT    GRADE_TYPE ARRAY [100]
```

continued on next slide

Figure 12.4c (continued) Illustrating some of the object features of SQL. Specifying UDTs for STUDENT_TYPE and EMPLOYEE_TYPE as two subtypes of PERSON_TYPE.

```
INSTANTIABLE
NOT FINAL
INSTANCE METHOD GPA( ) RETURNS FLOAT;
CREATE INSTANCE METHOD GPA( ) RETURNS FLOAT
    FOR STUDENT_TYPE
    BEGIN
        RETURN /* CODE TO CALCULATE A STUDENT'S GPA FROM
                  SELF.TRANSCRIPT */
    END;
);
CREATE TYPE EMPLOYEE_TYPE UNDER PERSON_TYPE AS (
    JOB_CODE        CHAR (4),
    SALARY          FLOAT,
    SSN             CHAR (11)
INSTANTIABLE
NOT FINAL
);
CREATE TYPE MANAGER_TYPE UNDER EMPLOYEE_TYPE AS (
     DEPT_MANAGED CHAR (20)
INSTANTIABLE
);
```

continued on next slide

Specifying Type Inheritance

- Type inheritance rules:
  - All attributes/operations are inherited
  - Order of supertypes in UNDER clause determines inheritance hierarchy
  - Instance (object) of a subtype can be used in every context in which a supertype instance used
  - Subtype can redefine any function defined in supertype

Creating Tables based on UDT

- UDT must be INSTANTIABLE
- One or more tables can be created
- Table inheritance:
  - UNDER keyword can also be used to specify supertable/subtable inheritance
  - Objects in subtable must be a **subset of** the objects in the supertable

Figure 12.4d Illustrating some of the object features of SQL. Creating tables based on some of the UDTs, and illustrating table inheritance.

```
(d) CREATE TABLE PERSON OF PERSON_TYPE
        REF IS PERSON_ID SYSTEM GENERATED;
    CREATE TABLE EMPLOYEE OF EMPLOYEE_TYPE
        UNDER PERSON;
    CREATE TABLE MANAGER OF MANAGER_TYPE
        UNDER EMPLOYEE;
    CREATE TABLE STUDENT OF STUDENT_TYPE
        UNDER PERSON;
```

continued on next slide

Specifying Relationships via Reference

- Component attribute of one tuple may be a **reference** to a tuple of another table
  - Specified using keyword **`REF`**
- Keyword **`SCOPE`**
  - Specify name of table whose tuples referenced
- **Dot notation**
  - Build path expressions
- **`->`**
  - Used for dereferencing

Figure 12.4e Illustrating some of the object features of SQL. Specifying relationships using REF and SCOPE.

```
(e) CREATE TYPE COMPANY_TYPE AS (
        COMP_NAME      VARCHAR (20),
        LOCATION       VARCHAR (20));
    CREATE TYPE EMPLOYMENT_TYPE AS (
        Employee REF (EMPLOYEE_TYPE) SCOPE (EMPLOYEE),
        Company REF (COMPANY_TYPE) SCOPE (COMPANY) );
    CREATE TABLE COMPANY OF COMPANY_TYPE (
        REF IS COMP_ID SYSTEM GENERATED,
        PRIMARY KEY (COMP_NAME) );
    CREATE TABLE EMPLOYMENT OF EMPLOYMENT_TYPE;
```

Summary of SQL Object Extensions

- UDT to specify complex types
  - INSTANTIABLE specifies if UDT can be used to create tables; NOT FINAL specifies if UDT can be inherited by a subtype
- REF for specifying **object identity** and inter-object references
- Encapsulation of operations in UDT
- Keyword `UNDER` to specify type inheritance and table inheritance

ODMG Object Model and Object Definition Language ODL

- ODMG object model
  - Data model for **object definition language (ODL)** and **object query language (OQL)**
- Objects and Literals
  - Basic building blocks of the object model
- Object has five aspects:
  - **Identifier**, **name**, **lifetime, structure**, and **creation**
- **Literal**
  - Value that does not have an object identifier

The ODMG Object Model and the ODL (cont'd.)

- **Behavior** refers to operations
- **State** refers to properties (attributes)
- **Interface**
  - Specifies only behavior of an object type
  - Typically **noninstantiable**
- **Class**
  - Specifies both state (attributes) and behavior (operations) of an object type
  - **Instantiable**

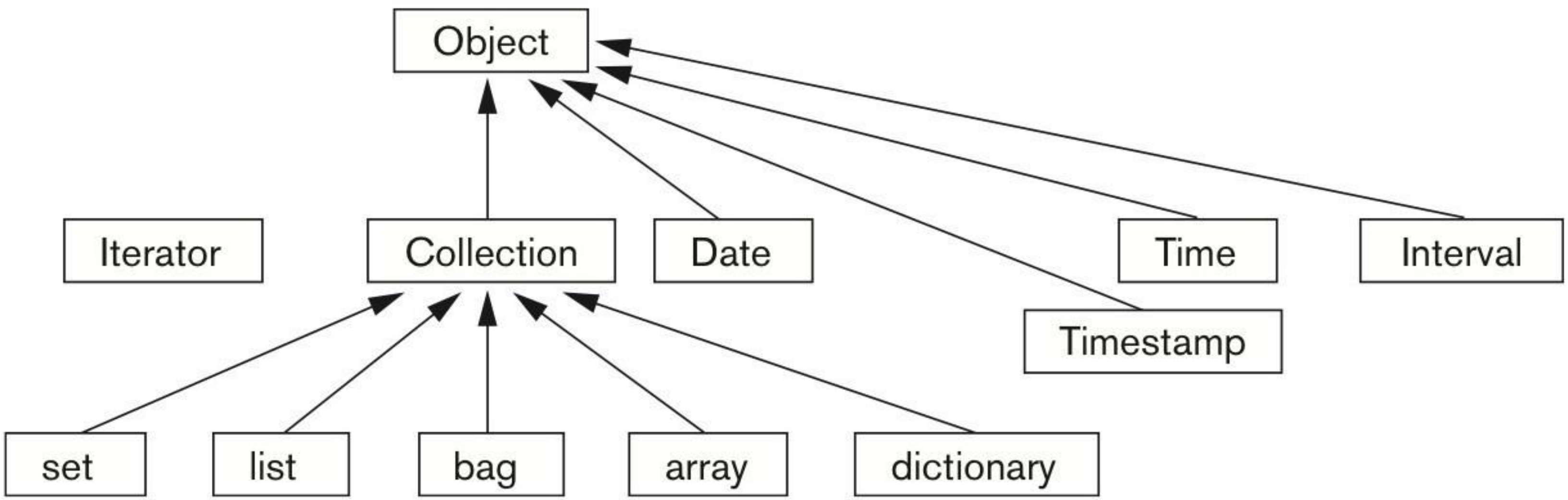
Inheritance in the Object Model of ODMG

- **Behavior inheritance**
  - Also known as IS-A or interface inheritance
  - Specified by the colon (:) notation
- **EXTENDS inheritance**
  - Specified by keyword **`extends`**
  - Inherit both state and behavior strictly among classes
  - Multiple inheritance via extends not permitted

Built-in Interfaces and Classes in the Object Model

- **Collection objects**
  - Inherit the basic Collection interface
- `i = o.create_iterator()`
  - Creates an iterator object for the collection
  - To loop over each object in a collection
- Collection objects further specialized into:
  - `set`, `list`, `bag`, `array`, and `dictionary`

Figure 12.6 Inheritance hierarchy for the built-in interfaces of the object model.



Atomic (User-Defined) Objects

- Specified using keyword `class` in ODL
- **Attribute**
  - Property; describes data in an object
- **Relationship**
  - Specifies inter-object references
  - Keyword `inverse`
    - Single conceptual relationship in inverse directions
- **Operation signature**:
  - Operation name, argument types, return value

Figure 12.7 The ... ion.

```
class EMPLOYEE
(       extent              ALL_EMPLOYEES
        key                 Ssn   )
{
        attribute           string                Name;
        attribute           string                Ssn;
        attribute           date Birth_date;
        attribute           enum Gender{M, F}     Sex;
        attribute           short                 Age;
        relationship        DEPARTMENT            Works_for
                                inverse DEPARTMENT::Has_emps;
        void                reassign_emp(in string New_dname)
                                raises(dname_not_valid);
};
class DEPARTMENT
(       extent              ALL_DEPARTMENTS
        key                 Dname, Dnumber )
{
        attribute           string                Dname;
        attribute           short                 Dnumber;
        attribute           struct Dept_mgr {EMPLOYEE Manager, date Start_date}
                                Mgr;
        attribute           set<string>           Locations;
        attribute           struct Projs {string Proj_name, time Weekly_hours)
                                Projs;
        relationship        set<EMPLOYEE>         Has_emps inverse EMPLOYEE::Works_for;
        void                add_emp(in string New_ename) raises(ename_not_valid);
        void                change_manager(in string New_mgr_name; in date
                                Start_date);
};
```

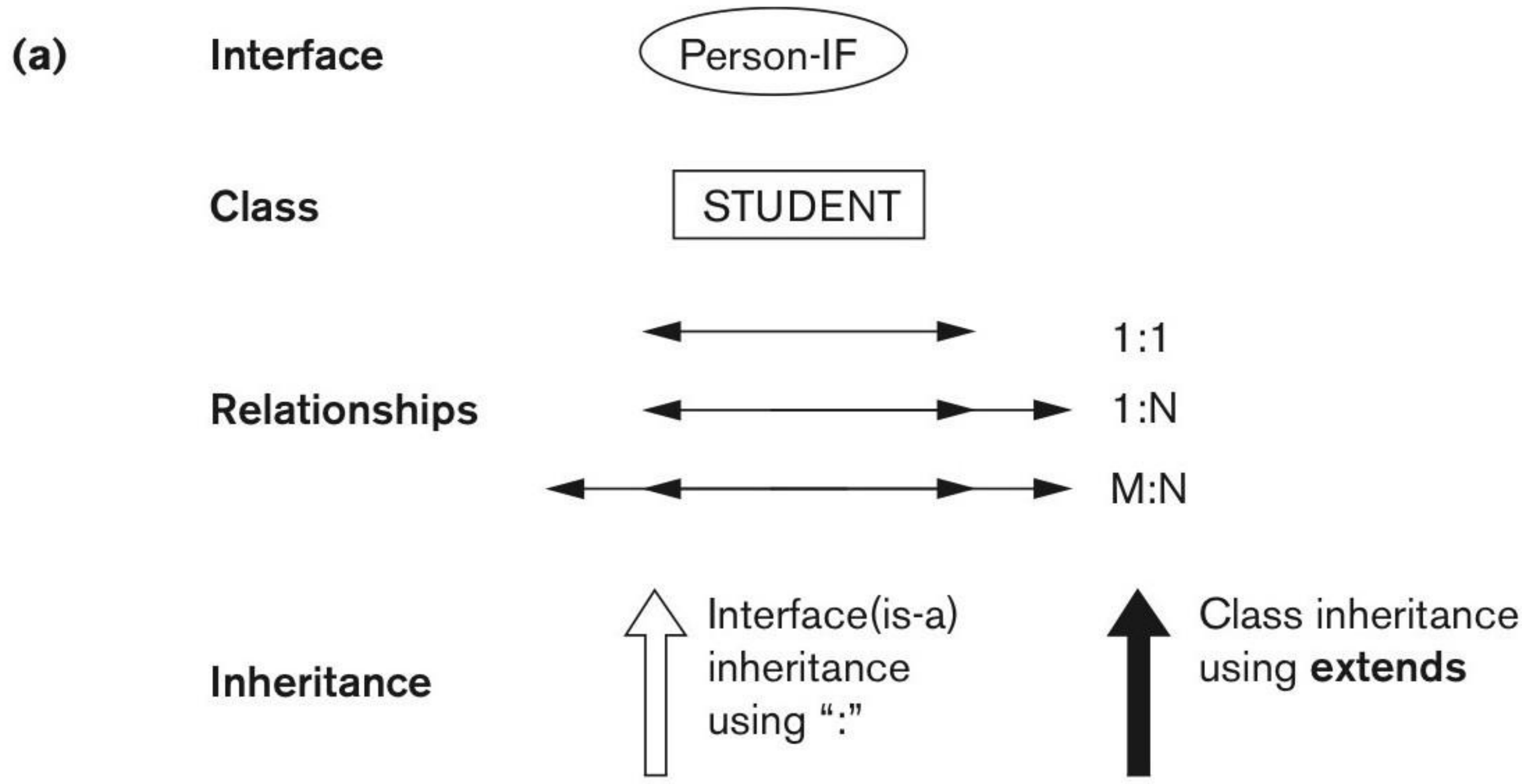
Extents, Keys, and Factory Objects

- **Extent**
  - A persistent named collection object that contains all persistent objects of class
- **Key**
  - One or more properties whose values are unique for each object in extent of a class
- **Factory object**
  - Used to generate or create individual objects via its operations

Object Definition Language ODL

- Support semantic constructs of ODMG object model
- Independent of any particular programming language
- Example on next slides of a UNIVERSITY database
- Graphical diagrammatic notation is a variation of EER diagrams

Figure 12.9a An example of a database schema. Graphical notation for representing ODL schemas.



continued on next slide

Figure 12.9b An example of a database schema. A graphical object database schema for part of the UNIVERSITY database (GRADE and DEGREE classes are not shown).

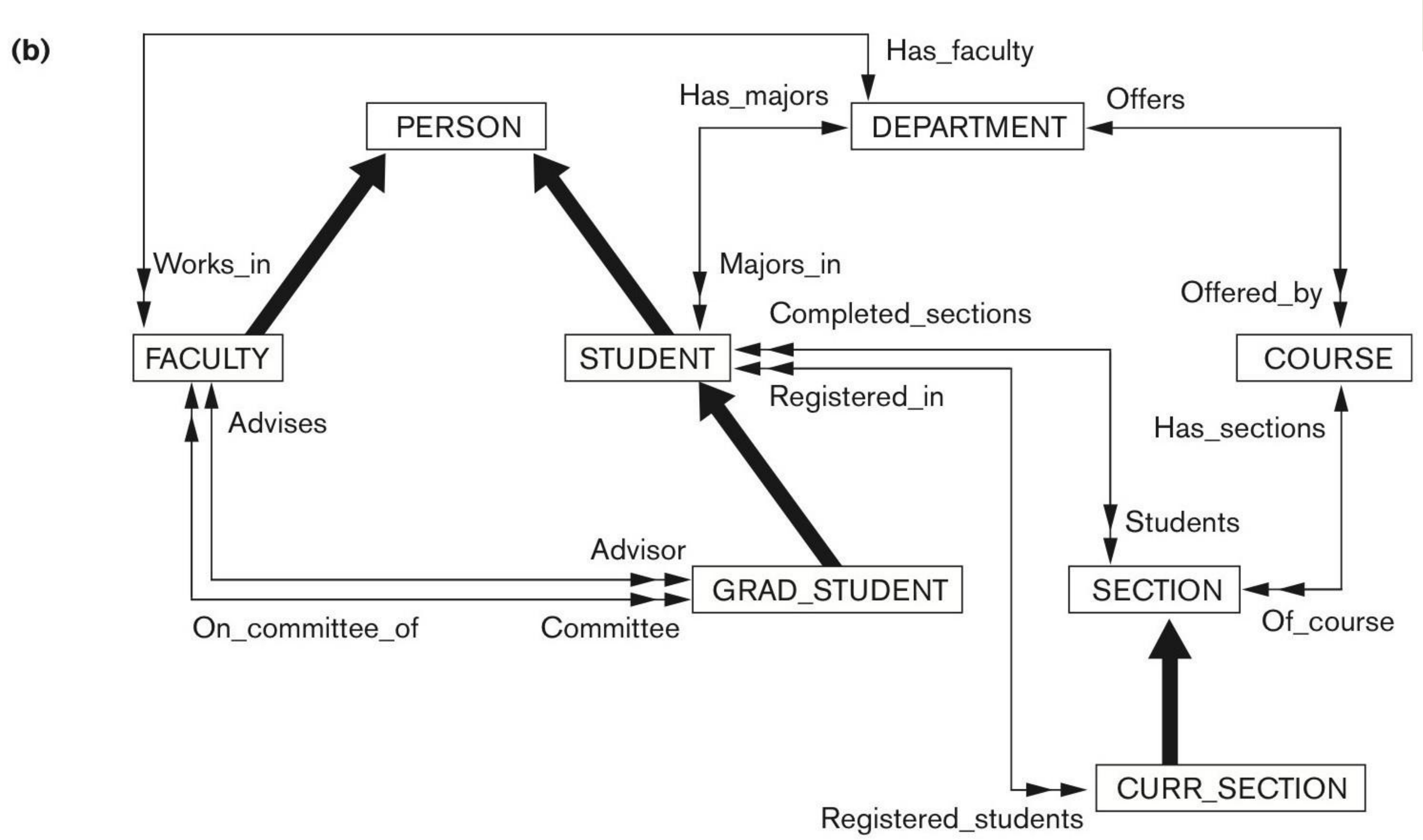


Figure 12.10 Possible ODL schema for the UNIVERSITY database in Figure 12.9(b).

```
class PERSON
(       extent          PERSONS
        key             Ssn )
{       attribute       struct Pname {  string  Fname,
                                        string  Mname,
                                        string  Lname }     Name;
        attribute       string                              Ssn;
        attribute       date                                Birth_date;
        attribute       enum Gender{M, F}                   Sex;
        attribute       struct Address {  short   No,
                                          string  Street,
                                          short   Apt_no,
                                          string  City,
                                          string  State,
                                          short   Zip }     Address;
        short           Age();   };
class FACULTY extends PERSON
(       extent          FACULTY )
{       attribute       string          Rank;
        attribute       float           Salary;
        attribute       string          Office;
        attribute       string          Phone;
        relationship    DEPARTMENT      Works_in inverse DEPARTMENT::Has faculty;
        relationship    set<GRAD_STUDENT> Advises inverse GRAD_STUDENT::Advisor;
        relationship    set<GRAD_STUDENT> On_committee_of inverse GRAD_STUDENT::Committee;
        void            give_raise(in float raise);
        void            promote(in string new rank); };
class GRADE
(       extent GRADES )
{
        attribute       enum GradeValues{A,B,C,D,F,I, P} Grade;
        relationship    SECTION Section inverse SECTION::Students;
        relationship STUDENT Student inverse STUDENT::Completed_sections; };
class STUDENT extends PERSON
(       extent          STUDENTS )
{       attribute       string          Class;
        attribute       Department      Minors_in;
        relationship    Department Majors_in inverse DEPARTMENT::Has_majors;
        relationship    set<GRADE> Completed_sections inverse GRADE::Student;
        relationship    set<CURR_SECTION> Registered_in INVERSE CURR_SECTION::Registered_students;
        void            change_major(in string dname) raises(dname_not_valid);
        float           gpa();
        void            register(in short secno) raises(section_not_valid);
        void            assign_grade(in short secno; IN GradeValue grade)
                              raises(section_not_valid,grade_not_valid); };
```

continued on next slide

Figure 12.10 (continued) Possible ODL schema for the UNIVERSITY database in Figure 12.9(b).

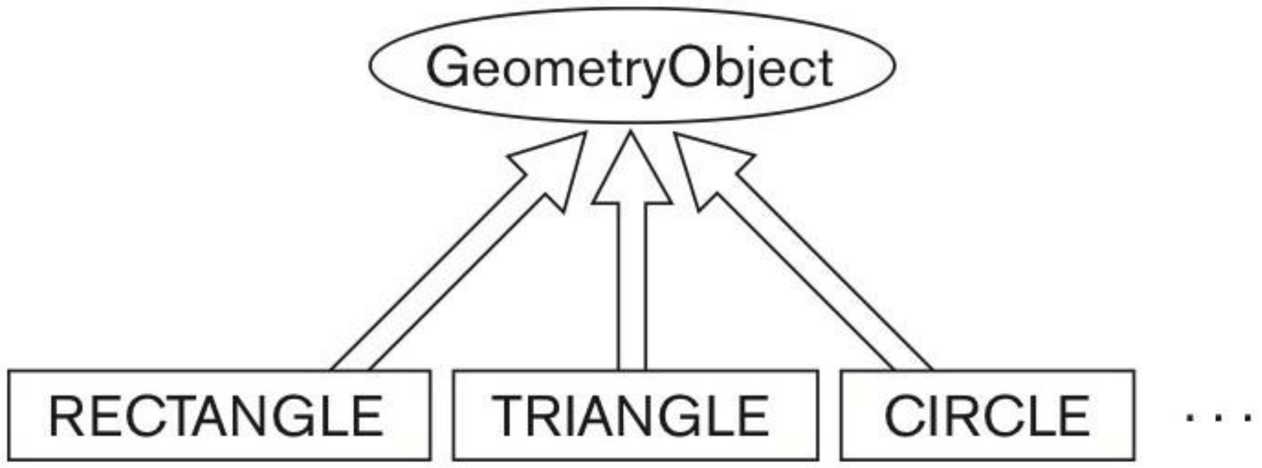
```
class DEGREE
{    attribute      string           College;
     attribute      string           Degree;
     attribute      string           Year; };
class GRAD_STUDENT extends STUDENT
(    extent         GRAD_STUDENTS )
{    attribute      set<Degree>      Degrees;
     relationship   Faculty advisor inverse FACULTY::Advises;
     relationship   set<FACULTY>     Committee inverse FACULTY::On_committee_of;
     void           assign_advisor(in string Lname; in string Fname)
                        raises(faculty_not_valid);
     void           assign_committee_member(in string Lname; in string Fname)
                        raises(faculty_not_valid); };
class DEPARTMENT
(    extent         DEPARTMENTS
     key            Dname )
{    attribute      string           Dname;
     attribute      string           Dphone;
     attribute      string           Doffice;
     attribute      string           College;
     attribute      FACULTY          Chair;
     relationship   set<FACULTY> Has_faculty inverse FACULTY::Works_in;
     relationship   set<STUDENT> Has_majors inverse STUDENT::Majors_in;
     relationship   set<COURSE> Offers inverse COURSE::Offered_by; };
class COURSE
(    extent         COURSES
     key            Cno )
{    attribute      string           Cname;
     attribute      string           Cno;
     attribute      string           Description;
     relationship   set<SECTION> Has_sections inverse SECTION::Of_course;
     relationship   <DEPARTMENT> Offered_by inverse DEPARTMENT::Offers; };
class SECTION
(    extent         SECTIONS )
{    attribute      short            Sec_no;
     attribute      string           Year;
     attribute      enum Quarter{Fall, Winter, Spring, Summer}
                        Qtr;
     relationship   set<Grade> Students inverse Grade::Section;
     relationship   COURSE Of_course inverse COURSE::Has_sections; };
class CURR_SECTION extends SECTION
(    extent         CURRENT_SECTIONS )
{    relationship   set<STUDENT> Registered_students
                        inverse STUDENT::Registered_in
     void           register_student(in string Ssn)
                        raises(student_not_valid, section_full); };
```

Interface Inheritance in ODL

- Next example illustrates interface inheritance in ODL

Figure 12.11a An illustration of interface inheritance via ":". Graphical schema representation.

(a)



continued on next slide

Figure 12.11b An illustration of interface inheritance via ":". Corresponding interface and clas

```
(b) 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); };
    class RECTANGLE : GeometryObject
    (   extent      RECTANGLES )
    {   attribute   struct      Point {short x, short y} Reference_point;
        attribute   short       Length;
        attribute   short       Height;
        attribute   float       Orientation_angle; };
    class TRIANGLE : GeometryObject
    (   extent      TRIANGLES )
    {   attribute   struct      Point {short x, short y} Reference_point;
        attribute   short       Side_1;
        attribute   short       Side_2;
        attribute   float       Side1_side2_angle;
        attribute   float       Side1_orientation_angle; };
    class CIRCLE : GeometryObject
    (   extent      CIRCLES )
    {   attribute   struct      Point {short x, short y} Reference_point;
        attribute   short       Radius; };
    ...
```

Object Database Conceptual Design

- Differences between conceptual design of ODB and RDB, handling of:
  - Relationships
  - Inheritance
- Philosophical difference between relational model and object model of data
  - In terms of behavioral specification

Mapping an EER Schema to an ODB Schema

- Create ODL class for each EER entity type
- Add relationship properties for each binary relationship
- Include appropriate operations for each class
- ODL class that corresponds to a subclass in the EER schema
  - Inherits type and methods of its superclass in ODL schema

Mapping an EER Schema to an ODB Schema (cont'd.)

- Weak entity types
  - Mapped same as regular entity types
- Categories (union types)
  - Difficult to map to ODL
- An *n*-ary relationship with degree *n* > 2
  - Map into a separate class, with appropriate references to each participating class

The Object Query Language OQL

- Query language proposed for ODMG object model
- Simple OQL queries, database entry points, and iterator variables
  - Syntax: select ... from ... where ... structure
  - Entry point: named persistent object
  - Iterator variable: define whenever a collection is referenced in an OQL query

Query Results and Path Expressions

- Result of a query
  - Any type that can be expressed in ODMG object model
- OQL orthogonal with respect to specifying path expressions
  - Attributes, relationships, and operation names (methods) can be used interchangeably within the path expressions

Other Features of OQL

- **Named query**
  - Specify identifier of named query
- OQL query will return collection as its result
  - If user requires that a query only return a single element use **`element`** operator
- Aggregate operators
- Membership and quantification over a collection

Other Features of OQL (cont'd.)

- Special operations for ordered collections
- **Group by** clause in OQL
  - Similar to the corresponding clause in SQL
  - Provides explicit reference to the collection of objects within each group or **partition**
- **Having clause**
  - Used to filter partitioned sets

Overview of the C++ Language Binding in the ODMG Standard

- Specifies how ODL constructs are mapped to C++ constructs
- Uses prefix `d_` for class declarations that deal with database concepts
- Template classes
  - Specified in library binding
  - Overloads operation new so that it can be used to create either persistent or transient objects

Summary

- Overview of concepts utilized in object databases
  - Object identity and identifiers; encapsulation of operations; inheritance; complex structure of objects through nesting of type constructors; and how objects are made persistent
- Description of the ODMG object model and object query language (OQL)
- Overview of the C++ language binding