Modeling Databases Using UML

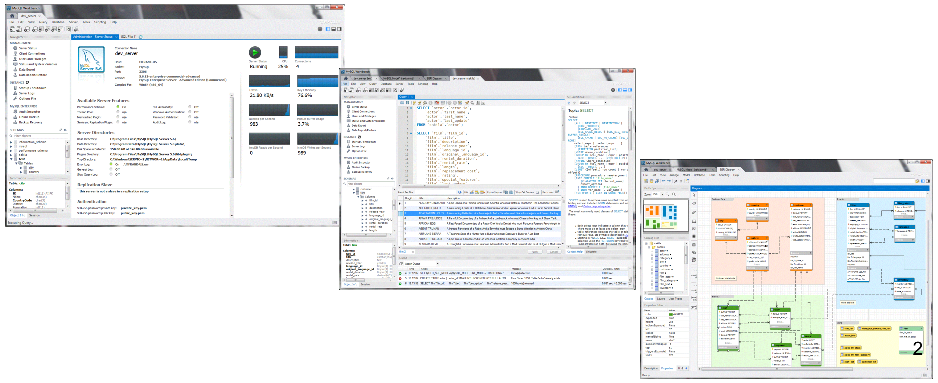
Fall 2016, Lecture 4

There is nothing worse than a sharp image of a fuzzy concept.

Ansel Adams

Software to be used in this Chapter…

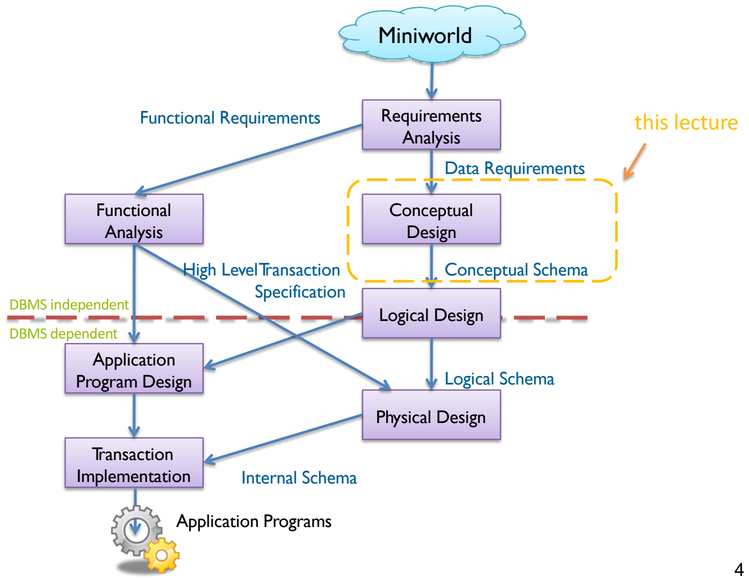
- Star UML http://www.mysql.com/products/workbench/
- Visual Paradigm: http://www.visual-paradigm.com (CE)



Software to be used in this Chapter…

- Microsoft Visio has a UML-like set of diagramming templates for databases
- For Macs OmniGraffle has UML or spreadsheet templates that can be used for ER diagrams

Recap: Steps in Database Design



Object-Oriented Modeling

- Becoming increasingly important as
  - Object-Oriented and Object-Relational DBMS continue to proliferate
  - Databases become more complex and have more complex relationships than are easily captured in ER or EER diagrams

Unified Modeling Language (UML)

- Combined three competing methods
- Can be used for graphically depicting
  - Software designs and interaction
  - Database
  - Processes

Object Benefits

- Encapsulate both data and behavior
- Object-oriented modeling methods can be used for both database design and process design
  - Real-World applications have more than just the data in the database they also involve the processes, calculations, etc performed on that data to get real tasks done
  - OOM can be used for more challenging and complex problems

Unified Modeling Language (UML)

- UML methodology
  - Used extensively in software design
  - Many types of diagrams for various software design purposes
- UML class diagrams
  - Entity in ER corresponds to an object in UML

UML Classes

- A class is a named description of a set of objects that share the same attributes (states), operations, relationships, and semantics.
  - An object is an instance of a class that encapsulates state and behavior.
    - These objects can represent real-world things or conceptual things.
  - An attribute is a named property of a class that describes a range of values that instances of that class might hold.
  - An operation is a named specification of a service that can be requested from any of a class's objects to affect behavior in some way or to return a value without affecting behavior

UML Classes

- Attributes have types.
- PK indicates an attribute in the primary key (optional) of the object.
- Methods have declarations: arguments (if any) and return type.

UML Relationships

- An relationship is a connection between or among model elements.
- The UML defines four basic kinds of relationships:
  - Association
  - Dependency
  - Generalization
  - Realization

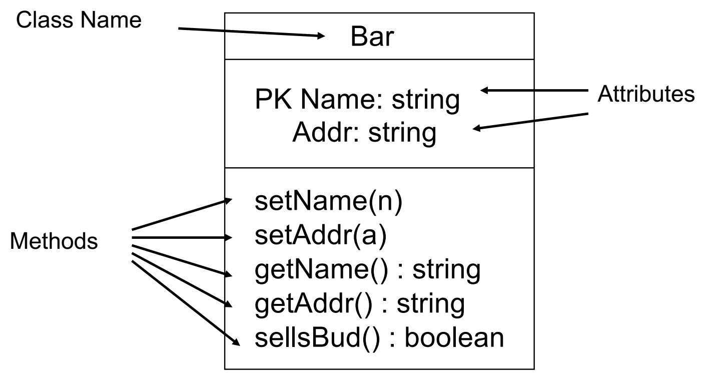
UML Diagrams

- The UML defines nine types of diagrams:
  - activity diagram
  - class diagram
    - Describes the data and some behavioral (operations) of a system
  - collaboration diagram
  - component diagram
  - deployment diagram
  - object diagram
  - sequence diagram
  - State chart diagram
  - use case diagram

Class Diagrams

- A class diagram is a diagram that shows a set of classes, interfaces, and/or collaborations and the relationships among these elements.

Example: Bar Class



Differences from Entities in ER

- Entities can be represented by Class diagrams
- But Classes of objects also have additional operations associated with them

Operations

- Three basic types for database
  - Constructor
  - Query
  - Update

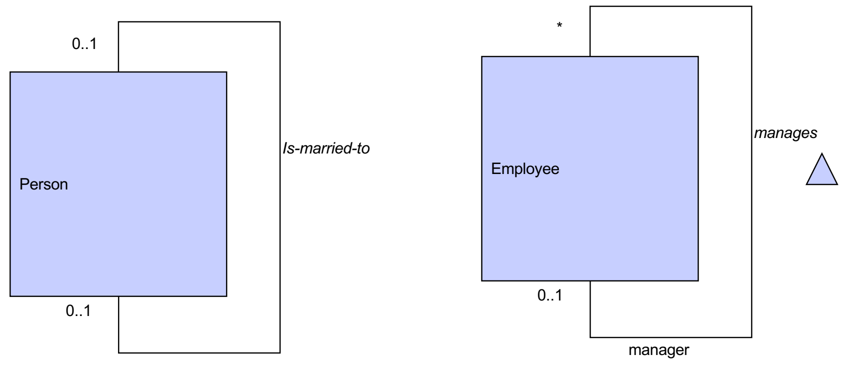
Associations

- An association is a relationship that describes a set of links between or among objects.
- An association can have a name that describes the nature of this relationship. You can put a triangle next to this name to indicate the direction in which the name should be read.

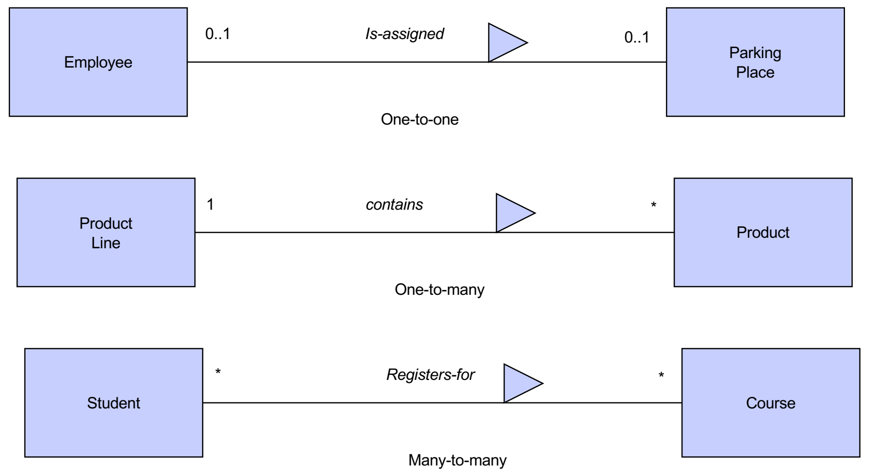
Associations

- An association contains an ordered list of association ends.
  - An association with exactly two association ends is called a binary association
  - An association with more than two ends is called an n-ary association.

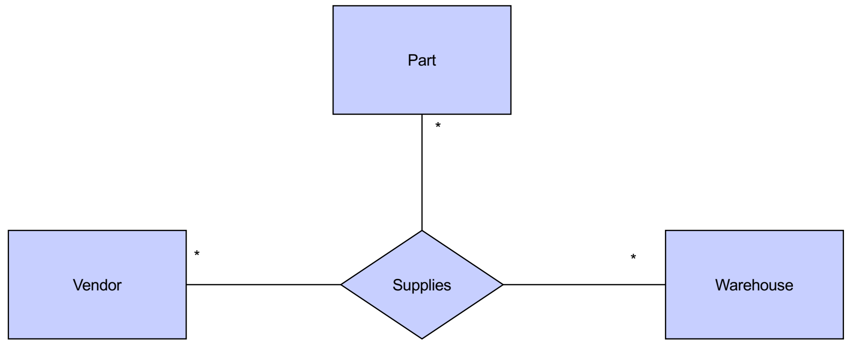
Associations: Unary relationships



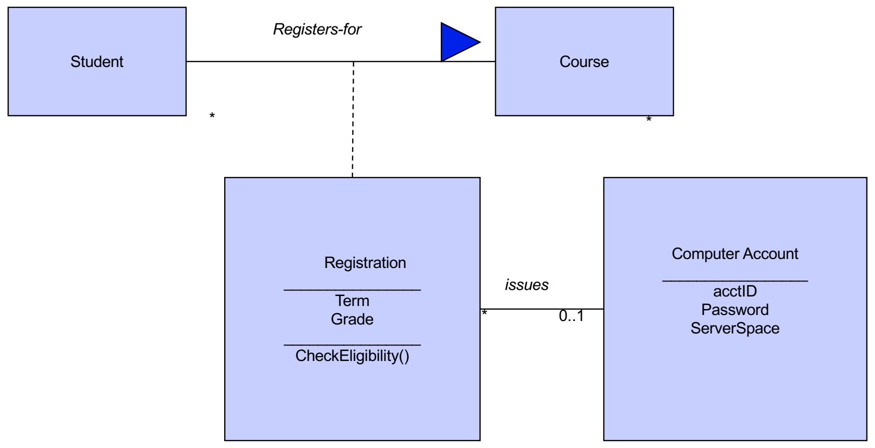
Associations: Binary Relationship



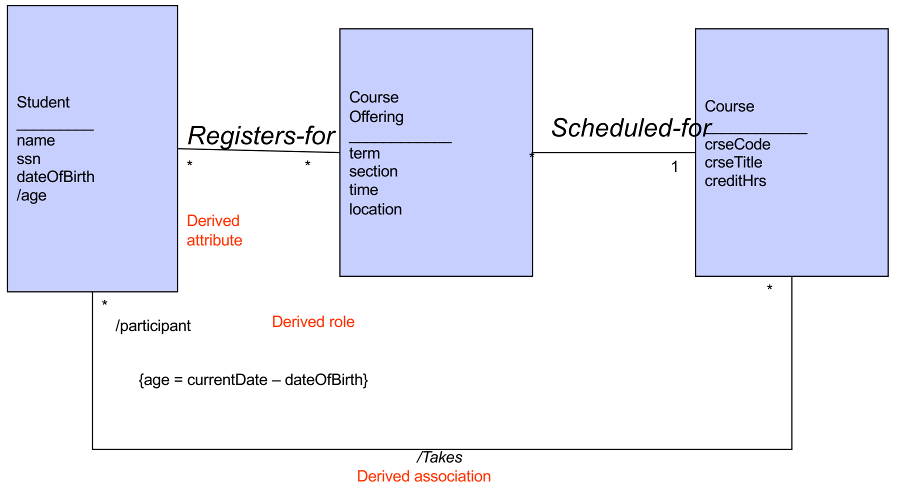
Associations: Ternary Relationships



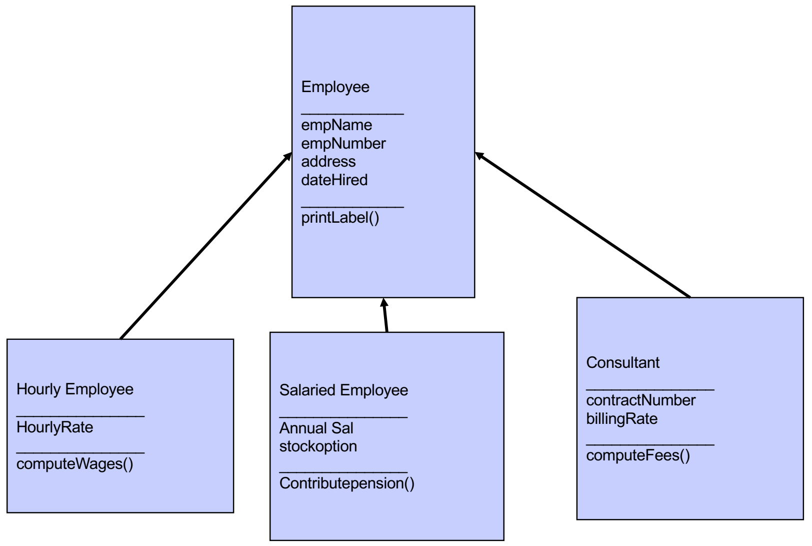
Association Classes



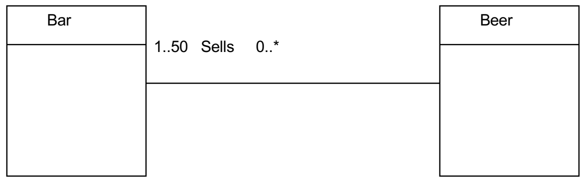
Derived Attributes, Associations, and Roles



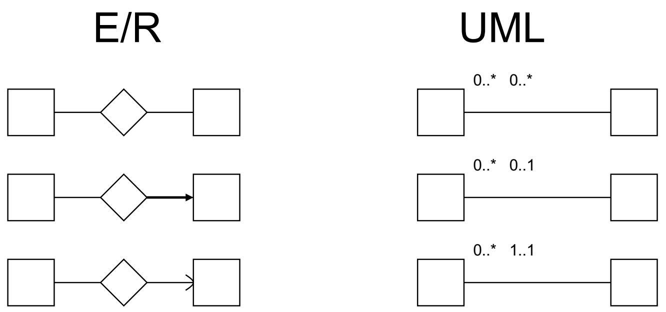
Generalization



Example: Association



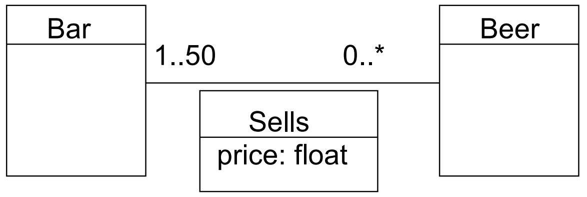
Comparison With E/R Multiplicities



Association Classes

- Attributes on associations are permitted.
  - Called an *association class*.
  - Analogous to attributes on relationships in E/R.

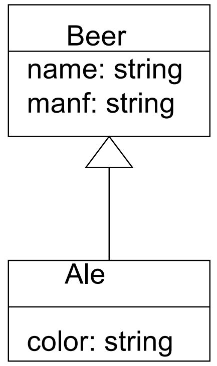
Example: Association Class



Subclasses

- Like E/R, but subclass points to superclass with a line ending in a triangle.
- The subclasses of a class can be:
  - *Complete* (every object is in at least one subclass) or *partial*.
  - *Disjoint* (object in at most one subclass) or *overlapping*.

Example: Subclasses



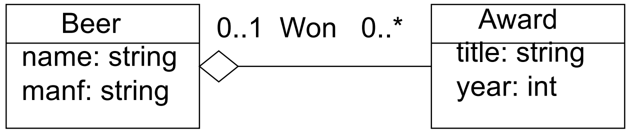
Conversion to Relations

- We can use any of the three strategies outlined for E/R to convert a class and its subclasses to relations.
  1. E/R-style: each subclass' relation stores only its own attributes, plus key.
  2. OO-style: relations store attributes of subclass and all superclasses.
  3. Nulls: One relation, with NULL's as needed.

Aggregations

- Relationships with implication that the objects on one side are "owned by" or are part of objects on the other side.
- Represented by a diamond at the end of the connecting line, at the "owner" side.
- Implication that in a relational schema, owned objects are part of owner tuples.

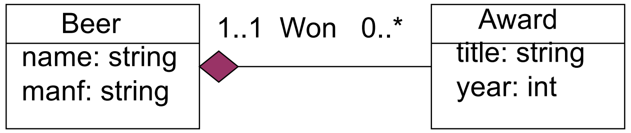
Example: Aggregation



Compositions

- Like aggregations, but with the implication that every object is definitely owned by one object on the other side.
- Represented by solid diamond at owner.
- Often used for subobjects or structured attributes.

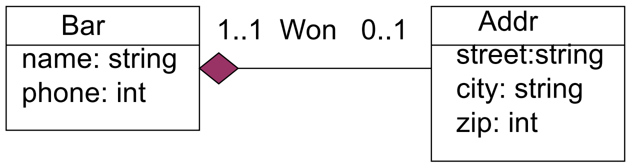
Example: Composition



Conversion to Relations

- We could store the awards of a beer with the beer tuple.
- Requires an object-relational or nested-relation model for tables, since there is no limit to the number of awards a beer can win.

Example: Composition



Conversion to Relations

- Since a bar has at most one address, it is quite feasible to add the street, city, and zip attributes of Addr to the Bars relation.
- In object-relational databases, Addr can be one attribute of Bars, with structure.

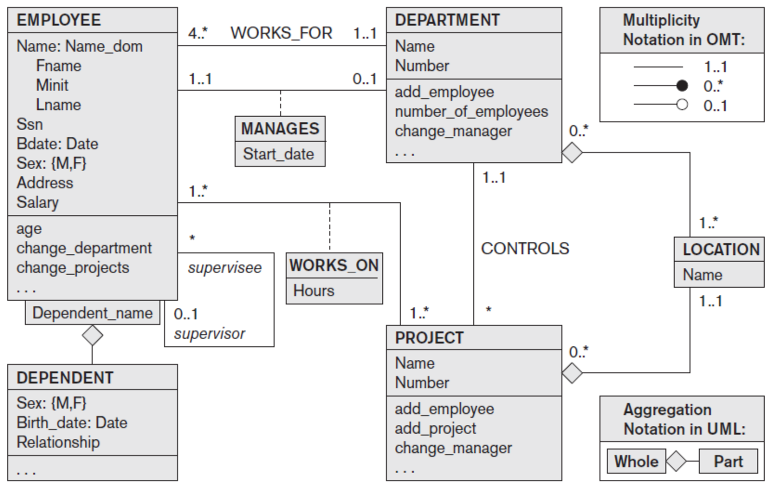


Figure 7.16
The COMPANY conceptual schema in UML class diagram notation.

Chapter 10

Practical Database Design Methodology and Use of UML Diagrams

Chapter 10 Outline

- The Role of Information Systems in Organizations
- The Database Design and Implementation Process
- Use of UML Diagrams as an Aid to Database Design Specification
- Rational Rose: A UML-Based Design Tool
- Automated Database Design Tools

Practical Database Design Methodology and Use of UML Diagrams

- Design methodology
  - Target database managed by some type of database management system
- Various design methodologies
- **Large database**
  - Several dozen gigabytes of data and a schema with more than 30 or 40 distinct entity types

The Role of Information Systems in Organizations

- Organizational context for using database systems
  - Organizations have created the position of database administrator (DBA) and database administration departments
  - Information technology (IT) and information resource management (IRM) departments
    - Key to successful business management

The Role of Information Systems in Organizations (cont'd.)

- Database systems are integral components in computer-based information systems
- Personal computers and database system-like software products
  - Utilized by users who previously belonged to the category of casual and occasional database users
- **Personal databases** gaining popularity
- Databases are distributed over multiple computer systems
  - Better local control and faster local processing

The Role of Information Systems in Organizations (cont'd.)

- **Data dictionary systems** or **information repositories**
  - Mini DBMSs
  - Manage **meta-data**
- High-performance transaction processing systems require around-the-clock nonstop operation
  - Performance is critical

The Information System Life Cycle

- **Information system (IS)**
  - Resources involved in collection, management, use, and dissemination of information resources of organization

The Information System Life Cycle

- **Macro life cycle**
  - **Feasibility analysis**
  - **Requirements collection and analysis**
  - **Design**
  - **Implementation**
  - **Validation and acceptance testing**
  - **Requirements collection and analysis**

The Information System Life Cycle (cont'd.)

- The database application system life cycle: **micro life cycle**
  - System definition
  - Database design
  - Database implementation
  - Loading or data conversion

The Information System Life Cycle (cont'd.)

- Application conversion
- Testing and validation
- Operation
- Monitoring and maintenance

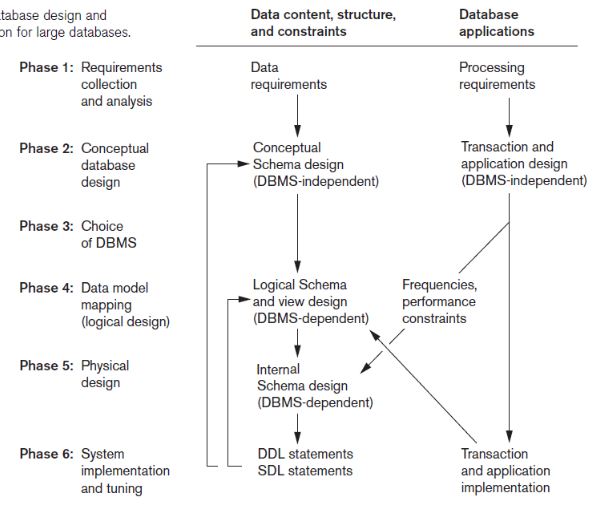
The Database Design and Implementation Process

- Design logical and physical structure of one or more databases
  - Accommodate the information needs of the users in an organization for a defined set of applications
- Goals of database design
  - Very hard to accomplish and measure
- Often begins with informal and incomplete requirements

The Database Design and Implementation Process (cont'd.)

- Main phases of the overall database design and implementation process:
  - 1. Requirements collection and analysis
  - 2. Conceptual database design
  - 3. Choice of a DBMS
  - 4. Data model mapping (also called logical database design)
  - 5. Physical database design
  - 6. Database system implementation and tuning

Figure 10.1
Phases of database design and implementation for large databases.



Data content, structure, and constraints
Database applications
Phase 1: Requirements collection and analysis
Data requirements
Processing requirements
Phase 2: Conceptual database design
Conceptual Schema design (DBMS-independent)
Transaction and application design (DBMS-independent)
Phase 3: Choice of DBMS
Phase 4: Data model mapping (logical design)
Logical Schema and view design (DBMS-dependent)
Frequencies, performance constraints
Phase 5: Physical design
Internal Schema design (DBMS-dependent)
Phase 6: System implementation and tuning
DDL statements SDL statements
Transaction and application implementation

The Database Design and Implementation Process (cont'd.)

- Parallel activities
  - **Data content**, **structure**, and **constraints** of the database
  - Design of database applications
- **Data-driven** versus **process-driven** design
- **Feedback loops** among phases and within phases are common

The Database Design and Implementation Process (cont'd.)

- Heart of the database design process
  - **Conceptual database design (Phase 2)**
  - **Data model mapping (Phase 4)**
  - **Physical database design (Phase 5)**
  - **Database system implementation and tuning (Phase 6)**

Phase 1: Requirements Collection and Analysis

- Activities
  - Identify application areas and user groups
  - Study and analyze documentation
  - Study current operating environment
  - Collect written responses from users

Phase 1 (cont'd.)

- **Requirements specification techniques**
  - Oriented analysis (OOA)
  - Data flow diagrams (DFDs
  - Refinement of application goals
  - Computer-aided

Phase 2: Conceptual Database Design

- Phase 2a: Conceptual Schema Design
  - Important to use a conceptual high-level data model
  - Approaches to conceptual schema design
    - **Centralized (or one shot) schema design approach**
    - **View integration approach**

Phase 2: (cont'd.)

- Strategies for schema design
  - **Top-down strategy**
  - **Bottom-up strategy**
  - **Inside-out strategy**
  - **Mixed strategy**
- Schema (view) integration
  - Identify correspondences/conflicts among schemas:
    - **Naming conflicts, type conflicts, domain (value set) conflicts, conflicts among constraints**
  - Modify views to conform to one another
  - Merge of views and restructure

Phase 2: (cont'd.)

- Strategies for the view integration process
  - **Binary ladder integration**
  - **N-ary integration**
  - **Binary balanced strategy**
  - **Mixed strategy**
- Phase 2b: Transaction Design
  - In parallel with Phase 2a
  - Specify transactions at a conceptual level
  - Identify **input/output** and **functional behavior**
  - Notation for specifying processes

Phase 3: Choice of a DBMS

- Costs to consider
  - Software acquisition cost
  - Maintenance cost
  - Hardware acquisition cost
  - Database creation and conversion cost
  - Personnel cost
  - Training cost
  - Operating cost
- Consider DBMS portability among different types of hardware

Phase 4: Data Model Mapping (Logical Database Design)

- Create a conceptual schema and external schemas
  - In data model of selected DBMS
- Stages
  - System-independent mapping
  - Tailoring schemas to a specific DBMS

Phase 5: Physical Database Design

- Choose specific file storage structures and access paths for the database files
  - Achieve good performance
- Criteria used to guide choice of physical database design options:
  - Response time
  - Space utilization
  - Transaction throughput

Phase 6: Database System Implementation and Tuning

- Typically responsibility of the DBA
  - Compose DDL
  - Load database
  - Convert data from earlier systems
- Database programs implemented by application programmers
- Most systems include monitoring utility to collect performance statistics

Use of UML Diagrams as an Aid to Database Design Specification

- Use UML as a design specification standard
- Unified Modeling Language (UML) approach
  - Combines commonly accepted concepts from many object-oriented (O-O) methods and methodologies
  - Includes **use case diagrams**, **sequence diagrams**, and **statechart diagrams**

UML for Database Application Design

- Advantages of UML
  - Resulting models can be used to design relational, object-oriented, or object-relational databases
  - Brings traditional database modelers, analysts, and designers together with software application developers

Different Types of Diagrams in UML

- Structural diagrams
  - **Class diagrams and package diagrams**
  - **Object diagrams**
  - **Component diagrams**
  - **Deployment diagrams**

Different Types of Diagrams in UML (cont'd.)

- Behavioral diagrams
  - **Use case diagrams**
  - **Sequence diagrams**
  - **Collaboration diagrams**
  - **Statechart diagrams**
  - **Activity diagrams**

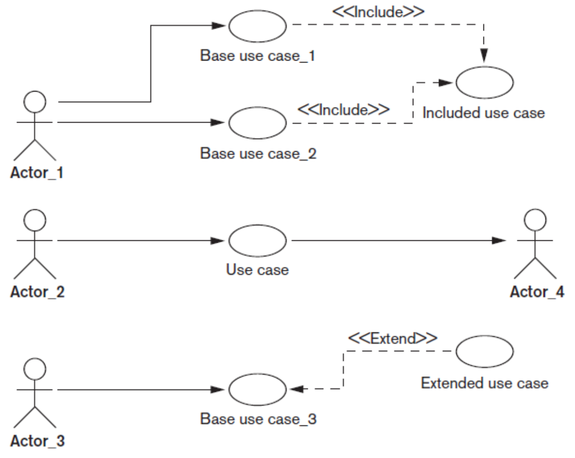


Figure 10.7
The use case diagram notation.

Different Types of Diagrams in UML (cont'd.)

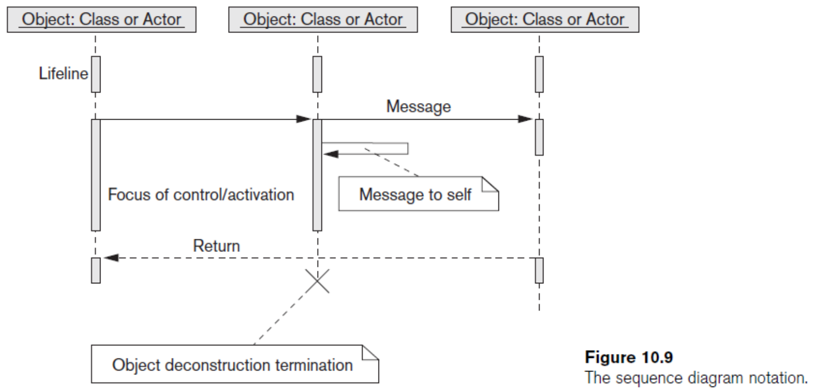
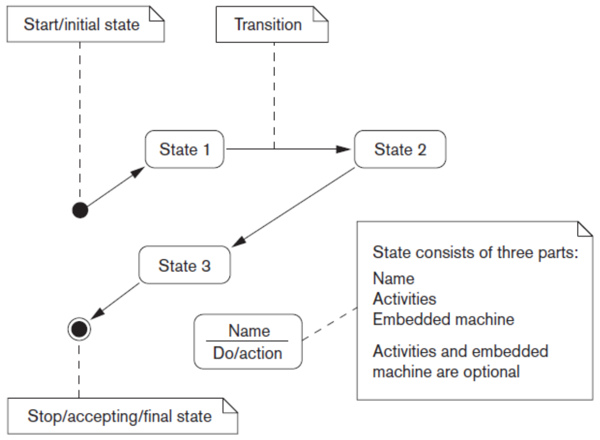


Figure 10.9
The sequence diagram notation.

Different Types of Diagrams in UML (cont'd.)



Start/initial state
Transition
State 1
State 2
State 3
Name
Do/action
State consists of three parts:
Name
Activities
Embedded machine
Activities and embedded machine are optional
Stop/accepting/final state

Figure 10.10
The statechart diagram notation.

Modeling and Design Example: UNIVERSITY Database

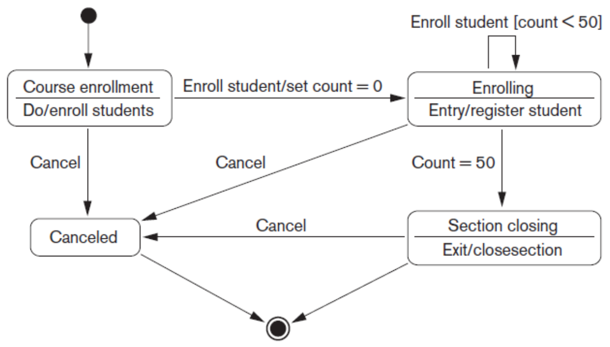


Figure 10.11
A sample statechart diagram for the UNIVERSITY database.

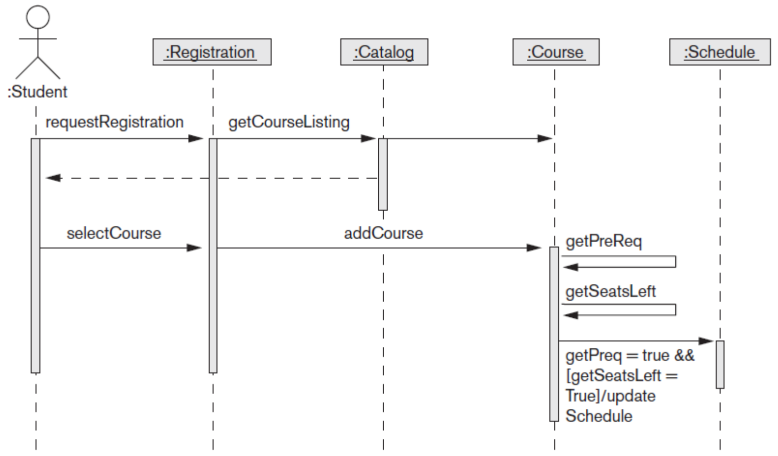


Figure 10.12
A sequence diagram for the UNIVERSITY database.

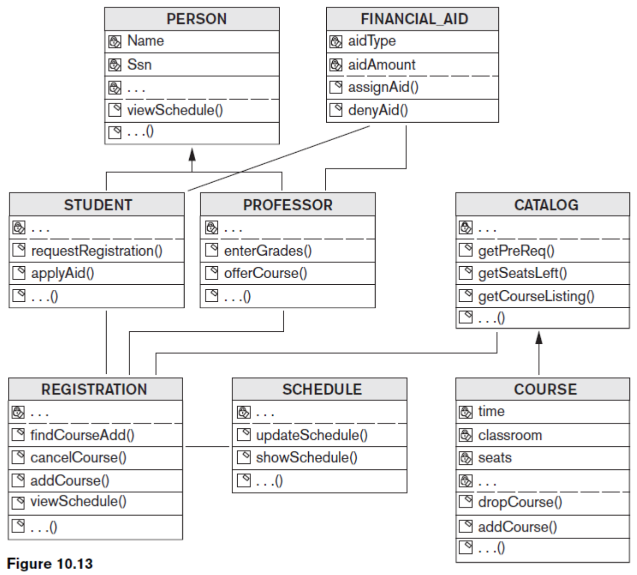


Figure 10.13
The design of the UNIVERSITY database as a class diagram.

Rational Rose: A UML-Based Design Tool

- Rational Rose for database design
  - Modeling tool used in the industry to develop information systems
- Rational Rose data modeler
  - Visual modeling tool for designing databases
  - Provides capability to:
    - **Forward engineer** a database
    - **Reverse engineer** an existing implemented database into conceptual design

Data Modeling Using Rational Rose Data Modeler

- Reverse engineering
  - Allows the user to create a conceptual data model based on an existing database schema specified in a DDL file
- Forward engineering and DDL generation
  - Create a data model directly from scratch in Rose
  - Generate DDL for a specific DBMS

Data Modeling Using Rational Rose Data Modeler (cont'd.)

- Conceptual design in UML notation
  - Build ER diagrams using class diagrams in Rational Rose
  - **Identifying relationships**
    - Object in a child class cannot exist without a corresponding parent object
  - **Non-identifying relationships**
    - Specify a regular association (relationship) between two independent classes

Data Modeling Using Rational Rose Data Modeler (cont'd.)

- Converting logical data model to object model and vice versa
  - Logical data model can be converted to an object model
  - Allows a deep understanding of relationships between conceptual and implementation models

Data Modeling Using Rational Rose Data Modeler (cont'd.)

- Synchronization between the conceptual design and the actual database
- Extensive domain support
  - Create a standard set of user-defined data types
- Easy communication among design teams
  - Application developer can access both the object and data models

Automated Database Design Tools

- Many CASE (computer-aided software engineering) tools for database design
- Combination of the following facilities
  - Diagramming
  - Model mapping
  - Design normalization

Automated Database Design Tools (cont'd.)

- Characteristics that a good design tool should possess:
  - Easy-to-use interface
  - Analytical components
  - Heuristic components
  - Trade-off analysis
  - Display of design results
  - Design verification

Automated Database Design Tools (cont'd.)

- Variety of products available
  - Some use expert system technology

Table 10.1 Some of the Currently Available Automated Database Design Tools

Company	Tool	Functionality
Embarcadero Technologies	ER/Studio	Database modeling in ER and IDEF1x
	DBArtisan	Database administration and space and security management
Oracle	Developer 2000 and Designer 2000	Database modeling, application development
Persistence Inc.	PowerTier	Mapping from O-O to relational model
Platinum Technology (Computer Associates)	Platinum ModelMart, ERwin, BPwin, AllFusion Component Modeler	Data, process, and business component modeling
Popkin Software	Telelogic System Architect	Data modeling, object modeling, process modeling, structured analysis/design
Rational (IBM)	Rational Rose XDE Developer Plus	Modeling in UML and application generation in C++ and Java
Resolution Ltd.	XCase	Conceptual modeling up to code maintenance
Sybase	Enterprise Application Suite	Data modeling, business logic modeling
Visio	Visio Enterprise	Data modeling, design and reengineering Visual Basic and Visual C++

Summary

- Six phases of the design process
  - Commonly include conceptual design, logical design (data model mapping), physical design
- UML diagrams
  - Aid specification of database models and design
- Rational Rose and the Rose Data Modeler
  - Provide support for the conceptual design and logical design phases of database