Review Terms

- Entity-relationship data model
- Entity and entity set
  - Attributes
  - Domain
  - Simple and composite attributes
  - Single-valued and multivalued attributes
  - Null value
  - Derived attribute
  - Superkey, candidate key, and primary key
- Relationship and relationship set
  - Binary relationship set
  - Degree of relationship set
  - Descriptive attributes
  - Superkey, candidate key, and primary key
  - Role
  - Recursive relationship set
- E-R diagram
- Mapping cardinality:
  - One-to-one relationship
  - One-to-many relationship
  - Many-to-one relationship
  - Many-to-many relationship
- Participation
  - Total participation
  - Partial participation
- Weak entity sets and strong entity sets
  - Discriminator attributes
  - Identifying relationship
- Specialization and generalization
  - Superclass and subclass
  - Attribute inheritance
  - Single and multiple inheritance
  - Condition-defined and user-defined membership
  - Disjoint and overlapping generalization
  - Total and partial generalization
- Aggregation
- UML
- UML class diagram

Practice Exercises

7.1 Construct an E-R diagram for a car insurance company whose customers own one or more cars each. Each car has associated with it zero to any number of recorded accidents. Each insurance policy covers one or more cars, and has one or more premium payments associated with it. Each payment is for a particular period of time, and has an associated due date, and the date when the payment was received.

7.2 Consider a database used to record the marks that students get in different exams of different course offerings (sections).
a. Construct an E-R diagram that models exams as entities, and uses a ternary relationship, for the database.

b. Construct an alternative E-R diagram that uses only a binary relationship between student and section. Make sure that only one relationship exists between a particular student and section pair, yet you can represent the marks that a student gets in different exams.

7.3 Design an E-R diagram for keeping track of the exploits of your favorite sports team. You should store the matches played, the scores in each match, the players in each match, and individual player statistics for each match. Summary statistics should be modeled as derived attributes.

7.4 Consider an E-R diagram in which the same entity set appears several times, with its attributes repeated in more than one occurrence. Why is allowing this redundancy a bad practice that one should avoid?

7.5 An E-R diagram can be viewed as a graph. What do the following mean in terms of the structure of an enterprise schema?

a. The graph is disconnected.

b. The graph has a cycle.

7.6 Consider the representation of a ternary relationship using binary relationships as described in Section 7.7.3 and illustrated in Figure 7.27b (attributes not shown).

Figure 7.27 E-R diagram for Practice Exercise 7.6 and Exercise 7.24.
a. Show a simple instance of \( E, A, B, C, R_A, R_B, \) \( \) and \( \) \( R_C \) that cannot correspond to any instance of \( A, B, C, \) and \( R. \)

b. Modify the E-R diagram of Figure 7.27b to introduce constraints that will guarantee that any instance of \( E, A, B, C, R_A, R_B, \) \( \) and \( \) \( R_C \) that satisfies the constraints will correspond to an instance of \( A, B, C, \) and \( R. \)

c. Modify the translation above to handle total participation constraints on the ternary relationship.

d. The above representation requires that we create a primary-key attribute for \( E. \) Show how to treat \( E \) as a weak entity set so that a primary-key attribute is not required.

7.7 A weak entity set can always be made into a strong entity set by adding to its attributes the primary-key attributes of its identifying entity set. Outline what sort of redundancy will result if we do so.

7.8 Consider a relation such as \( \text{sec}\_\text{course}, \) generated from a many-to-one relationship \( \text{sec}\_\text{course}. \) Do the primary and foreign key constraints created on the relation enforce the many-to-one cardinality constraint? Explain why.

7.9 Suppose the \( \text{advisor} \) relationship were one-to-one. What extra constraints are required on the relation \( \text{advisor} \) to ensure that the one-to-one cardinality constraint is enforced?

7.10 Consider a many-to-one relationship \( R \) between entity sets \( A \) and \( B. \) Suppose the relation created from \( R \) is combined with the relation created from \( A. \) In SQL, attributes participating in a foreign key constraint can be null. Explain how a constraint on total participation of \( A \) in \( R \) can be enforced using \( \text{not null} \) constraints in SQL.

7.11 In SQL, foreign key constraints can only reference the primary key attributes of the referenced relation, or other attributes declared to be a super key using the \( \text{unique} \) constraint. As a result, total participation constraints on a many-to-many relationship (or on the “one” side of a one-to-many relationship) cannot be enforced on the relations created from the relationship, using primary key, foreign key and not null constraints on the relations.

a. Explain why.

b. Explain how to enforce total participation constraints using complex check constraints or assertions (see Section 4.4.7). (Unfortunately, these features are not supported on any widely used database currently.)

7.12 Figure 7.28 shows a lattice structure of generalization and specialization (attributes not shown). For entity sets \( A, B, \) and \( C, \) explain how attributes
are inherited from the higher-level entity sets $X$ and $Y$. Discuss how to handle a case where an attribute of $X$ has the same name as some attribute of $Y$.

7.13 Temporal changes: An E-R diagram usually models the state of an enterprise at a point in time. Suppose we wish to track temporal changes, that is, changes to data over time. For example, Zhang may have been a student between 1 September 2005 and 31 May 2009, while Shankar may have had instructor Einstein as advisor from 31 May 2008 to 5 December 2008, and again from 1 June 2009 to 5 January 2010. Similarly, attribute values of an entity or relationship, such as title and credits of course, salary, or even name of instructor, and total credit of student, can change over time.

One way to model temporal changes is as follows. We define a new data type called valid time, which is a time-interval, or a set of time-intervals. We then associate a valid time attribute with each entity and relationship, recording the time periods during which the entity or relationship is valid. The end-time of an interval can be infinity; for example, if Shankar became a student on 2 September 2008, and is still a student, we can represent the end-time of the valid time interval as infinity for the Shankar entity. Similarly, we model attributes that can change over time as a set of values, each with its own valid time.

a. Draw an E-R diagram with the student and instructor entities, and the advisor relationship, with the above extensions to track temporal changes.

b. Convert the above E-R diagram into a set of relations.

It should be clear that the set of relations generated above is rather complex, leading to difficulties in tasks such as writing queries in SQL. An alternative approach, which is used more widely is to ignore temporal changes when designing the E-R model (in particular, temporal changes to attribute values), and to modify the relations generated from the E-R model to track temporal changes, as discussed later in Section 8.9.
Exercises

7.14 Explain the distinctions among the terms primary key, candidate key, and superkey.

7.15 Construct an E-R diagram for a hospital with a set of patients and a set of medical doctors. Associate with each patient a log of the various tests and examinations conducted.

7.16 Construct appropriate relation schemas for each of the E-R diagrams in Practice Exercises 7.1 to 7.3.

7.17 Extend the E-R diagram of Practice Exercise 7.3 to track the same information for all teams in a league.

7.18 Explain the difference between a weak and a strong entity set.

7.19 We can convert any weak entity set to a strong entity set by simply adding appropriate attributes. Why, then, do we have weak entity sets?

7.20 Consider the E-R diagram in Figure 7.29, which models an online bookstore.
   a. List the entity sets and their primary keys.
   b. Suppose the bookstore adds Blu-ray discs and downloadable video to its collection. The same item may be present in one or both formats, with differing prices. Extend the E-R diagram to model this addition, ignoring the effect on shopping baskets.
   c. Now extend the E-R diagram, using generalization, to model the case where a shopping basket may contain any combination of books, Blu-ray discs, or downloadable video.

7.21 Design a database for an automobile company to provide to its dealers to assist them in maintaining customer records and dealer inventory and to assist sales staff in ordering cars.
   Each vehicle is identified by a vehicle identification number (VIN). Each individual vehicle is a particular model of a particular brand offered by the company (e.g., the XF is a model of the car brand Jaguar of Tata Motors). Each model can be offered with a variety of options, but an individual car may have only some (or none) of the available options. The database needs to store information about models, brands, and options, as well as information about individual dealers, customers, and cars.
   Your design should include an E-R diagram, a set of relational schemas, and a list of constraints, including primary-key and foreign-key constraints.

7.22 Design a database for a world-wide package delivery company (e.g., DHL or FedEx). The database must be able to keep track of customers (who ship items) and customers (who receive items); some customers may do both.
Each package must be identifiable and trackable, so the database must be able to store the location of the package and its history of locations. Locations include trucks, planes, airports, and warehouses.

Your design should include an E-R diagram, a set of relational schemas, and a list of constraints, including primary-key and foreign-key constraints.

7.23 Design a database for an airline. The database must keep track of customers and their reservations, flights and their status, seat assignments on individual flights, and the schedule and routing of future flights.

Your design should include an E-R diagram, a set of relational schemas, and a list of constraints, including primary-key and foreign-key constraints.

7.24 In Section 7.7.3, we represented a ternary relationship (repeated in Figure 7.27a) using binary relationships, as shown in Figure 7.27b. Consider the alternative shown in Figure 7.27c. Discuss the relative merits of these two alternative representations of a ternary relationship by binary relationships.
7.25 Consider the relation schemas shown in Section 7.6, which were generated from the E-R diagram in Figure 7.15. For each schema, specify what foreign-key constraints, if any, should be created.

7.26 Design a generalization–specialization hierarchy for a motor vehicle sales company. The company sells motorcycles, passenger cars, vans, and buses. Justify your placement of attributes at each level of the hierarchy. Explain why they should not be placed at a higher or lower level.

7.27 Explain the distinction between condition-defined and user-defined constraints. Which of these constraints can the system check automatically? Explain your answer.

7.28 Explain the distinction between disjoint and overlapping constraints.

7.29 Explain the distinction between total and partial constraints.

Tools

Many database systems provide tools for database design that support E-R diagrams. These tools help a designer create E-R diagrams, and they can automatically create corresponding tables in a database. See bibliographic notes of Chapter 1 for references to database-system vendors’ Web sites.

There are also several database-independent data modeling tools that support E-R diagrams and UML class diagrams. The drawing tool Dia, which is available as freeware, supports E-R diagrams and UML class diagrams. Commercial tools include IBM Rational Rose (www.ibm.com/software/rational), Microsoft Visio (see www.microsoft.com/office/visio), CA’s ERwin (www.ca.com/us/databasing.aspx), Poseidon for UML (www.gentleware.com), and SmartDraw (www.smartdraw.com).

Bibliographical Notes

The E-R data model was introduced by Chen [1976]. A logical design methodology for relational databases using the extended E-R model is presented by Teorey et al. [1986]. The Integration Definition for Information Modeling (IDEF1X) standard NIST [1993] released by the United States National Institute of Standards and Technology (NIST) defined standards for E-R diagrams. However, a variety of E-R notations are in use today.


As of 2009, the current UML version was 2.2, with UML version 2.3 near final adoption. See www.uml.org for more information on UML standards and tools.