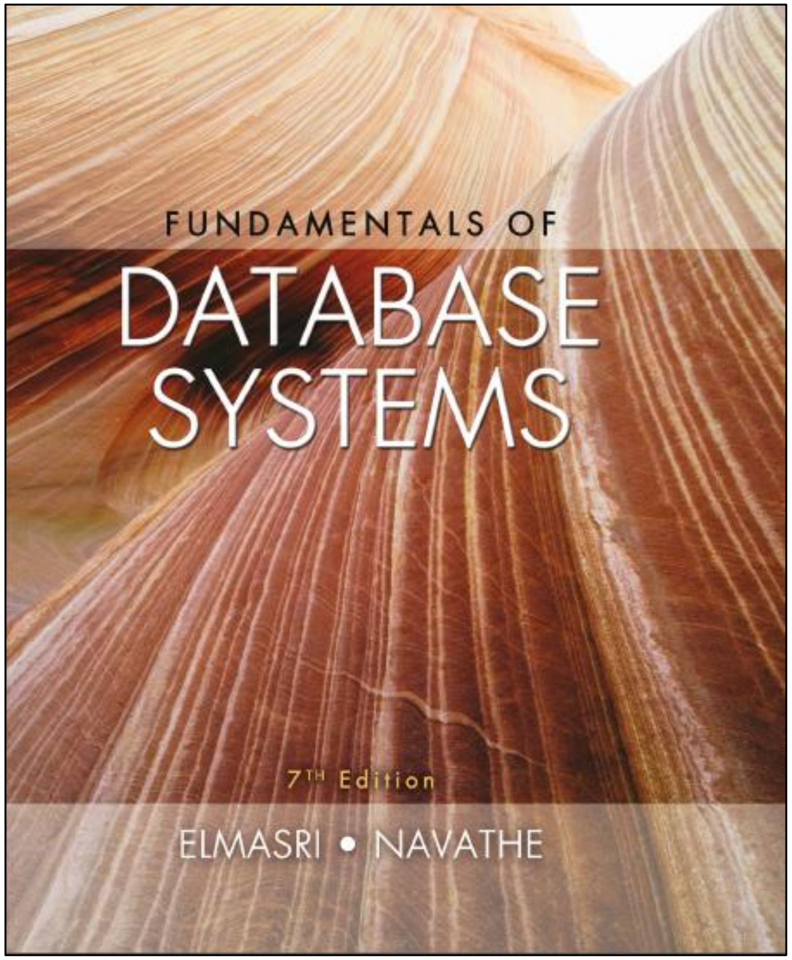
Fundamentals of Database Systems

Seventh Edition



Chapter 4

Enhanced Entity Relationship (EER) Modeling

Learning Objectives

4.1 EER stands for Enhanced ER or Extended ER

4.2 EER Model Concepts

- **4.2.1** Includes all modeling concepts of basic ER
- **4.2.2** Additional concepts:
    - **4.2.2.1** subclasses/superclasses
    - **4.2.2.2** specialization/generalization
    - **4.2.2.3** categories (UNION types)
    - **4.2.2.4** attribute and relationship inheritance
- **4.2.3** Constraints on Specialization/Generalization

4.3 The additional EER concepts are used to model applications more completely and more accurately

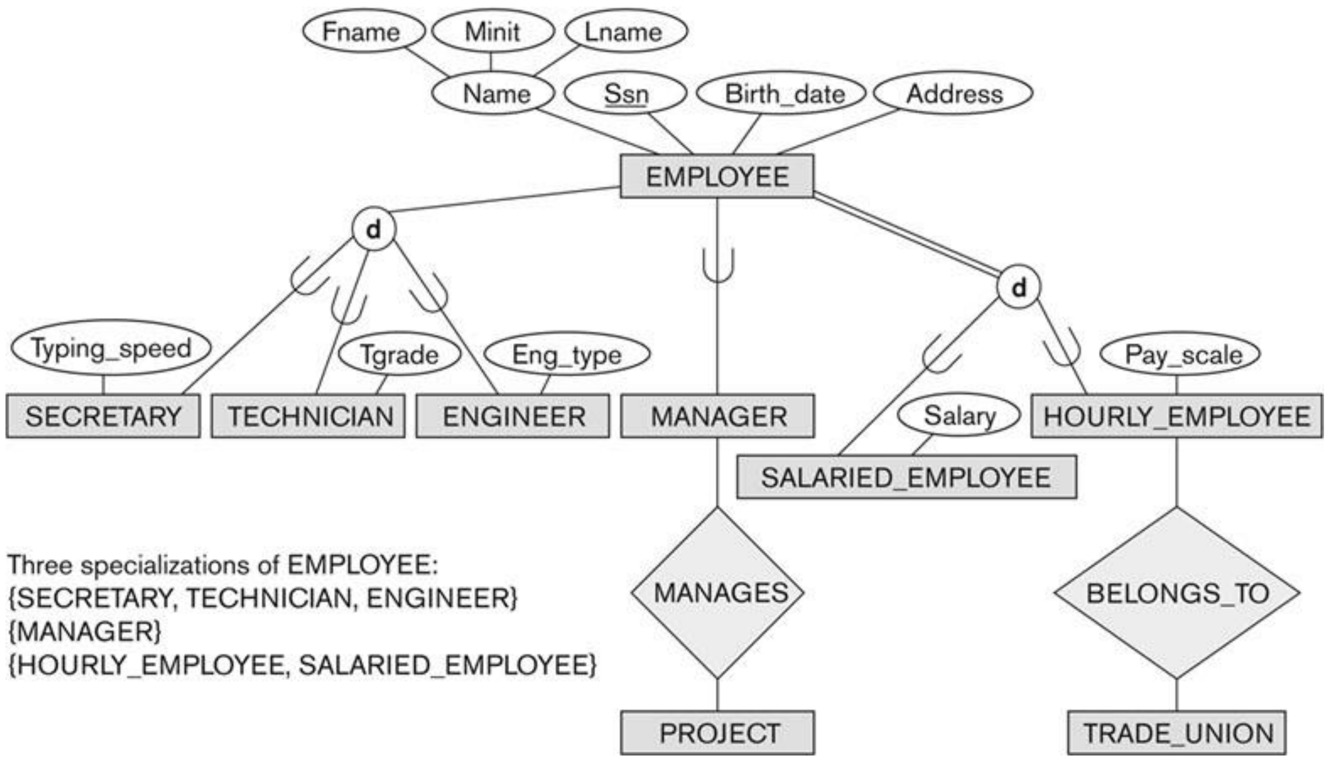
- **4.3.1** EER includes some object-oriented concepts, such as inheritance

Subclasses and Superclasses (1 of 5)

- An entity type may have additional meaningful subgroupings of its entities
  - Example: EMPLOYEE may be further grouped into:
    - SECRETARY, ENGINEER, TECHNICIAN, …
      - Based on the EMPLOYEE’s Job
    - MANAGER
      - EMPLOYEEs who are managers (the role they play)
    - SALARIED_EMPLOYEE, HOURLY_EMPLOYEE
      - Based on the EMPLOYEE’s method of pay
- EER diagrams extend ER diagrams to represent these additional subgroupings, called **subclasses** or **subtypes**

Subclasses and Superclasses (2 of 5)

Figure 4.1 EER diagram notation to represent subclasses and specialization.



Subclasses and Superclasses (3 of 5)

- Each of these subgroupings is a subset of EMPLOYEE entities
- Each is called a subclass of EMPLOYEE
- EMPLOYEE is the superclass for each of these subclasses
- These are called superclass/subclass relationships:
  - EMPLOYEE/SECRETARY
  - EMPLOYEE/TECHNICIAN
  - EMPLOYEE/MANAGER
  - …

Subclasses and Superclasses (4 of 5)

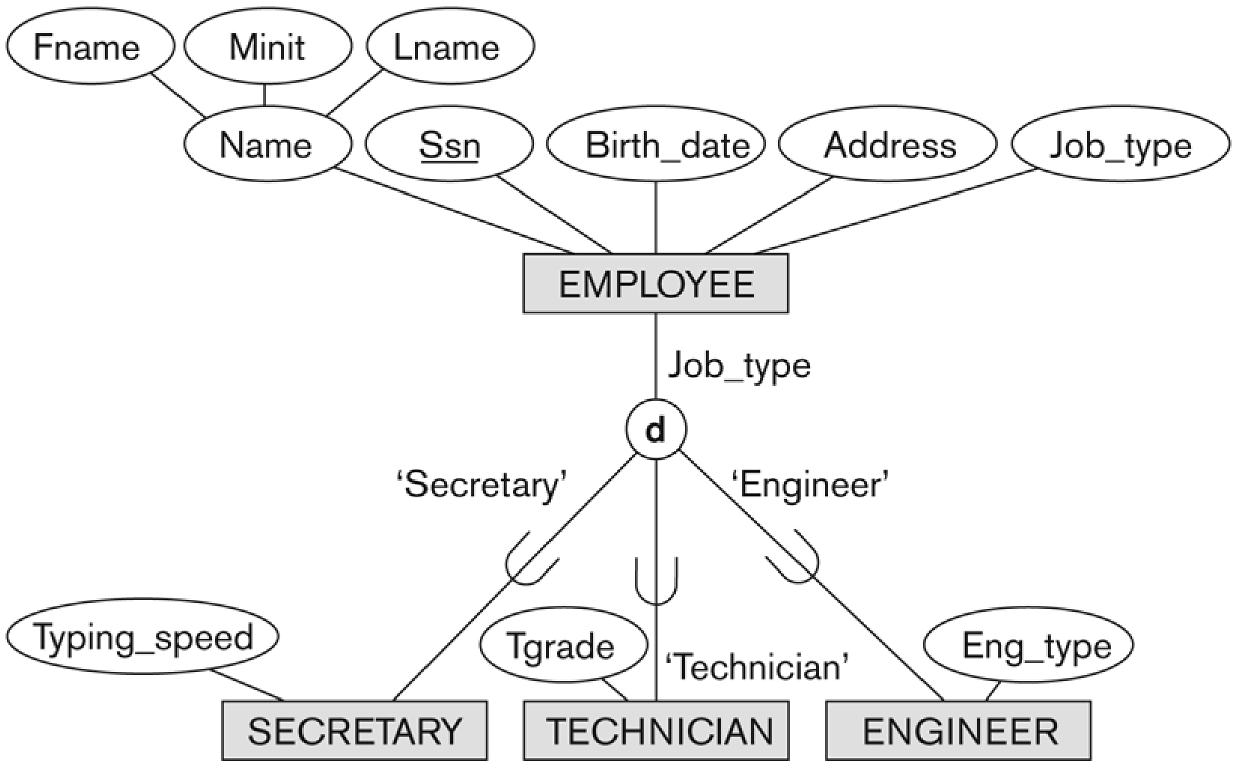
- These are also called IS-A relationships
  - SECRETARY IS-A EMPLOYEE, TECHNICIAN IS-A EMPLOYEE, ….
- Note: An entity that is member of a subclass represents the same real-world entity as some member of the superclass:
  - The subclass member is the same entity in a **distinct specific role**
  - An entity cannot exist in the database merely by being a member of a subclass; it must also be a member of the superclass
  - A member of the superclass can be optionally included as a member of any number of its subclasses

Subclasses and Superclasses (5 of 5)

- Examples:
  - A salaried employee who is also an engineer belongs to the two subclasses:
    - ENGINEER, and
    - SALARIED_EMPLOYEE
  - A salaried employee who is also an engineering manager belongs to the three subclasses:
    - MANAGER,
    - ENGINEER, and
    - SALARIED_EMPLOYEE
- It is not necessary that every entity in a superclass be a member of some subclass

Representing Specialization in EER Diagrams

Figure 4.4 EER diagram notation for an attribute-defined specialization on Job_type.



Attribute Inheritance in Superclass / Subclass Relationships

- An entity that is member of a subclass **inherits**
  - All attributes of the entity as a member of the superclass
  - All relationships of the entity as a member of the superclass

Attribute Inheritance in Superclass / Subclass Relationships

- Example:
  - In the previous slide, SECRETARY (as well as TECHNICIAN and ENGINEER) inherit the attributes Name, SSN, …, from EMPLOYEE
  - Every SECRETARY entity will have values for the inherited attributes

Specialization

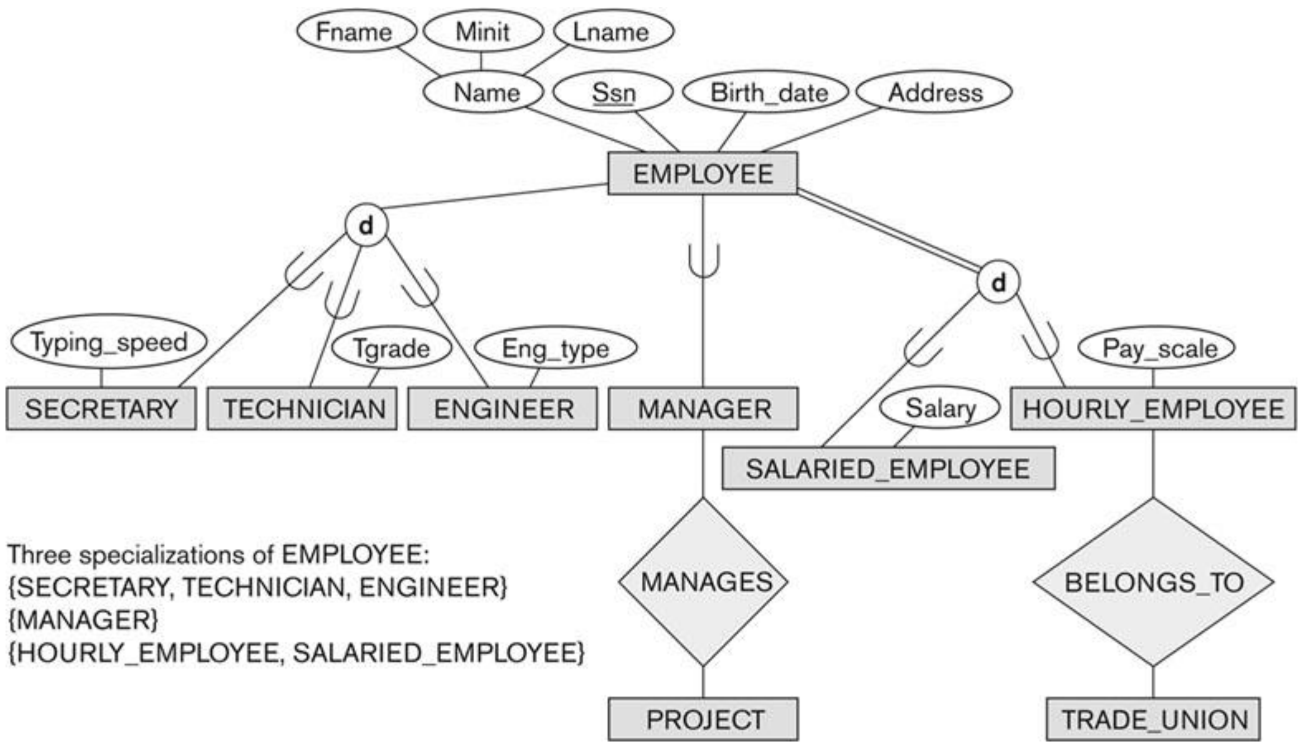
- Specialization is the process of defining a set of subclasses of a superclass
- The set of subclasses is based upon some distinguishing characteristics of the entities in the superclass
  - Example: {SECRETARY, ENGINEER, TECHNICIAN} is a specialization of EMPLOYEE based upon **job type**.
  - Example: MANAGER **is a specialization of EMPLOYEE based on the role the employee plays**
    - May have several specializations of the same superclass

Specialization

- Example: Another specialization of EMPLOYEE based on **method of pay** is {SALARIED_EMPLOYEE, HOURLY_EMPLOYEE}.
  - Superclass/subclass relationships and specialization can be diagrammatically represented in EER diagrams
  - Attributes of a subclass are called **specific** or **local** attributes.
    - For example, the attribute TypingSpeed of SECRETARY
  - The subclass can also participate in specific relationship types.
    - For example, a relationship BELONGS_TO of HOURLY_EMPLOYEE

Specialization

Figure 4.1 EER diagram notation to represent subclasses and specialization.

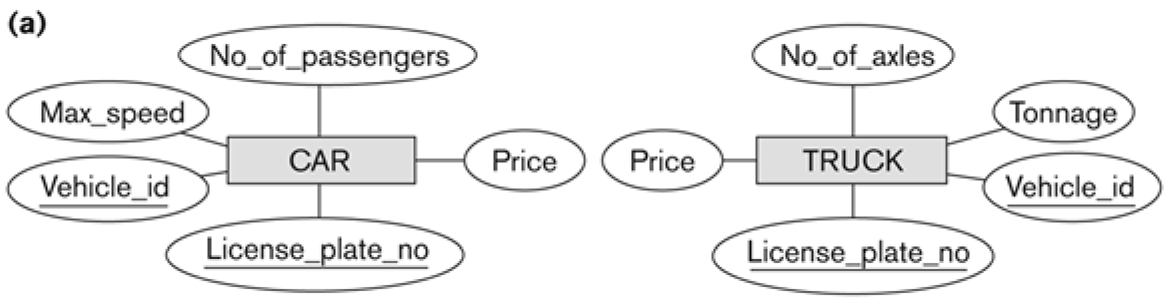


Generalization

- Generalization is the reverse of the specialization process
- Several classes with common features are generalized into a superclass;
  - original classes become its subclasses

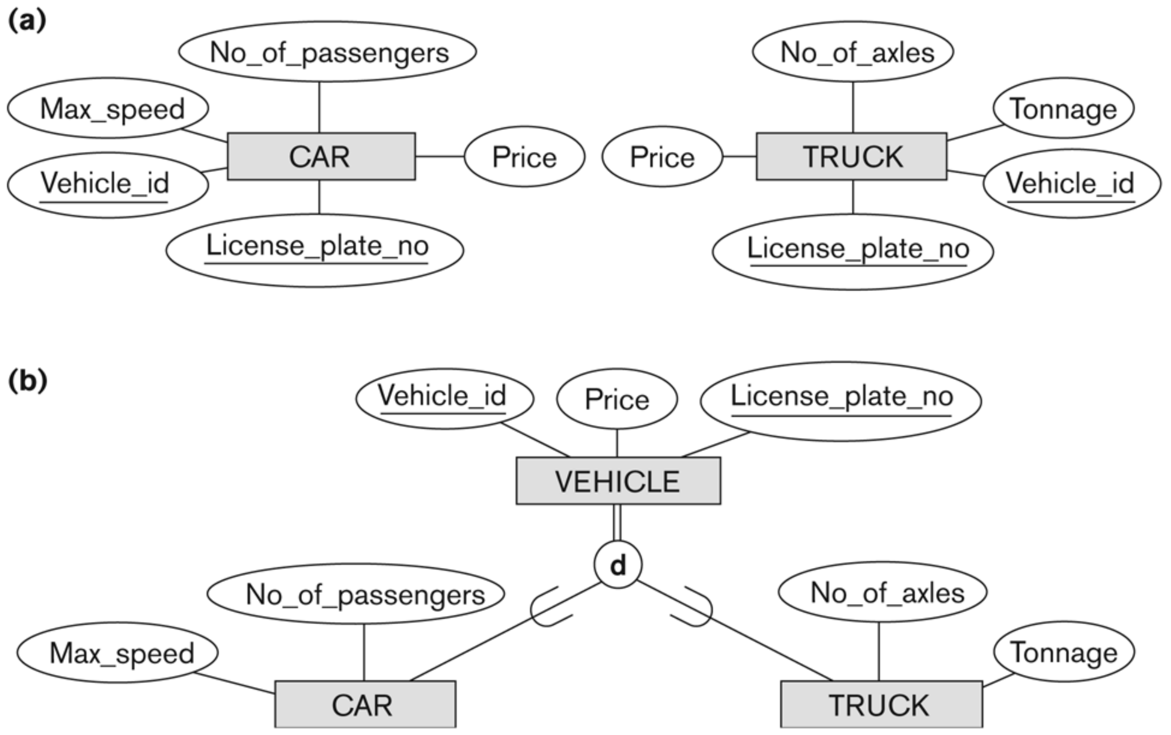
Generalization

Figure 4.3 Generalization. (a) Two entity types, CAR and TRUCK.



Generalization

Figure 4.3 Generalization. (a) Two entity types, CAR and TRUCK. (b) Generalizing CAR and TRUCK into the superclass VEHICLE.



Generalization

- Example: CAR, TRUCK generalized into VEHICLE;
  - both CAR, TRUCK become subclasses of the superclass VEHICLE.
  - We can view {CAR, TRUCK} as a specialization of VEHICLE
  - Alternatively, we can view VEHICLE as a generalization of CAR and TRUCK

Generalization and Specialization (1 of 2)

- Diagrammatic notations are sometimes used to distinguish between generalization and specialization
  - Arrow pointing to the generalized superclass represents a generalization
  - Arrows pointing to the specialized subclasses represent a specialization
  - We **do not use** this notation because it is often subjective as to which process is more appropriate for a particular situation
  - We advocate not drawing any arrows

Generalization and Specialization (2 of 2)

- Data Modeling with Specialization and Generalization
  - A superclass or subclass represents a collection (or set or grouping) of entities
  - It also represents a particular **type of entity**
  - Shown in rectangles in EER diagrams (as are entity types)
  - We can call all entity types (and their corresponding collections) **classes**, whether they are entity types, superclasses, or subclasses

Types of Specialization

- **Predicate-defined** (or condition-defined) : based on some predicate. E.g., based on value of an attribute, say, Job-type, or Age.
- **Attribute-defined:** shows the name of the attribute next to the line drawn from the superclass toward the subclasses (see Figure 4.1)
- **User-defined:** membership is defined by the user on an entity by entity basis

Constraints on Specialization and Generalization (1 of 6)

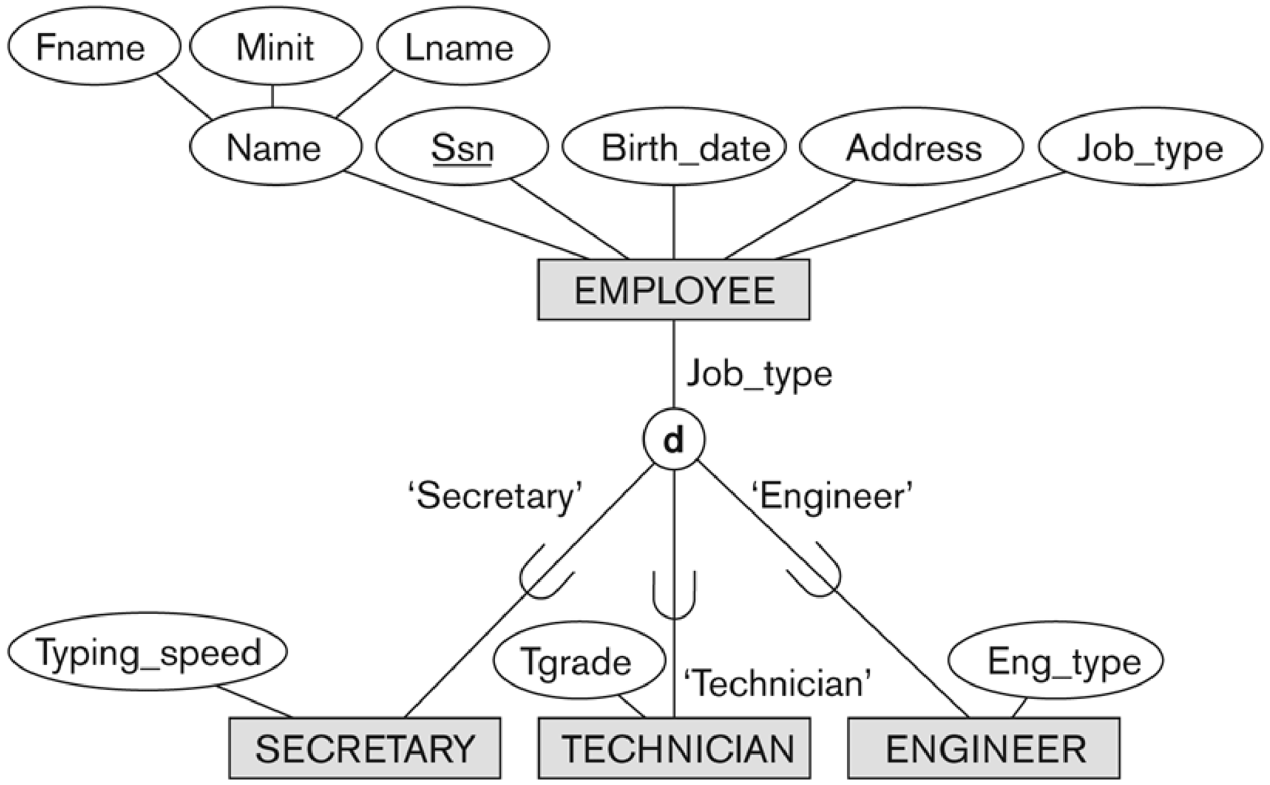
- If we can determine exactly those entities that will become members of each subclass by a condition, the subclasses are called predicate-defined (or condition-defined) subclasses
  - Condition is a constraint that determines subclass members
  - Display a predicate-defined subclass by writing the predicate condition next to the line attaching the subclass to its superclass

Constraints on Specialization and Generalization (2 of 6)

- If all subclasses in a specialization have membership condition on same attribute of the superclass, specialization is called an attribute-defined specialization
  - Attribute is called the defining attribute of the specialization
  - Example: JobType is the defining attribute of the specialization {SECRETARY, TECHNICIAN, ENGINEER} of EMPLOYEE
- If no condition determines membership, the subclass is called user-defined
  - Membership in a subclass is determined by the database users by applying an operation to add an entity to the subclass
  - Membership in the subclass is specified individually for each entity in the superclass by the user

Displaying an Attribute-Defined Specialization in EER diagrams

Figure 4.4 EER diagram notation for an attribute-defined specialization on Job_type.



Constraints on Specialization and Generalization (3 of 6)

- Two basic constraints can apply to a specialization/generalization:
  - Disjointness Constraint:
  - Completeness Constraint:

Constraints on Specialization and Generalization (4 of 6)

- Disjointness Constraint:
  - Specifies that the subclasses of the specialization must be **disjoint**:
    - an entity can be a member of at most one of the subclasses of the specialization
  - Specified by **d** in EER diagram
  - If not disjoint, specialization is **overlapping**:
    - that is the same entity may be a member of more than one subclass of the specialization
  - Specified by **o** in EER diagram

Constraints on Specialization and Generalization (5 of 6)

- Completeness (Exhaustiveness) Constraint:
  - **Total** specifies that every entity in the superclass must be a member of some subclass in the specialization/generalization
  - Shown in EER diagrams by a **double line**

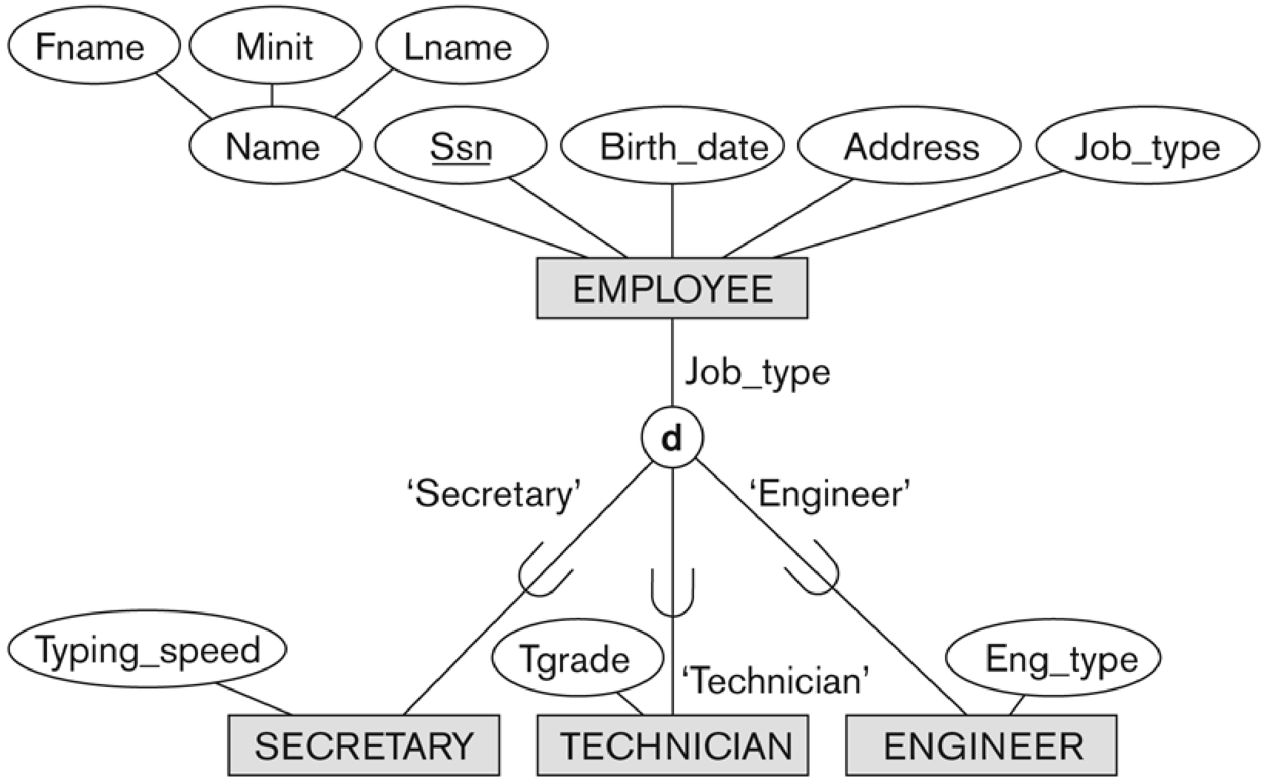
  - **Partial** allows an entity not to belong to any of the subclasses
  - Shown in EER diagrams by a single line

Constraints on Specialization and Generalization (6 of 6)

- Hence, we have four types of specialization/generalization:
  - Disjoint, total
  - Disjoint, partial
  - Overlapping, total
  - Overlapping, partial
- Note: Generalization usually is total because the superclass is derived from the subclasses.

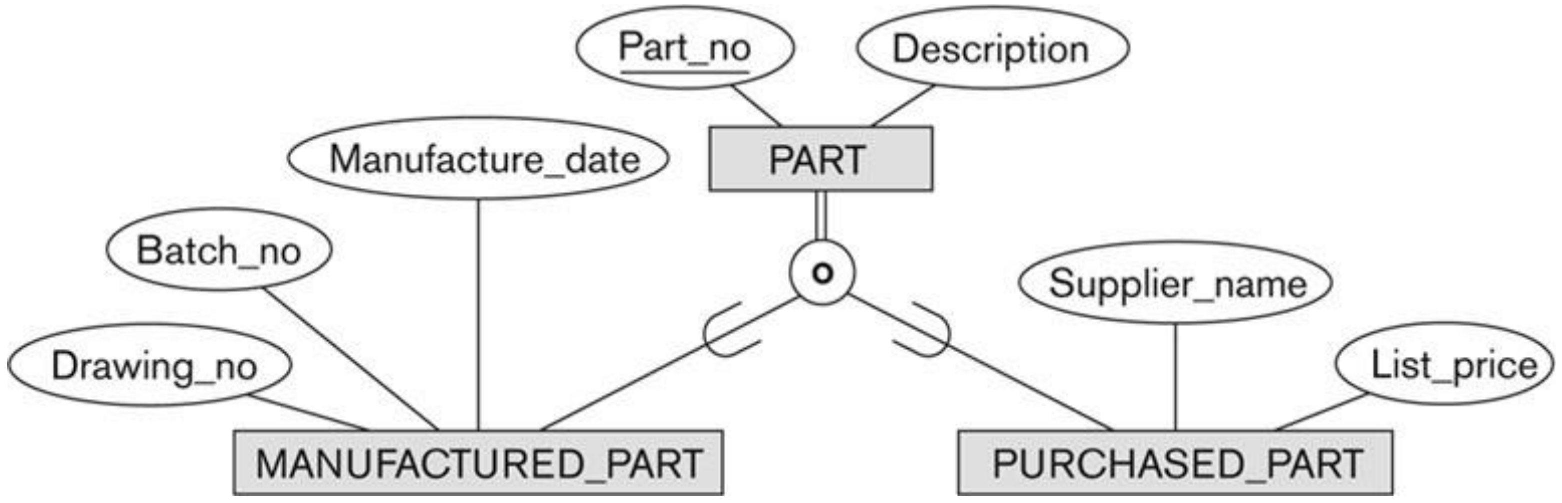
Example of Disjoint Partial Specialization

Figure 4.4 EER diagram notation for an attribute-defined specialization on Job_type.



Example of Overlapping Total Specialization

Figure 4.5 EER diagram notation for an overlapping (nondisjoint) specialization.

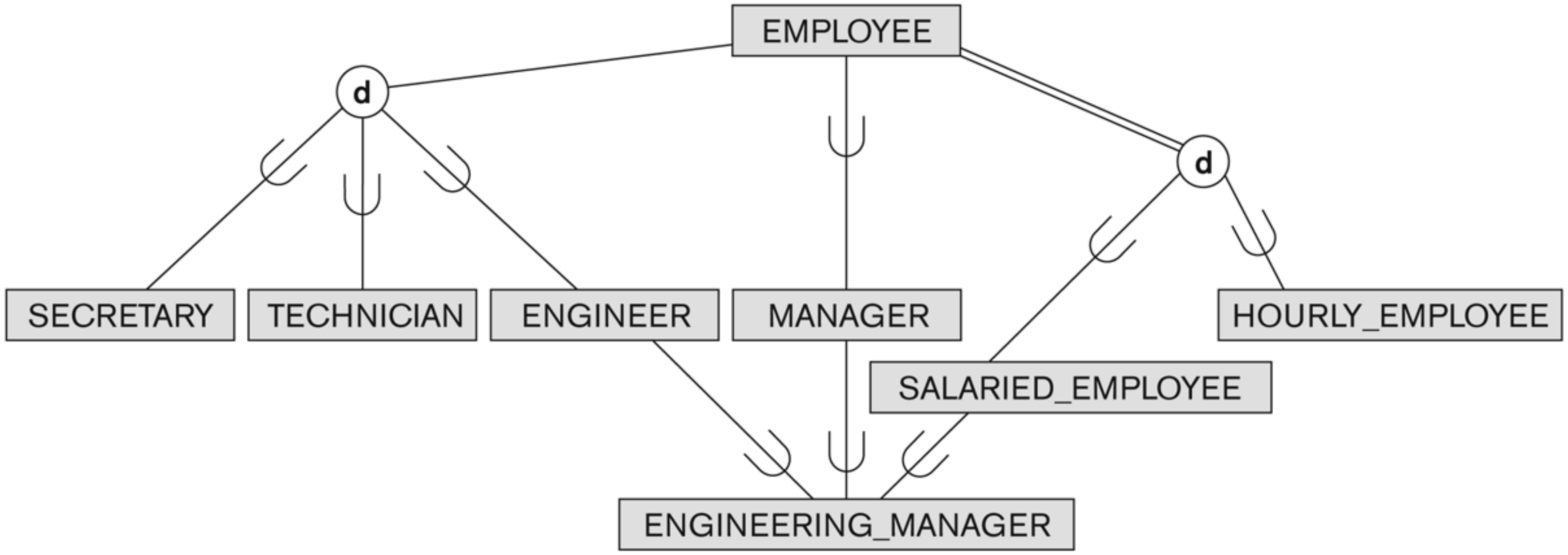


Specialization/Generalization Hierarchies, Lattices & Shared Subclasses (1 of 3)

- A subclass may itself have further subclasses specified on it
  - forms a hierarchy or a lattice
- **Hierarchy** has a constraint that every subclass has only one superclass (called **single inheritance**); this is basically a **tree structure**
- In a **lattice**, a subclass can be subclass of more than one superclass (called **multiple inheritance**)

Shared Subclass “Engineering_Manager”

Figure 4.6 A specialization lattice with shared subclass ENGINEERING_MANAGER.



Specialization/Generalization Hierarchies, Lattices & Shared Subclasses (2 of 3)

- In a lattice or hierarchy, a subclass inherits attributes not only of its direct superclass, but also of all its predecessor superclasses
- A subclass with more than one superclass is called a shared subclass (multiple inheritance)
- Can have:
  - **specialization** hierarchies or lattices, or
  - **generalization** hierarchies or lattices,
  - depending on how they were **derived**
- We just use **specialization** (to stand for the end result of either specialization or generalization)

Specialization/Generalization Hierarchies, Lattices & Shared Subclasses (3 of 3)

- In **specialization**, start with an entity type and then define subclasses of the entity type by successive specialization
  - called a **top down** conceptual refinement process
- In **generalization**, start with many entity types and generalize those that have common properties
  - Called a **bottom up** conceptual synthesis process
- In practice, a **combination of both processes** is usually employed

EER UNIVERSITY example

- The database keeps track of three types of persons: employees, alumni, and students. A person can belong to one, two, or all three of these types. Each person has a name, SSN, gender, address, and birth date.

- Each employee has a salary, and there are three types of employees: faculty, staff, and student assistants. Each employee belongs to exactly one of these types. For each alumnus, a record of the degree or degrees that he or she earned at the university is kept, including the name of the degree, the year granted, and the major department. Each student has a major department.

EER UNIVERSITY example

- Each faculty has a rank, whereas each staff member has a staff position. Student assistants are classified further as either research assistants or teaching assistants, and the percent of time that they work is recorded in the database. Research assistants have the current course they work on.

- Students are further classified as either graduate or undergraduate, with the specific attributes degree program (M.S., Ph.D., M.B.A., and so on) for graduate students and class (freshman, sophomore, and so on) for undergraduates.

Categories (UNION TYPES) (1 of 2)

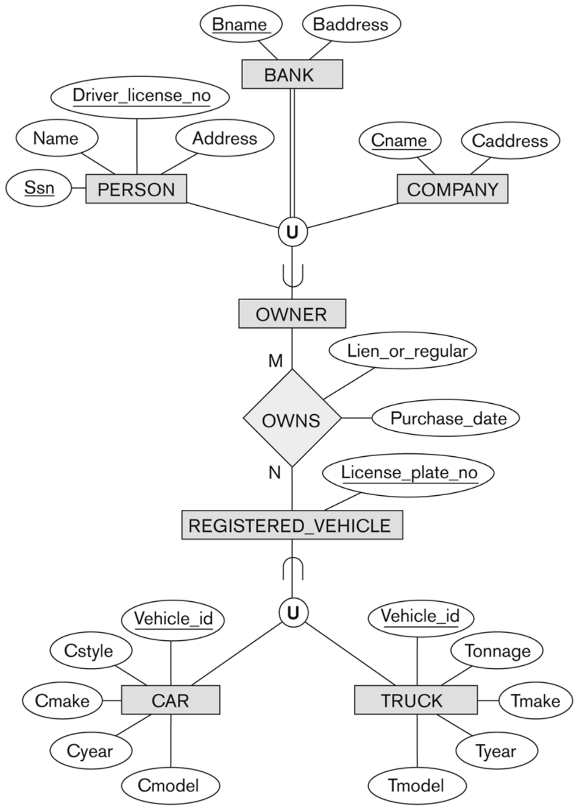
- All of the **superclass/subclass relationships** we have seen thus far have a single superclass
- A shared subclass is a subclass in:
  - **more than one** distinct superclass/subclass relationships
  - each relationships has a **single** superclass
  - shared subclass leads to multiple inheritance
- In some cases, we need to model a **single superclass/subclass relationship with more than one superclass**
- Superclasses can represent different entity types
- Such a subclass is called a category or UNION TYPE

Categories (UNION TYPES) (2 of 2)

- Example: In a database for vehicle registration, a vehicle owner can be a PERSON, a BANK (holding a lien on a vehicle) or a COMPANY.
  - A **category** (UNION type) called OWNER is created to represent a subset of the **union** of the three superclasses COMPANY, BANK, and PERSON
  - A category member must exist in **at least one (typically just one)** of its superclasses
- Difference from **shared subclass**, which is a:
  - subset of the **intersection** of its superclasses
  - shared subclass member must exist in **all** of its superclasses

Two Categories (UNION Types): OWNER, REGISTERED_VEHICLE

Figure 4.8 Two categories (union types): OWNER and REGISTERED_VEHICLE.



Formal Definitions of EER Model (1 of 4)

- Class C:
  - A type of entity with a corresponding set of entities:
    - could be entity type, subclass, superclass, or category
- Note: The definition of **relationship type** in ER/EER should have ‘entity type’ replaced with ‘class’ to allow relationships among classes in general
- Subclass S is a class whose:
  - Type inherits all the attributes and relationship of a class C
  - Set of entities must always be a subset of the set of entities of the other class C
    - $S \subseteq C$
  - C is called the superclass of S
  - A superclass/subclass relationship exists between S and C

Formal Definitions of EER Model (2 of 4)

- Specialization $Z : Z = \{S1, S2, \ldots, Sn\}$ is a set of subclasses with same superclass G; hence, G/Si is a superclass relationship $\text{for } i = 1, \ldots.., n.$
  - G is called a generalization of the subclasses $\{S1, S2, \ldots, Sn\}$
  - Z is total if we always have:
    - $S1 \cup S2 \cup \ldots \cup Sn = G;$
    - Otherwise, Z is partial.
  - Z is disjoint if we always have:
    - $Si \cap S2 \text{ empty - set for } i \neq j;$
  - Otherwise, Z is overlapping.

Formal Definitions of EER Model (3 of 4)

- Subclass S of C is predicate defined if predicate (condition) p on attributes of C is used to specify membership in S;
  - that is, S = C[p], where C[p] is the set of entities in C that satisfy condition p
- A subclass not defined by a predicate is called user-defined
- Attribute-defined specialization: if a predicate A = ci (where A is an attribute of G and ci is a constant value from the domain of A) is used to specify membership in each subclass Si in Z
  - Note: If $ci \neq cj$ for $i \neq j$, and A is single-valued, then the attribute-defined specialization will be disjoint.

Formal Definitions of EER Model (4 of 4)

- Category or UNION type T
  - A class that is a subset of the **union** of n defining superclasses

    $D1, D2, \ldots Dn, n > 1$:
    - $T \subseteq (D1 \cup D2 \cup \ldots \cup Dn)$
  - Can have a predicate pi on the attributes of Di to specify entities of Di that are members of T.
  - If a predicate is specified on every

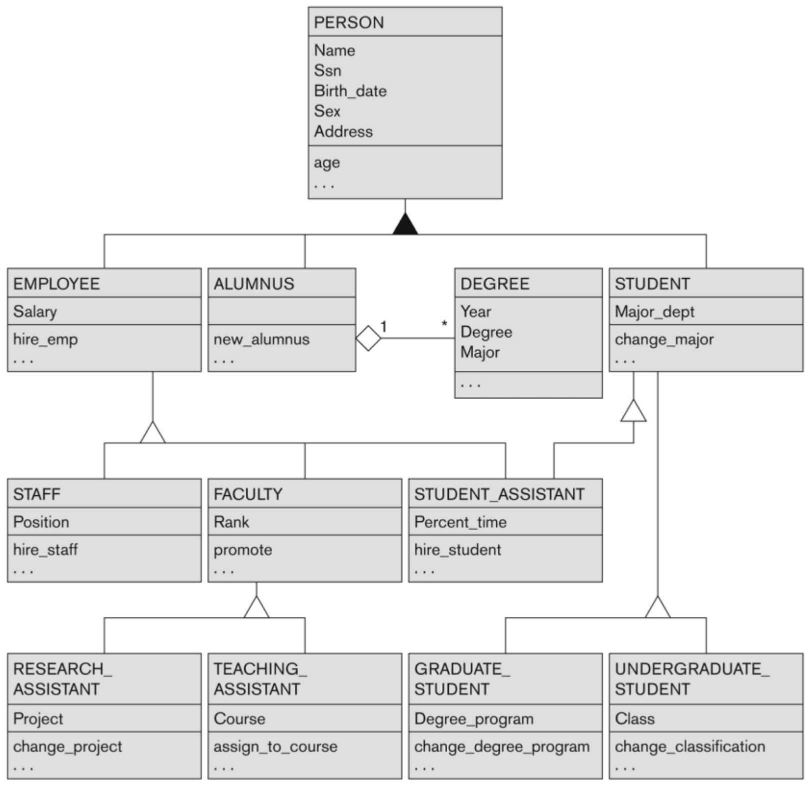
    $Di : T = (D1[p1] \cup D2[p2] \cup \ldots \cup Dn[pn])$

Alternative Diagrammatic Notations (1 of 2)

- ER/EER diagrams are a specific notation for displaying the concepts of the model diagrammatically
- DB design tools use many alternative notations for the same or similar concepts
- One popular alternative notation uses **UML class diagrams**
- see next slides for UML class diagrams and other alternative notations

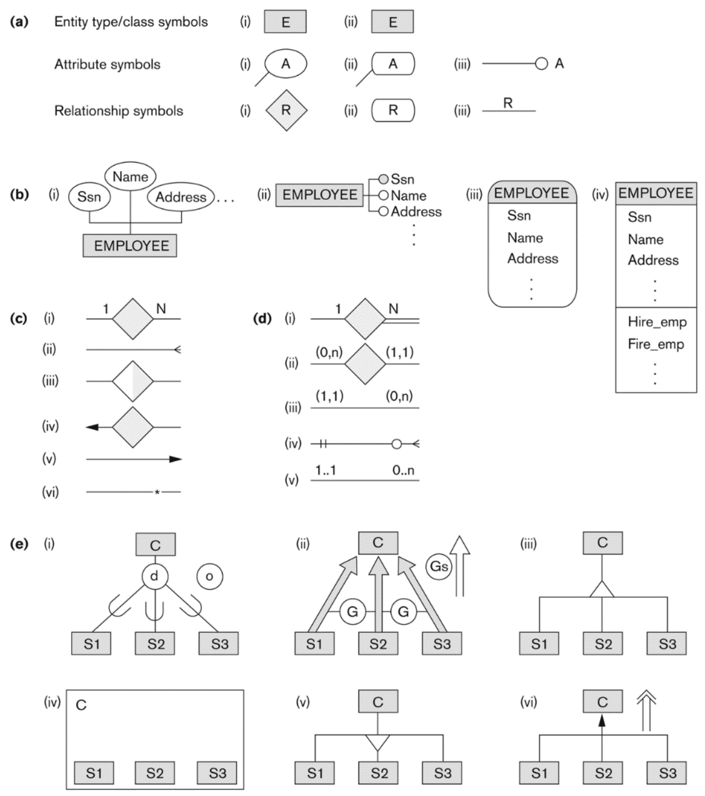
UML Example for Displaying Specialization / Generalization

Figure 4.10 A UML class diagram corresponding to the EER diagram in Figure 4.7, illustrating UML notation for specialization/generalization.



Alternative Diagrammatic Notations (2 of 2)

Figure A.1 Alternative notations. (a) Symbols for entity type/class, attribute, and relationship. (b) Displaying attributes. (c) Displaying cardinality ratios. (d) Various (min, max) notations. (e) Notations for displaying specialization/generalization.



(a) Entity type/class symbols (i) E (ii) E
Attribute symbols (i) A (ii) A (iii) A
Relationship symbols (i) R (ii) R (iii) R
(b) (i) Name Ssn Address EMPLOYEE
(ii) EMPLOYEE Ssn Name Address
(iii) EMPLOYEE Ssn Name Address
(iv) EMPLOYEE Ssn Name Address Hire_emp Fire_emp
(c) (i) 1 N (ii) (iii) (iv) (v) (vi)
(d) (i) 1 N (ii) (0,n) (1,1) (iii) (1,1) (0,n) (iv) (v) 1..1 0..n
(e) (i) C d o S1 S2 S3
(ii) C G G Gs S1 S2 S3
(iii) C S1 S2 S3
(iv) C S1 S2 S3
(v) C S1 S2 S3
(vi) C S1 S2 S3

Summary

- Introduced the EER model concepts
  - Class/subclass relationships
  - Specialization and generalization
  - Inheritance
- Constraints on EER schemas
- These augment the basic ER model concepts introduced in Chapter 3
- EER diagrams and alternative notations were presented
- Knowledge Representation and Ontologies were introduced and compared with Data Modeling