Enhanced Entity-Relationship (EER) Modeling

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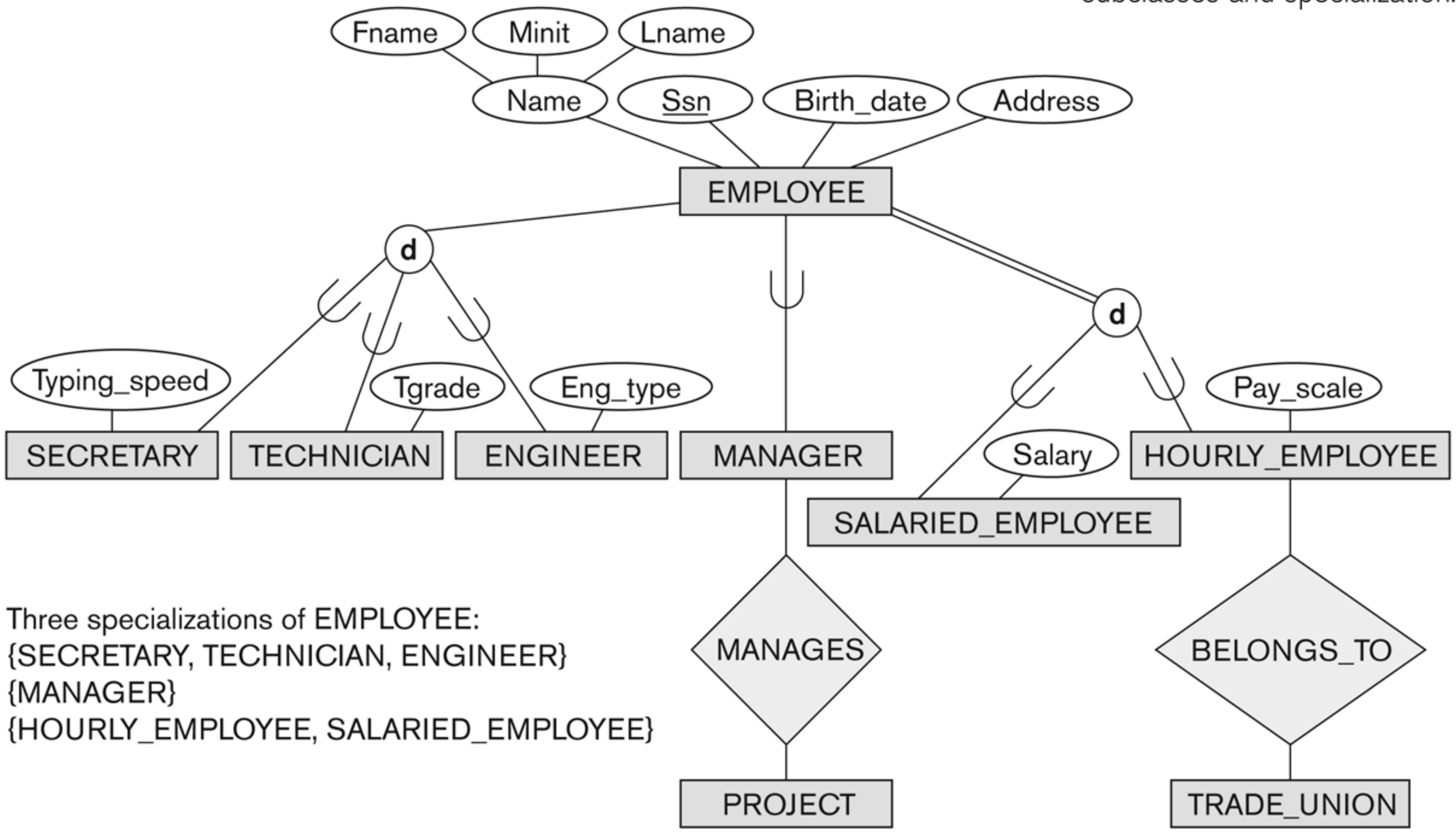
- EER stands for Enhanced ER or Extended ER
- EER Model Concepts
  - Includes all modeling concepts of basic ER
  - Additional concepts:
    - subclasses/superclasses
    - specialization/generalization
    - categories (UNION types)
    - attribute and relationship inheritance
  - These are fundamental to conceptual modeling
- The additional EER concepts are used to model applications more completely and more accurately
  - EER includes some object-oriented concepts, such as inheritance

Subclasses and Superclasses (1)

- 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
    - 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

Figure 4.1
EER diagram notation to represent subclasses and specialization.



Three specializations of EMPLOYEE:
{SECRETARY, TECHNICIAN, ENGINEER}
{MANAGER}
{HOURLY_EMPLOYEE, SALARIED_EMPLOYEE}

Subclasses and Superclasses (2)

- 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 (3)

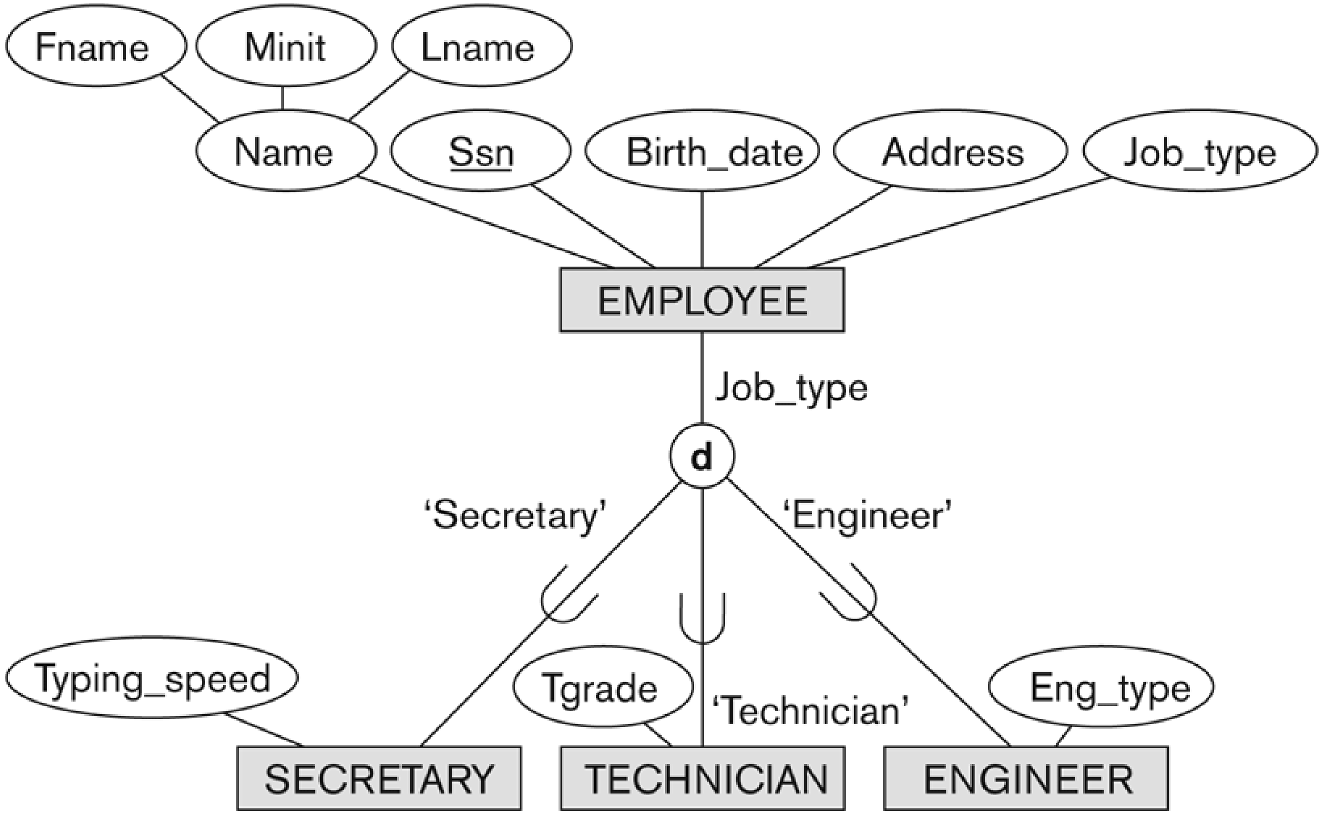
- These are also called IS-A relationships
  - SECRETARY IS-A EMPLOYEE, TECHNICIAN IS-A EMPLOYEE, ….
- Note: An entity that is member of a subclass represents the same real-world entity as some member of the superclass:
  - The subclass member is the same entity in a *distinct specific role*
  - An entity 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 (4)

- 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
- 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 (1)

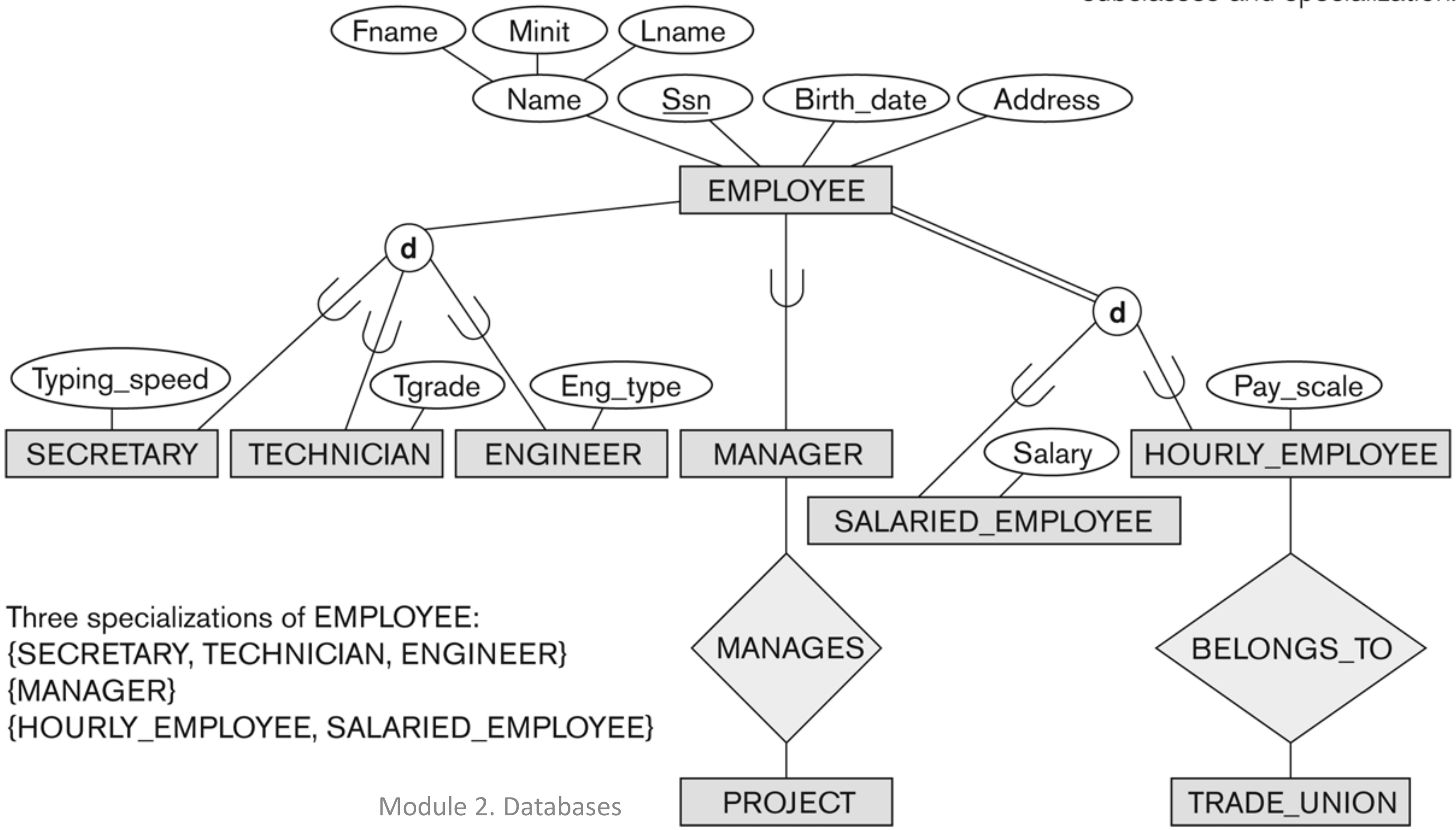
- Specialization is the process of defining a set of subclasses of a superclass
- The set of subclasses is based upon some distinguishing characteristics of the entities in the superclass
  - Example: {SECRETARY, ENGINEER, TECHNICIAN} is a specialization of EMPLOYEE based upon *job type.*
    - May have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

Specialization (2)

- 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 (3)

Figure 4.1
EER diagram notation to represent subclasses and specialization.



Three specializations of EMPLOYEE:
{SECRETARY, TECHNICIAN, ENGINEER}
{MANAGER}
{HOURLY_EMPLOYEE, SALARIED_EMPLOYEE}

Generalization

- Generalization is the reverse of the specialization process
- Several classes with common features are generalized into a superclass;
  - original classes become its subclasses
- 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 (2)

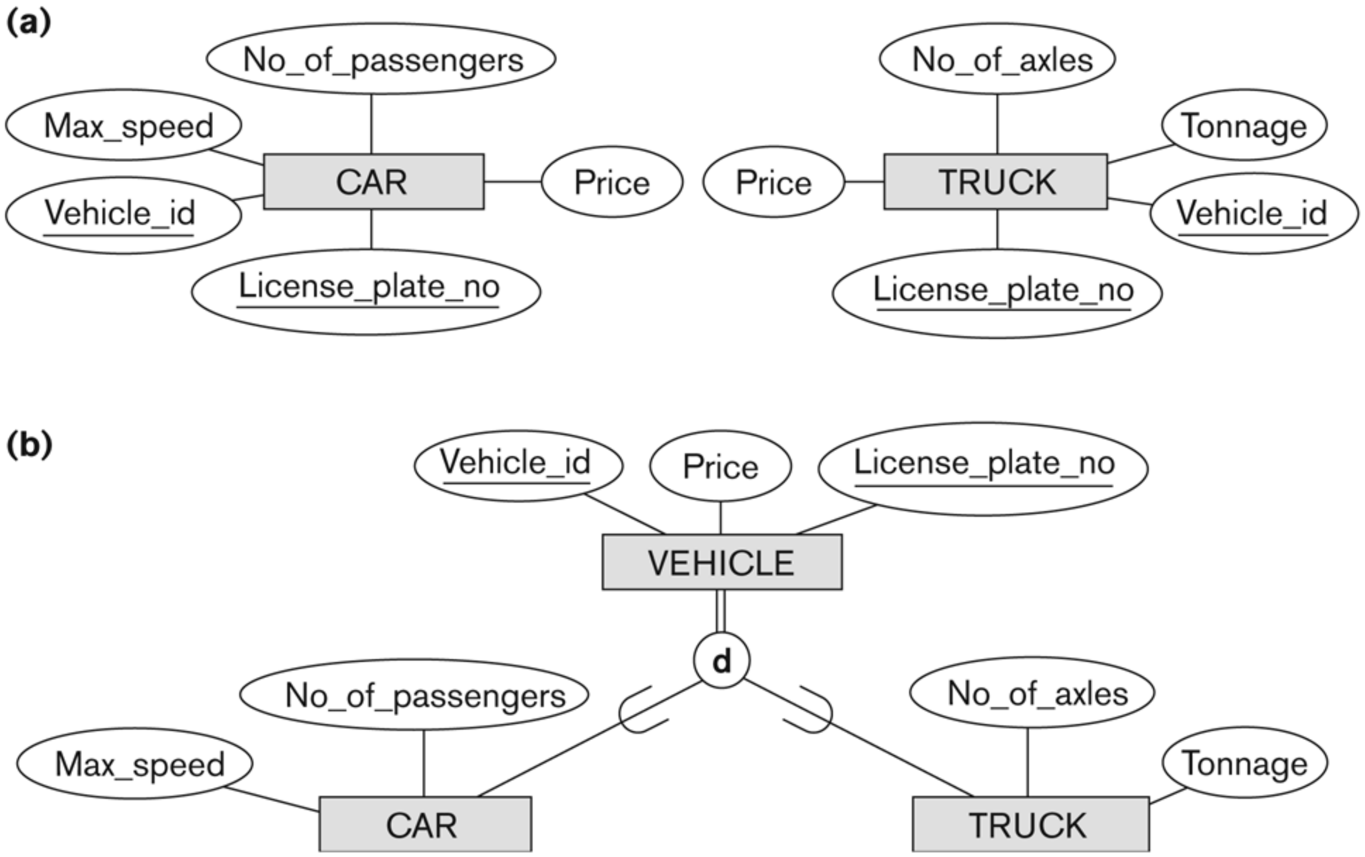


Figure 4.3
Generalization. (a) Two entity types, CAR and TRUCK.
(b) Generalizing CAR and TRUCK into the superclass VEHICLE.

Generalization and Specialization (1)

- Diagrammatic notation 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)

- 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

Constraints on Specialization and Generalization (1)

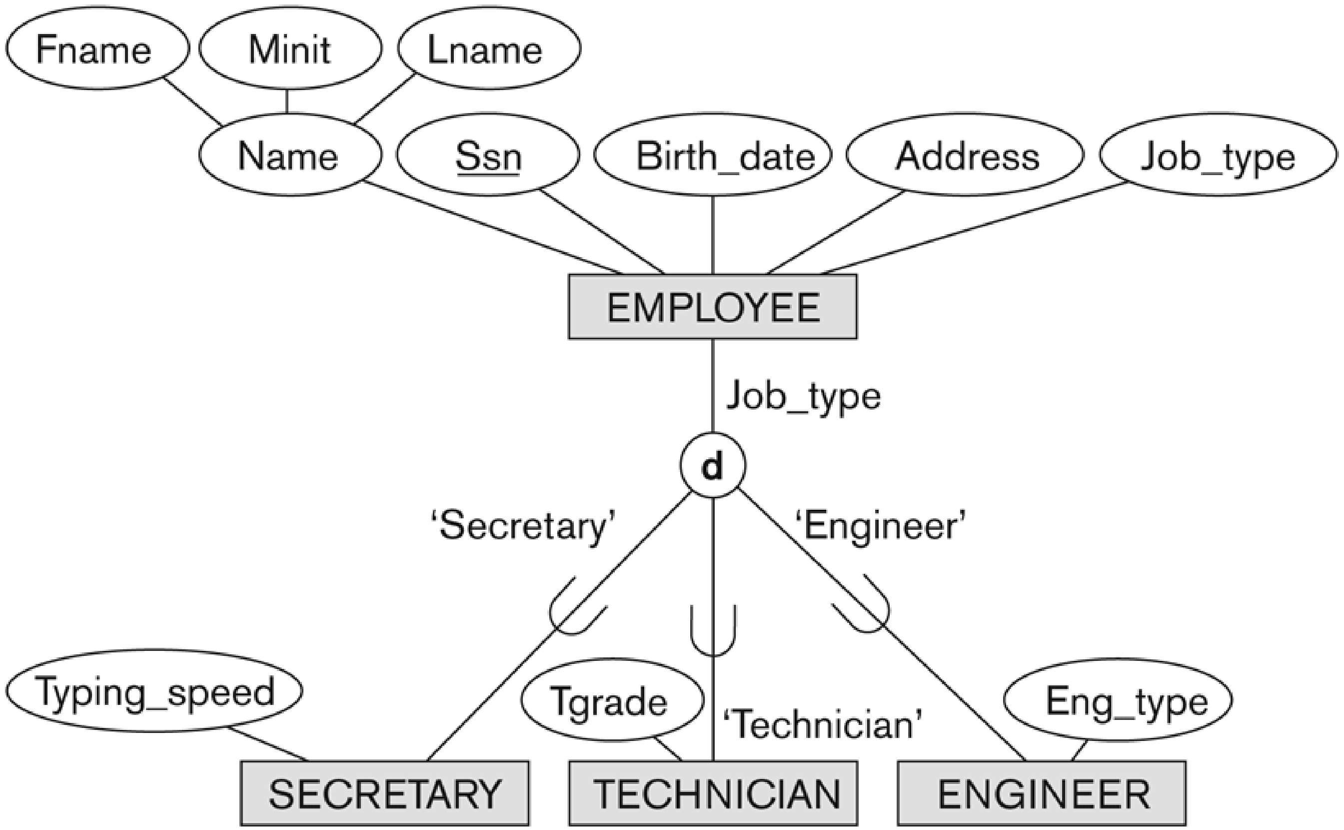
- If we can determine exactly those entities that will become members of each subclass by a condition, the subclasses are called predicate-defined (or condition-defined) subclasses
  - Condition is a constraint that determines subclass members
  - Display a predicate-defined subclass by writing the predicate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

Constraints on Specialization and Generalization (2)

- 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)

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

Constraints on Specialization and Generalization (4)

- 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)

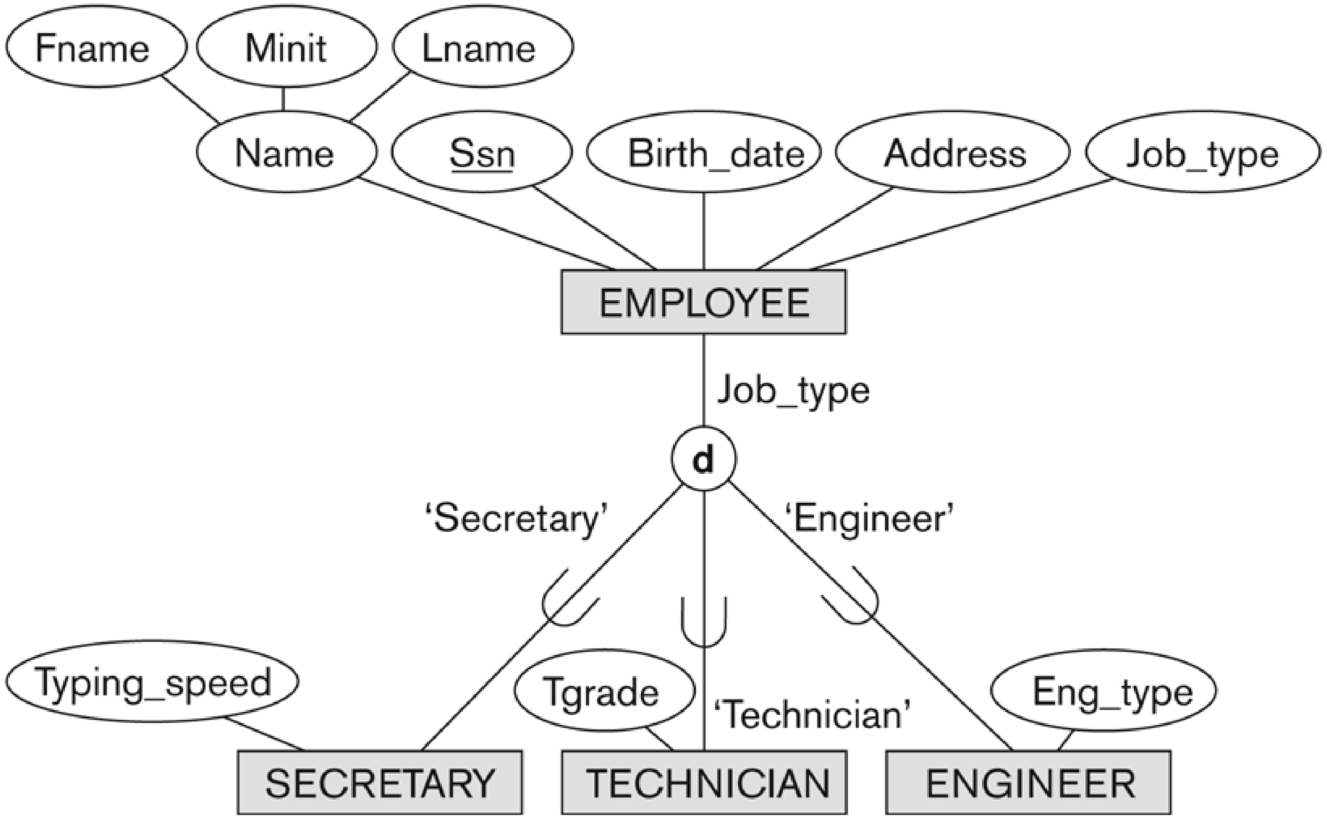
- Completeness Constraint:
  - *Total* specifies that every entity in the superclass must be a member of some subclass in the specialization/generalization
  - Shown in EER diagrams by a ***<u>double line</u>***
  - *Partial* allows an entity not to belong to any of the subclasses
  - Shown in EER diagrams by a single line

Constraints on Specialization and Generalization (6)

- 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

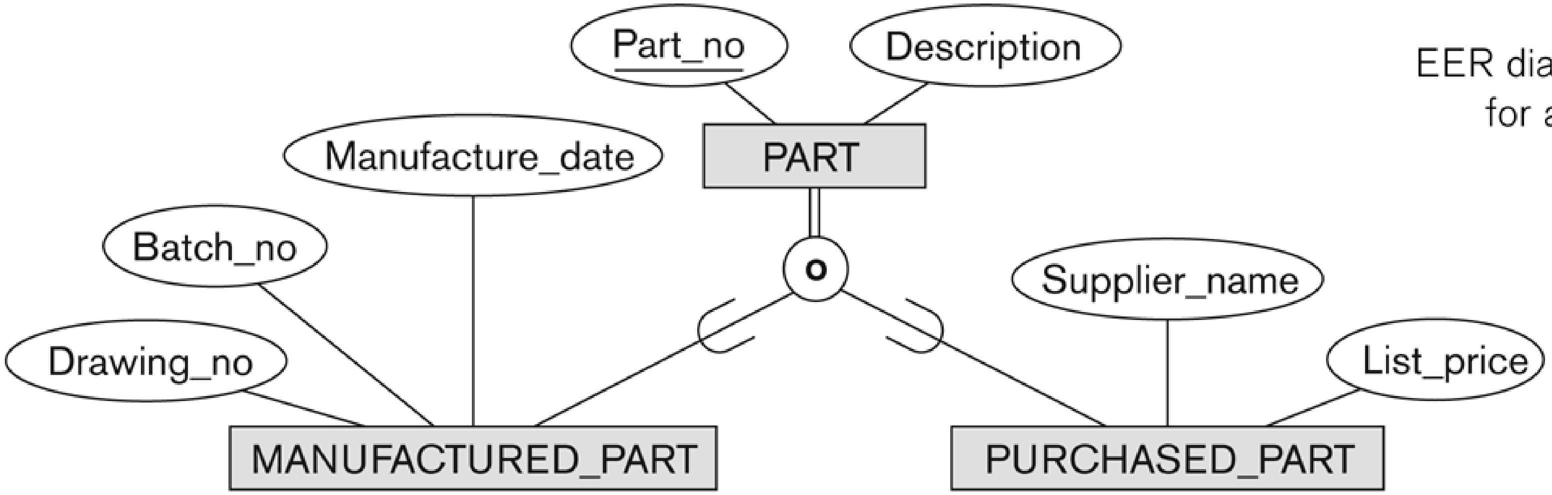


Figure 4.5
EER diagram notation for an overlapping (nondisjoint) specialization.

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

- 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”

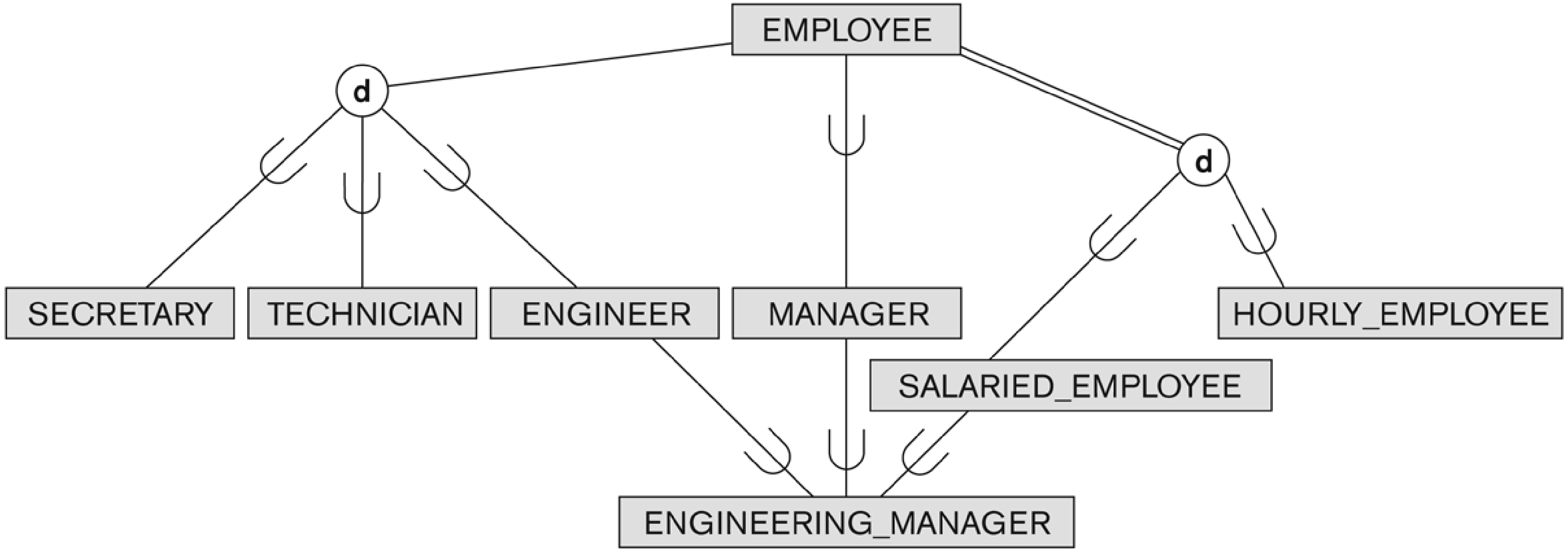


Figure 4.6
A specialization lattice with shared subclass ENGINEERING_MANAGER.

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

- 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)

- 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

Specialization / Generalization Lattice Example (UNIVERSITY)

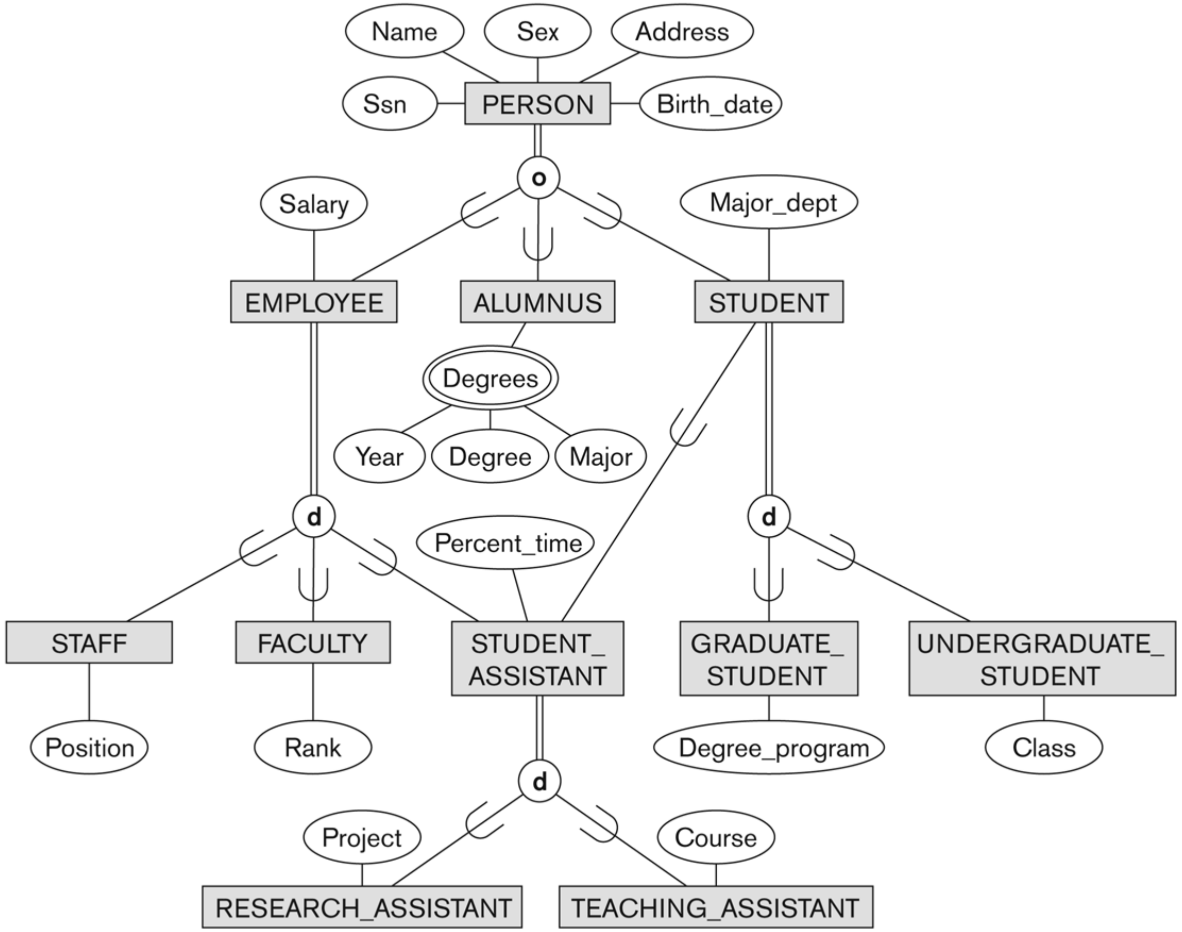


Figure 4.7
A specialization lattice with multiple inheritance for a UNIVERSITY database.

Categories (UNION TYPES) (1)

- 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)

- 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*** 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

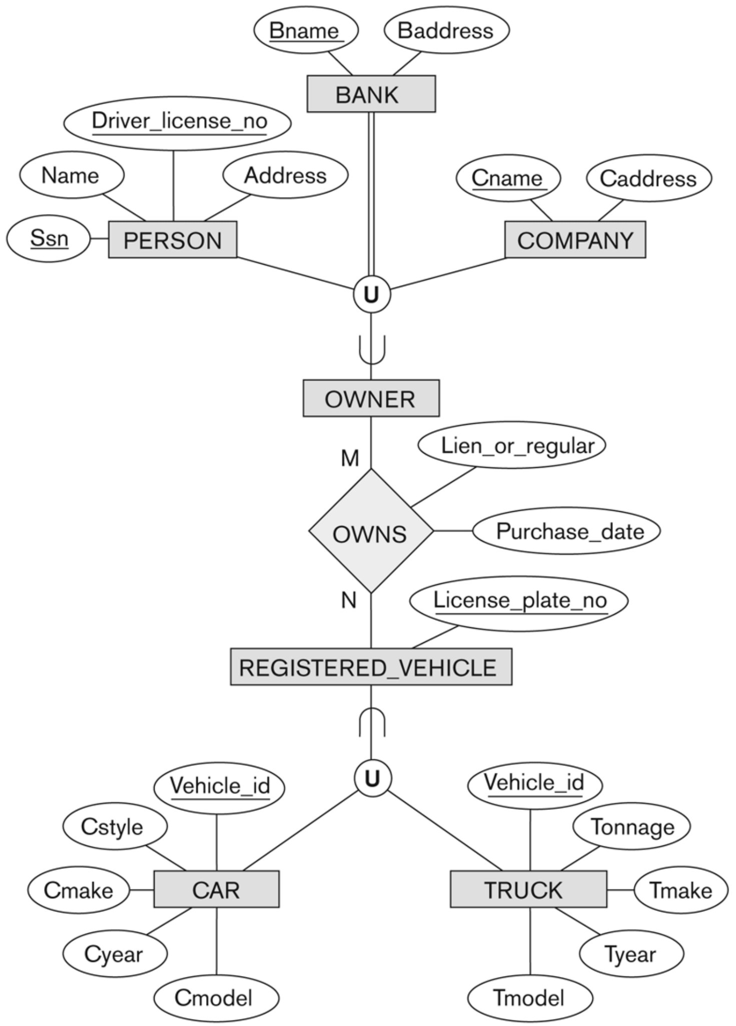


Figure 4.8
Two categories (union types): OWNER and REGISTERED_VEHICLE.

Formal Definitions of EER Model (1)

- 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)

- Specialization Z: Z = {S1, S2,…, Sn} is a set of subclasses with same superclass G; hence, G/Si is a superclass relationship for i = 1, …., n.
  - G is called a generalization of the subclasses {S1, S2,…, 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:
    - $Si \cap S2$ empty-set for $i \neq j$;
  - Otherwise, Z is overlapping.

Formal Definitions of EER Model (3)

- 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 ≠ cj for i ≠ j, and A is single-valued, then the attribute-defined specialization will be disjoint.

Formal Definitions of EER Model (4)

- Category or UNION type T
  - A class that is a subset of the *union* of n defining superclasses D1, D2,…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

- 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

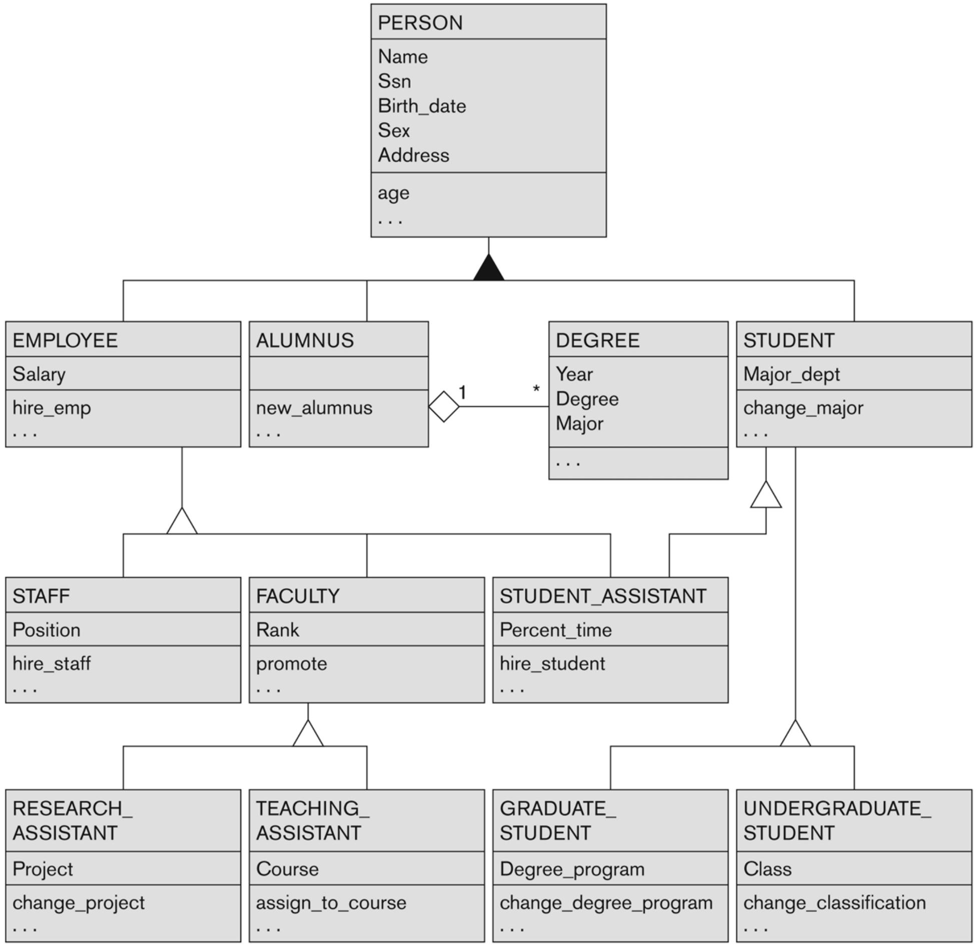


Figure 4.10
A UML class diagram corresponding to the EER diagram in Figure 4.7, illustrating UML notation for specialization/generalization.

Alternative Diagrammatic Notations

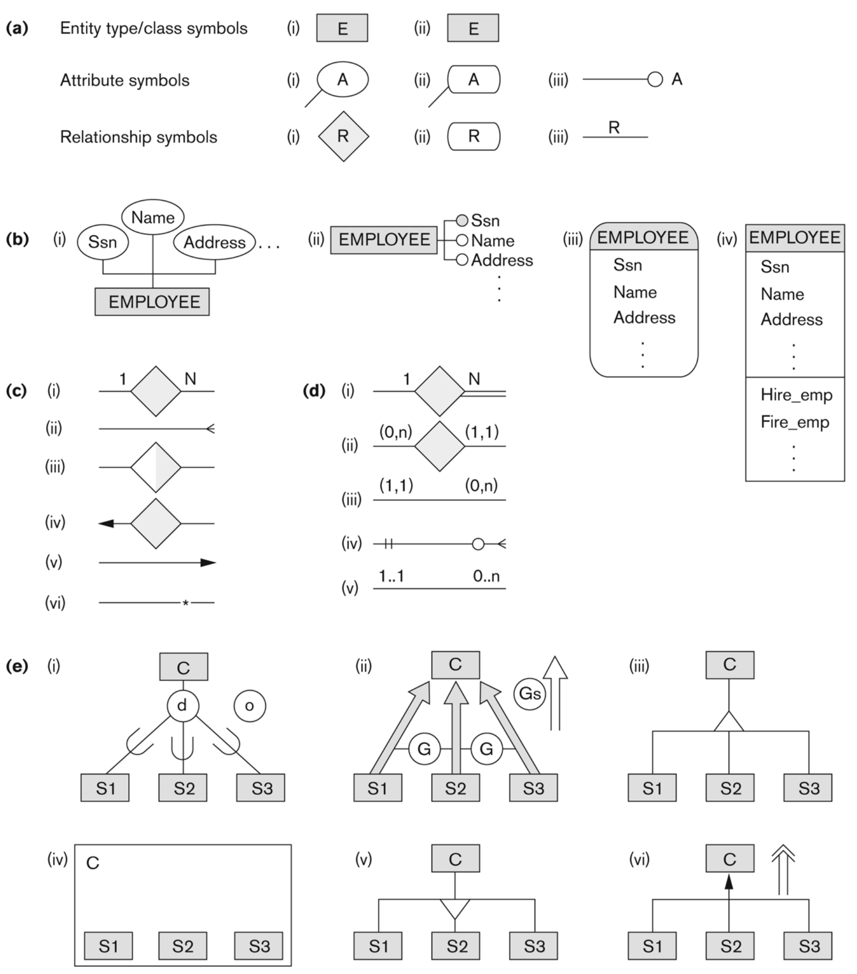


Figure A.1
Alternative notations. (a) Symbols for entity type/class, attribute, and relationship. (b) Displaying attributes. (c) Displaying cardinality ratios. (d) Various (min, max) notations. (e) Notations for displaying specialization/generalization.

General Conceptual Modeling Concepts

- GENERAL DATA ABSTRACTIONS
  - CLASSIFICATION and INSTANTIATION
  - AGGREGATION and ASSOCIATION (relationships)
  - GENERALIZATION and SPECIALIZATION
  - IDENTIFICATION
- CONSTRAINTS
  - CARDINALITY (Min and Max)
  - COVERAGE (Total vs. Partial, and Exclusive (disjoint) vs. Overlapping)

Ontologies

- Use conceptual modeling and other tools to develop “a specification of a conceptualization”
  - **Specification** refers to the language and vocabulary (data model concepts) used
  - **Conceptualization** refers to the description (schema) of the concepts of a particular field of knowledge and the relationships among these concepts
- Many medical, scientific, and engineering ontologies are being developed as a means of standardizing concepts and terminology

Summary

- Introduced the EER model concepts
  - Class/subclass relationships
  - Specialization and generalization
  - Inheritance
- These augment the basic ER model concepts introduced in Chapter 3
- EER diagrams and alternative notations were presented