Extended Entity Relationship Model

Enhanced-ER (EER) Model Concepts

- Includes all modeling concepts of basic ER
- Additional concepts: subclasses/superclasses, specialization/generalization, categories, attribute inheritance
- The resulting model is called the enhanced-ER or Extended ER (E2R or EER) model
- It is used to model applications more completely and accurately if needed
- It 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, MANAGER, TECHNICIAN, SALARIED_EMPLOYEE, HOURLY_EMPLOYEE,…
  - Each of these groupings 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.
- Example: EMPLOYEE/SECRETARY, EMPLOYEE/TECHNICIAN

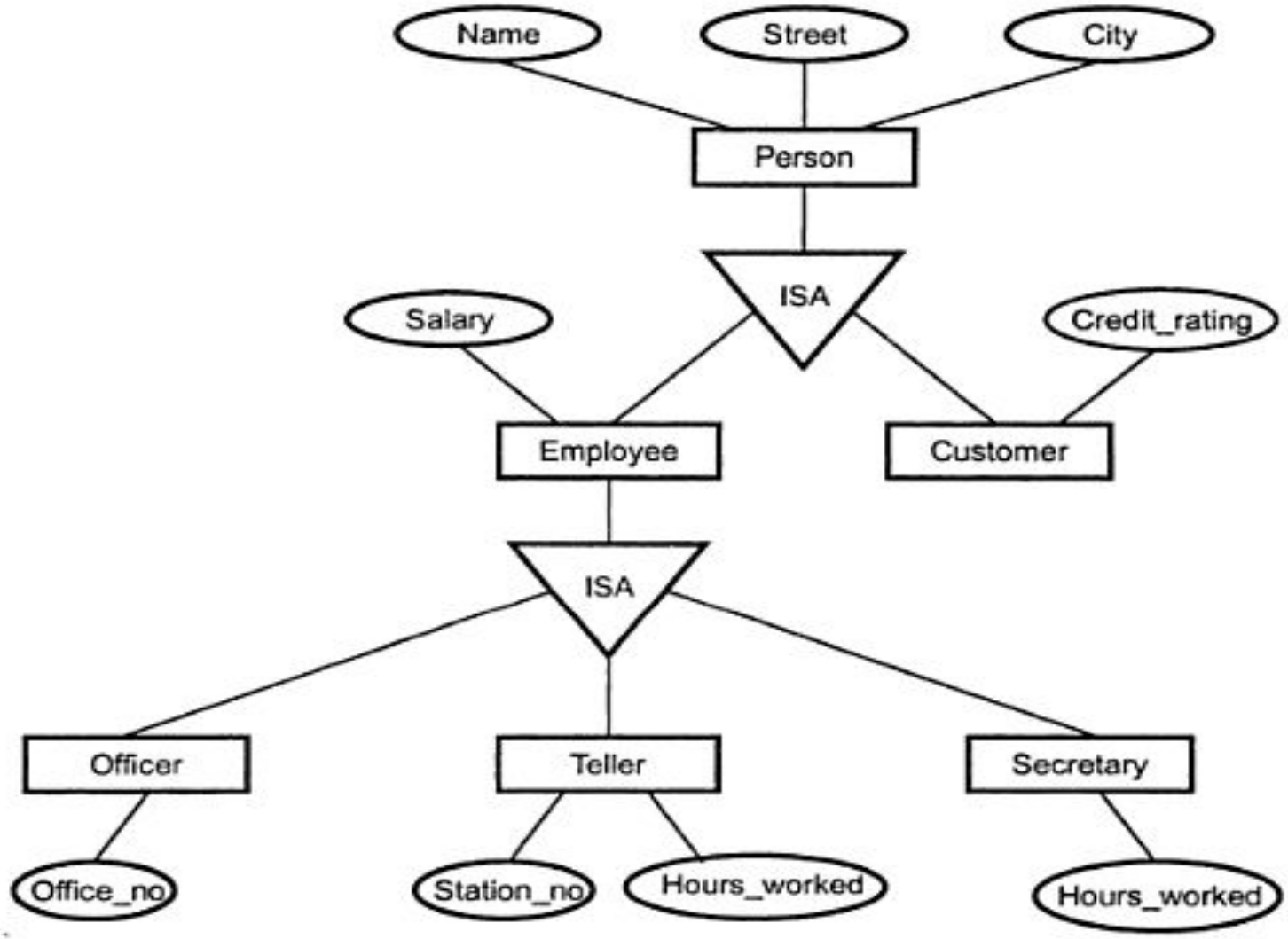
Subclasses and Superclasses (2)

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

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
- It also inherits all relationships

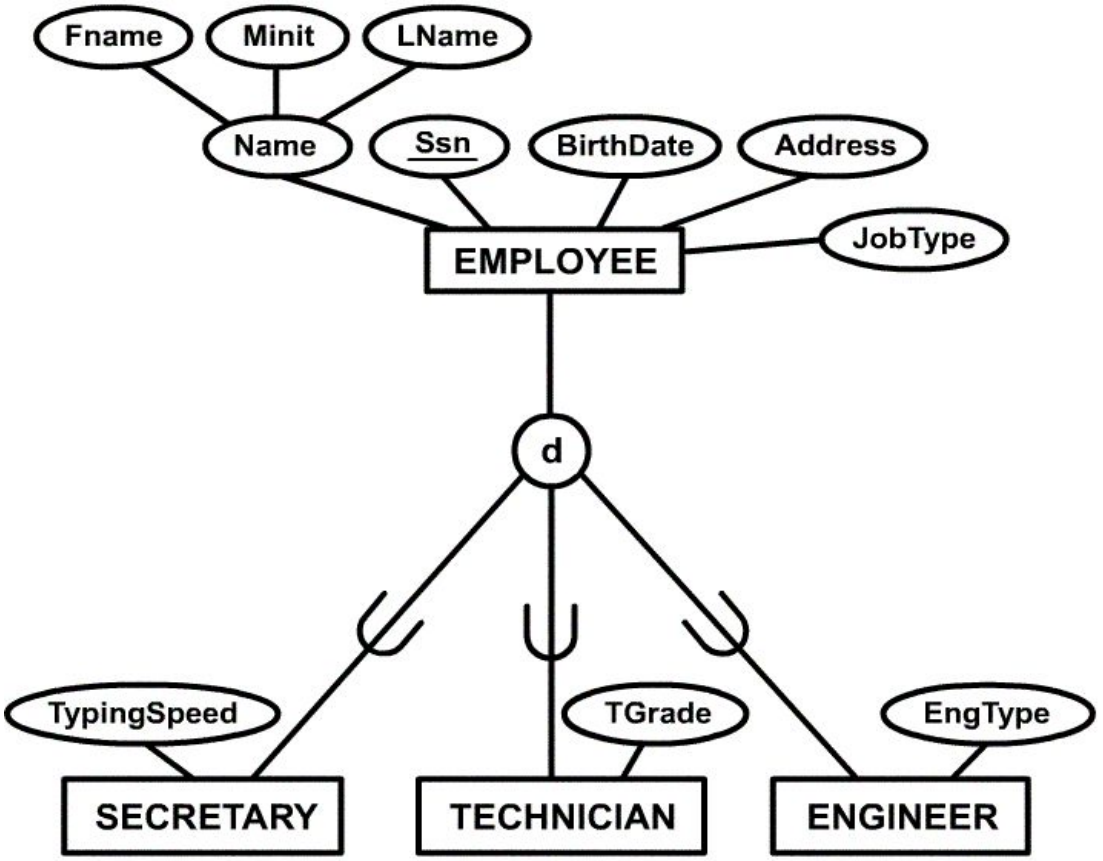
Example of a Specialization



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*.
  - May have several specializations of the same superclass
- Example: Another specialization of EMPLOYEE based in *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 attributes. For example, TypingSpeed of SECRETARY
  - The subclass can participate in specific relationship types. For example, BELONGS_TO of HOURLY_EMPLOYEE

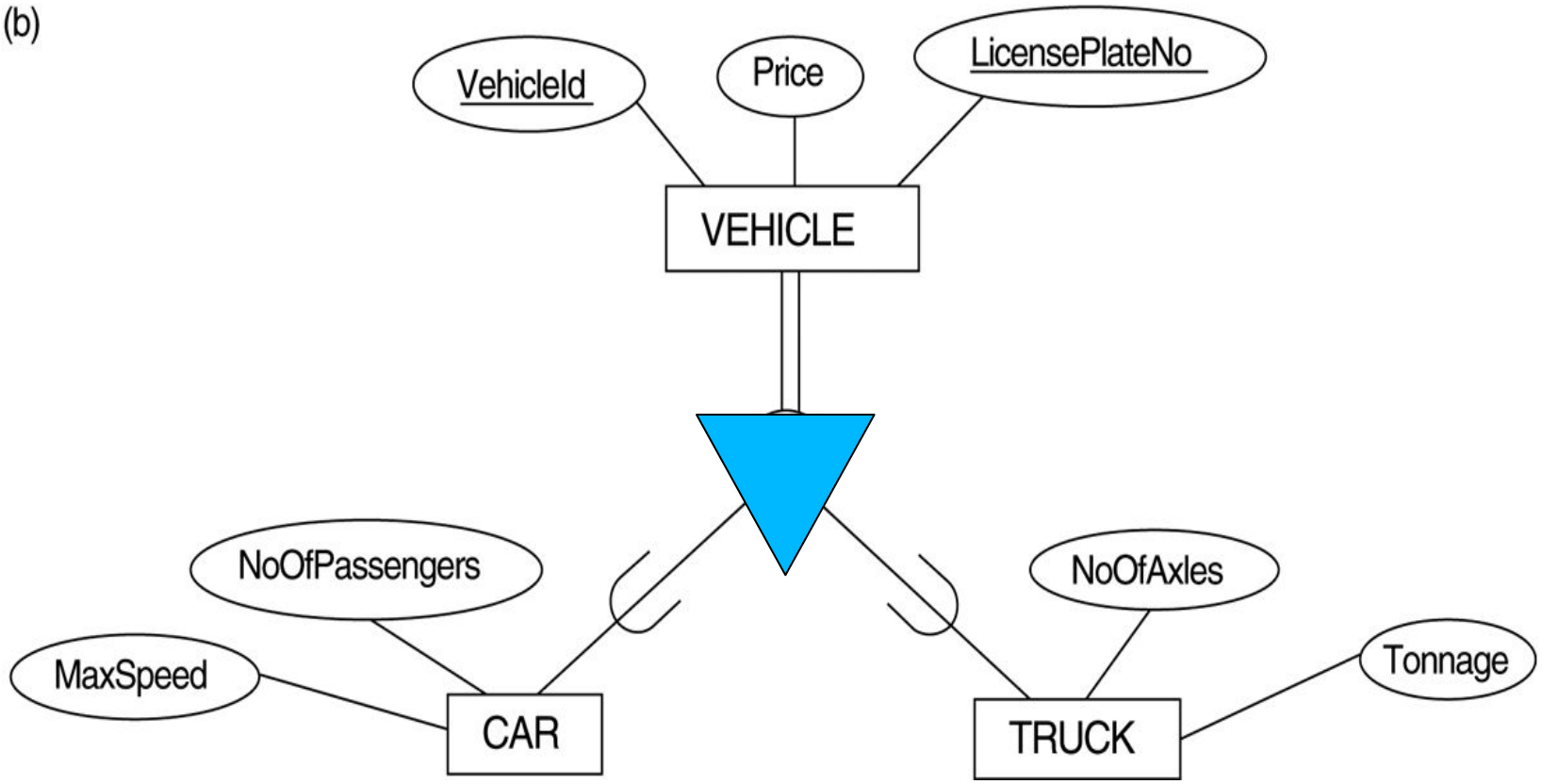
Example of a Specialization



Generalization

- 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

(b)


VehicleId
Price
LicensePlateNo
VEHICLE
NoOfPassengers
MaxSpeed
CAR
NoOfAxles
Tonnage
TRUCK

Generalization and Specialization

- Diagrammatic notation 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 in these situations
- Data Modeling with Specialization and Generalization
  - A superclass or subclass represents a set of entities
  - Shown in rectangles in EER diagrams (as are entity types)
  - Sometimes, all entity sets are simply called classes, whether they are entity types, superclasses, or subclasses

Constraints on Specialization and Generalization (1)

Condition defined : In condition-defined lower-level entity sets, membership is evaluated on the basis of whether or not an entity satisfies an explicit condition or predicate. For example, assume that the higher-level entity set Account is having attribute Account_type. Only those entities that satisfy the condition Account_type = "Savings account" are allowed to belong to the lower-level entity set 'Savings_account'. All entities that satisfy the condition Account_type = "checking account" are included in checking account.

Constraints on Specialization and Generalization (1)

User defined : These types of constraints are defined by user. For example, let us assume that, after 3 months of employment bank employees are assigned to one of four work teams. We therefore represent the teams as four lower-level entity sets of the higher-level Employee entity set. A given Employee is assigned to one of the four teams by incharge of the teams.

Constraints on Specialization and Generalization (1)

Disjoint : A *disjointness* constraint requires that an entity belong to only one lower-level entity set. For example, an Account entity may be either Saving_account or Checking_account. It satisfies just one condition at a time.

Overlapping : In overlapping generalization, the same entity may belong to more than one lower-level entity set within a single generalization.

Constraints on Specialization and Generalization (1)

A final constraint, is a **completeness constraint** on a generalization/specialization, which specifies whether or not an entity in the higher-level entity set must belong to at least one of the lower-level entity sets within the generalization/specialization. This constraint may be one of the following :

- **Total generalization or specialization :** Each higher-level entity must belong to a lower-level entity set.
- **Partial generalization or specialization :** Some higher-level entities may not belong to any lower-level entity set. Partial generalization is the default.

Constraints on Specialization and Generalization (1)

can specify total generalization in an E-R diagram by using a double line to connect the box representing the higher-level entity set to the triangle symbol.

For example : Employees are assigned to a team only ofter 3 months on the job. Some Employee entities may not be members of any of the lower-level team entity sets. We may charactize the team entity sets more fully as a partial, overlapping specialization of Employee.

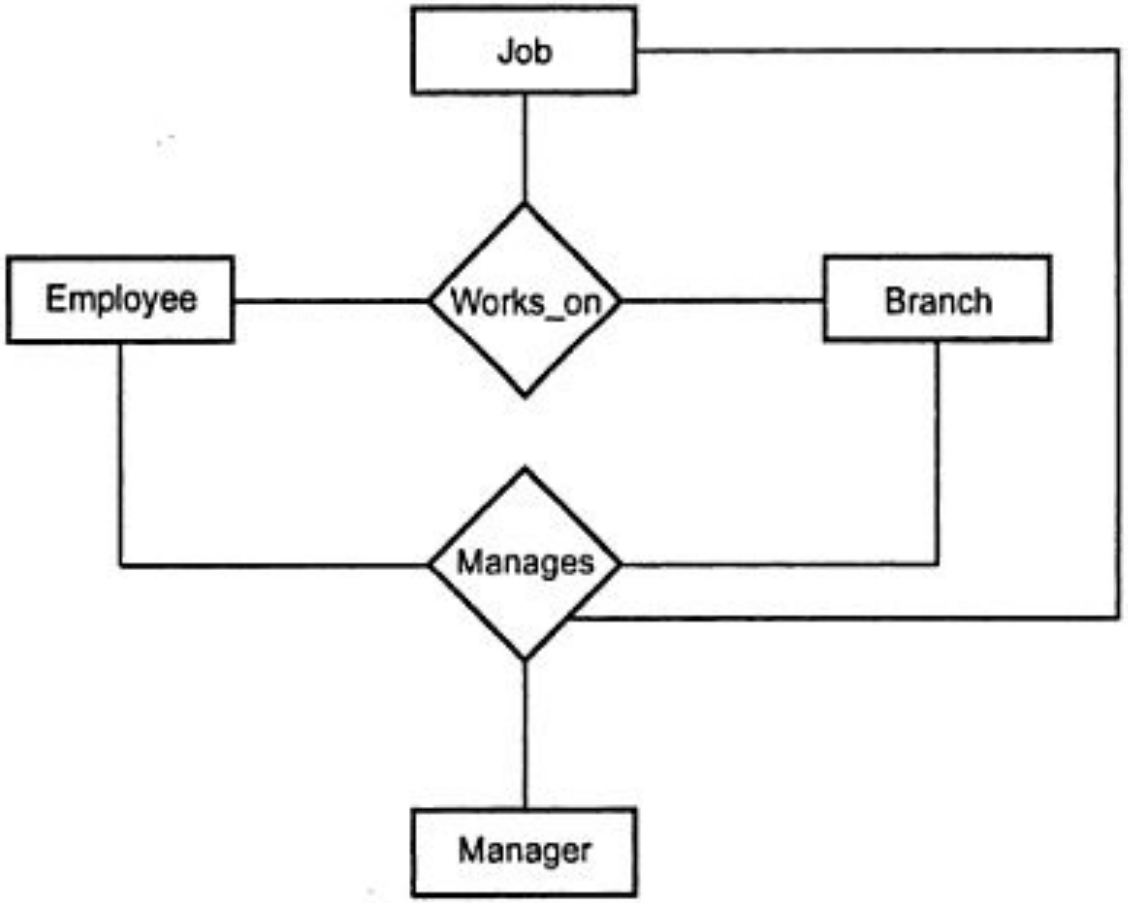
The generalization of Checking_account and Savings_account into Account is a total disjoint generalization.

Attribute Inheritance

"A crucial property of the higher and lower-level entities created by specialization and generalization is **attribute inheritance**".

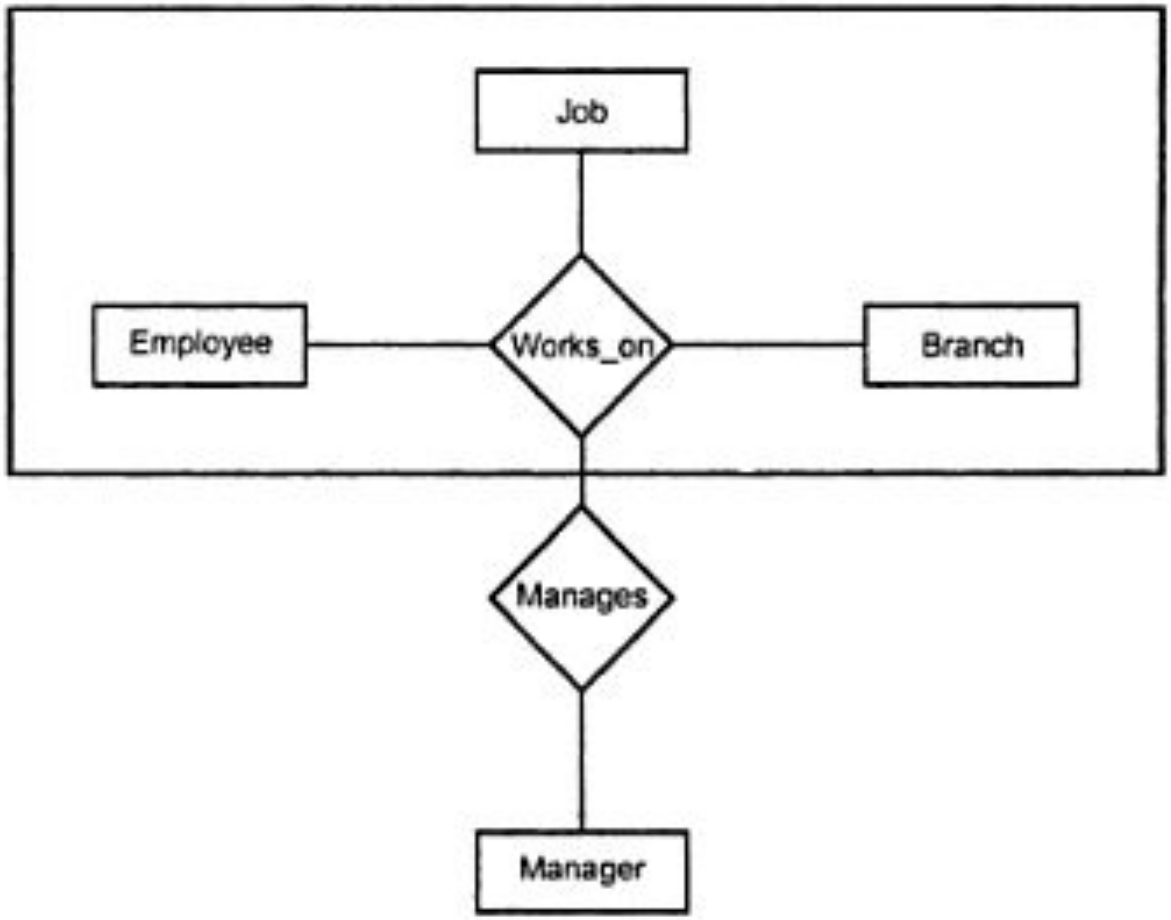
The attributes of the higher-level entity sets are said to be inherited by the lower-level entity sets. For example, Customer and Employee inherit the atributes of the Person. Thus, Customer is described by Name, Street, City and with additional attribute Customer_id. Similarly, Employee is described by Name, Street, City and additional attributes Employee_code and Salary.

Aggregation



E-R diagram with redundant relationships

Aggregation



E-R diagram with aggregation

Aggregation

The best way to model above situation is to use aggregation. **Aggregation** is an abstraction through which relationships are treated as higher-level entities. Thus, the relationship set Works_on relating the entity sets Employee, Branch and Job is considered as a higher_level entity set called Works_on. We can then create a binary relationship manges between Works_on and Manger to represent who manages what tasks.

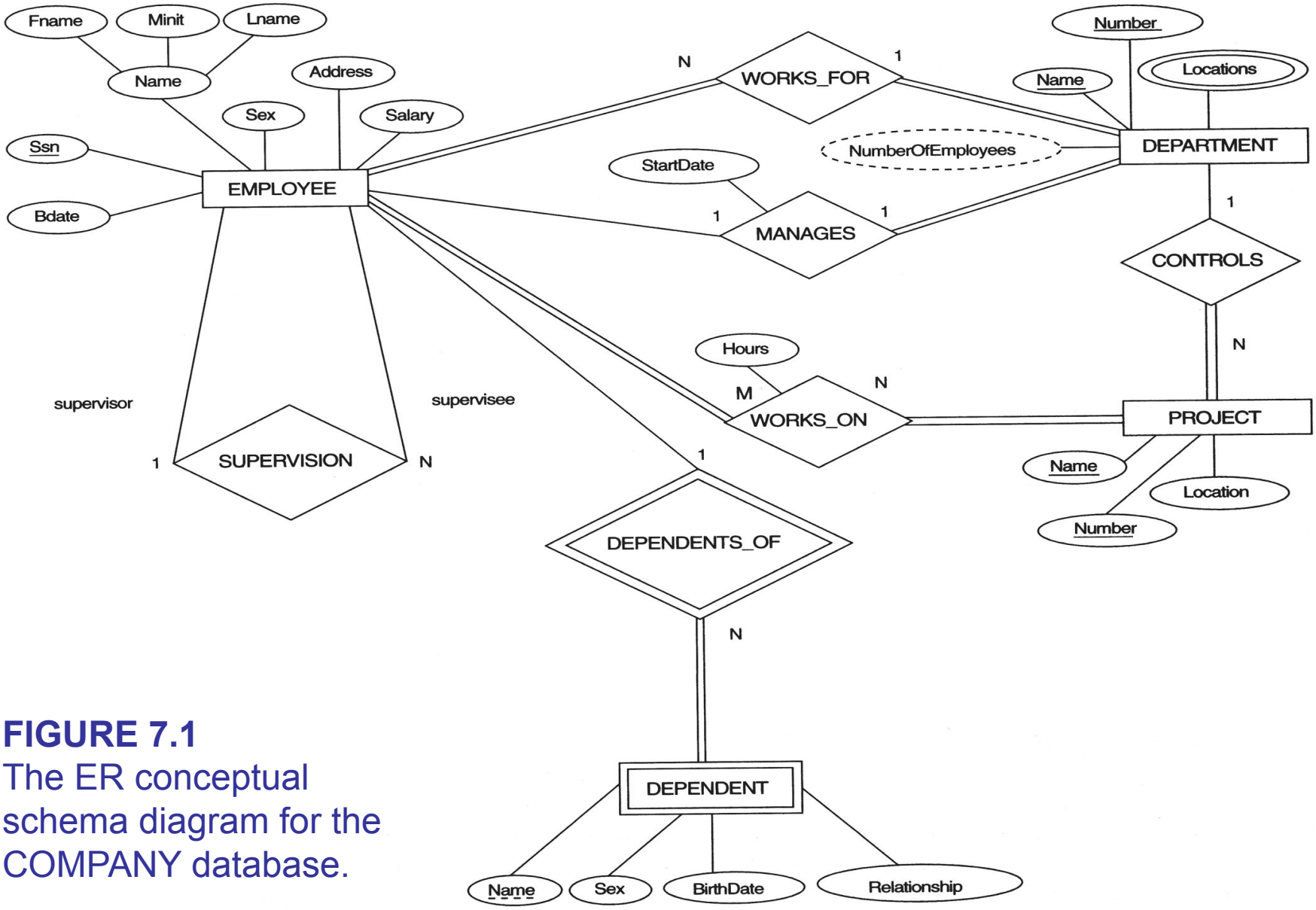
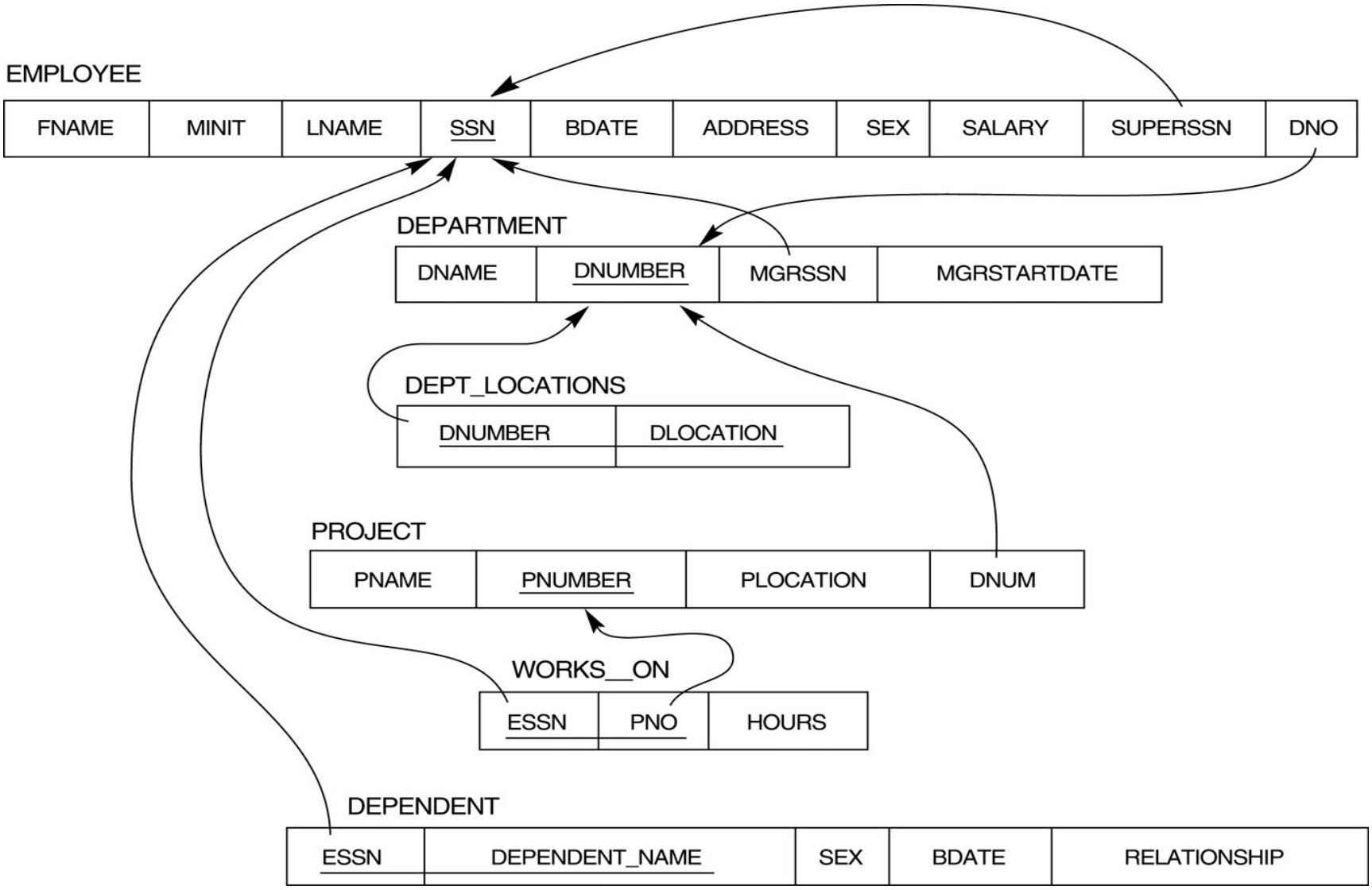


FIGURE 7.1
The ER conceptual schema diagram for the COMPANY database.

FIGURE 7.2

Result of mapping the COMPANY ER schema into a relational schema.



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
- 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

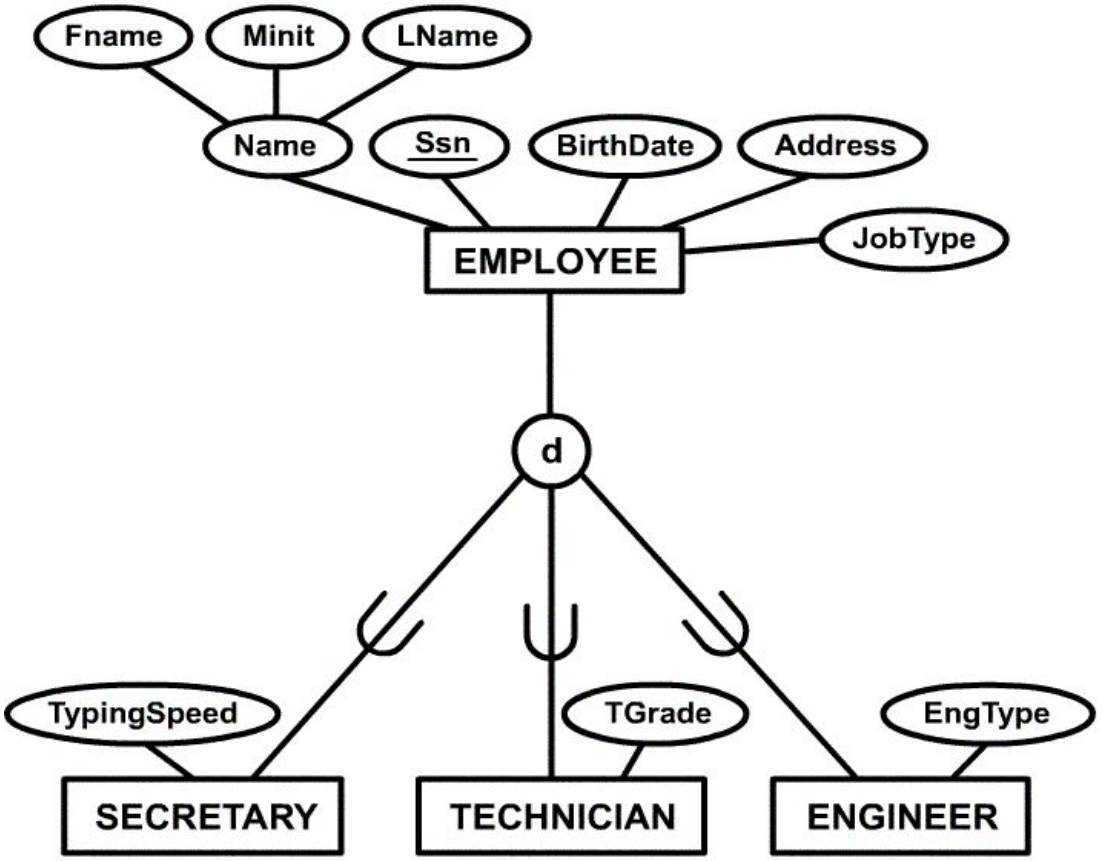
Constraints on Specialization and Generalization (2)

- Two other conditions apply to a specialization/generalization:
- **Disjointness Constraint**:
  - Specifies that the subclasses of the specialization must be disjointed (an entity can be a member of at most one of the subclasses of the specialization)
  - Specified by d in EER diagram
  - If not disjointed, overlap; that is the same entity may be a member of more than one subclass of the specialization
  - Specified by o in EER diagram
- **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 double line
  - Partial allows an entity not to belong to any of the subclasses
  - Shown in EER diagrams by a single line

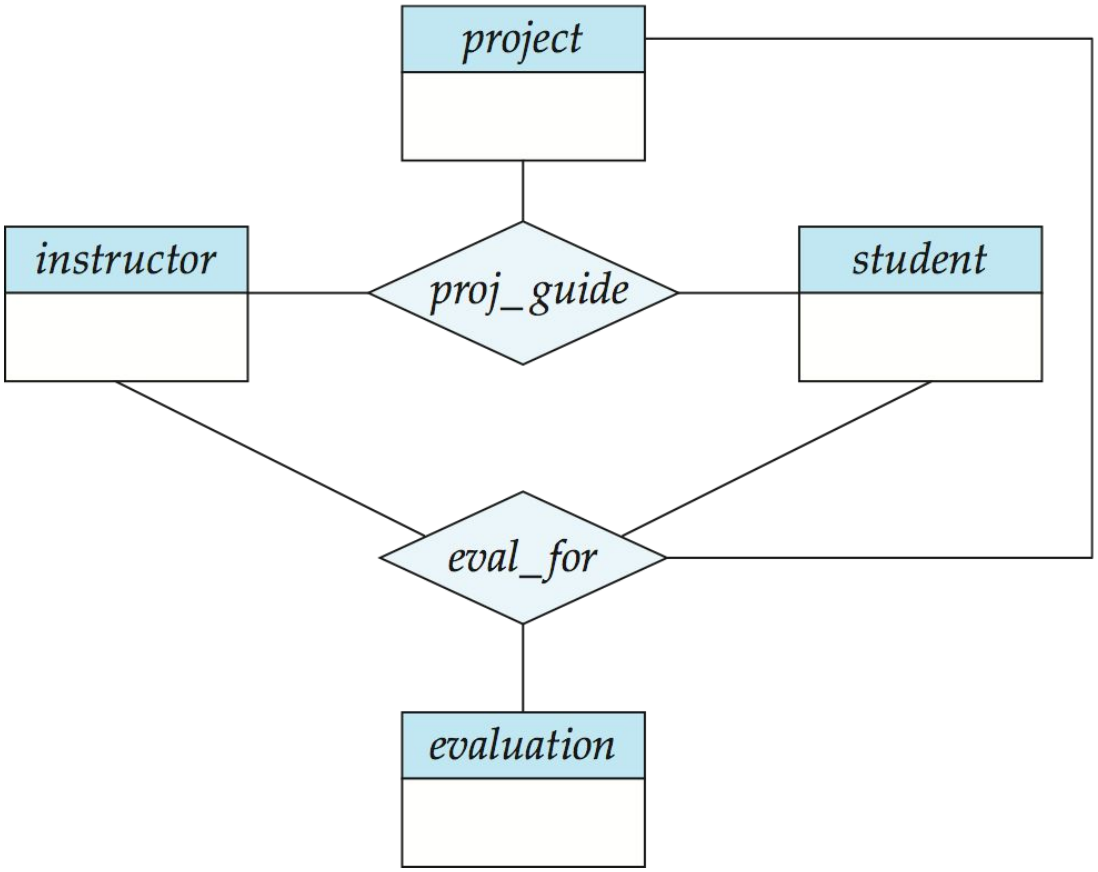
Constraints on Specialization and Generalization (3)

- 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



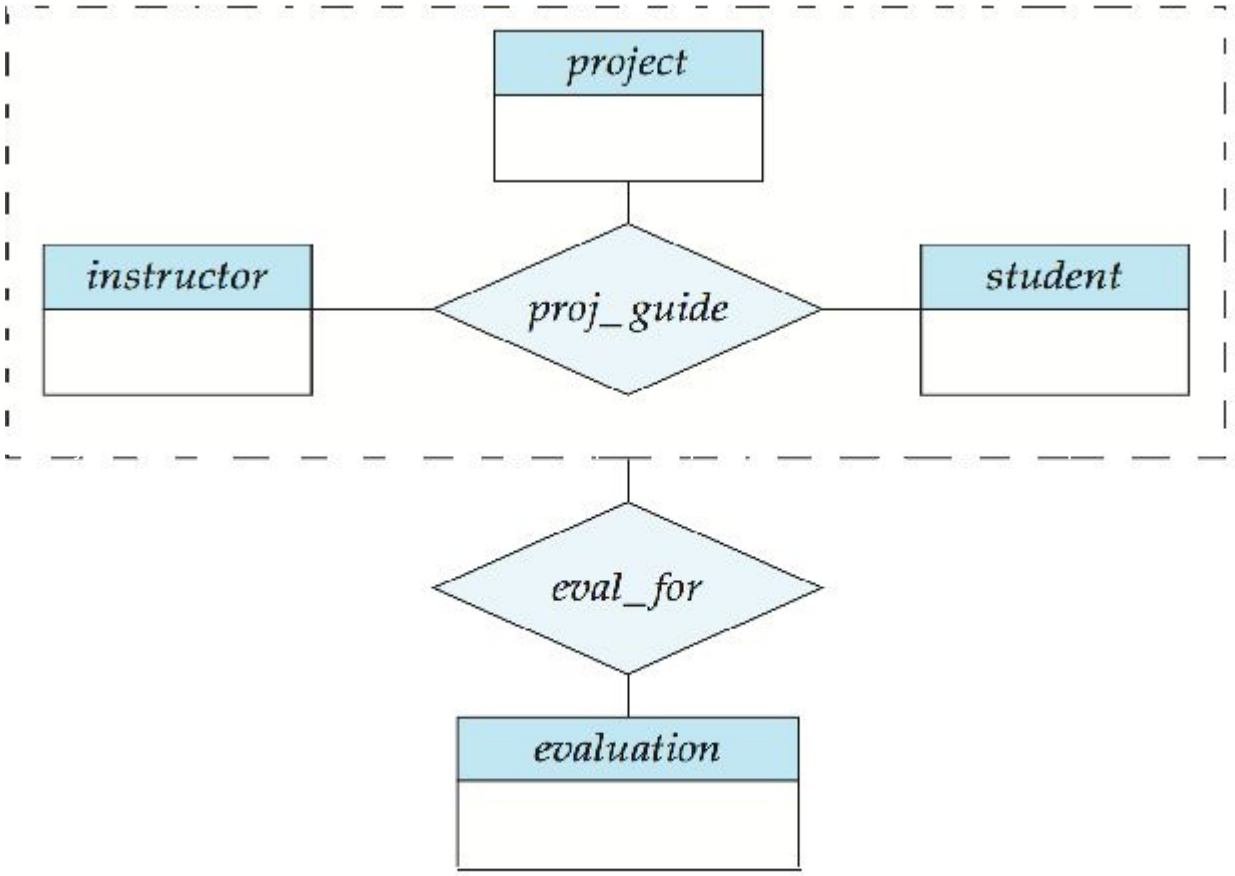
Motivation for Aggregation



Aggregation (Cont.)

- Aggregation is an important concept in database design where composite objects can be modelled during the design of database applications.
- Without introducing redundancy, the following diagram represents:
  - A student is guided by a particular instructor on a particular project
  - A student, instructor, project combination may have an associated evaluation

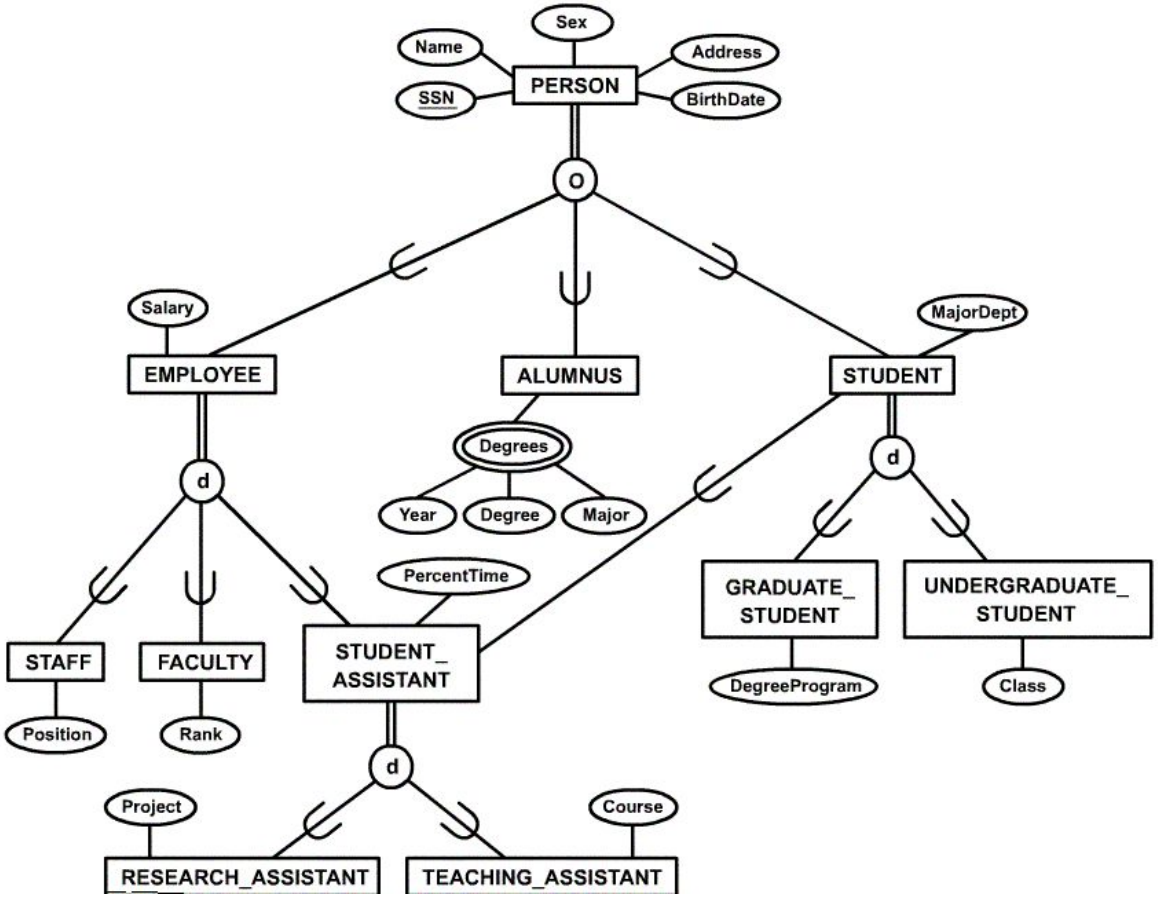
Aggregation - a feature of the entity relationship model that allows a relationship set to participate in another relationship set. This is indicated on an ER diagram by drawing a dashed box around the aggregation



Specialization / Generalization Hierarchies, Lattices and Shared Subclasses

- 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*)
- In a lattice, a subclass can be subclass of more than one superclass (called *multiple inheritance*)
- 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
- Can have specialization hierarchies or lattices, or generalization hierarchies or lattices
- In specialization, start with an entity type and then define subclasses of the entity type by successive specialization (top down conceptual refinement process)
- In generalization, start with many entity types and generalize those that have common properties (bottom up conceptual synthesis process)
- In practice, the combination of two processes is employed

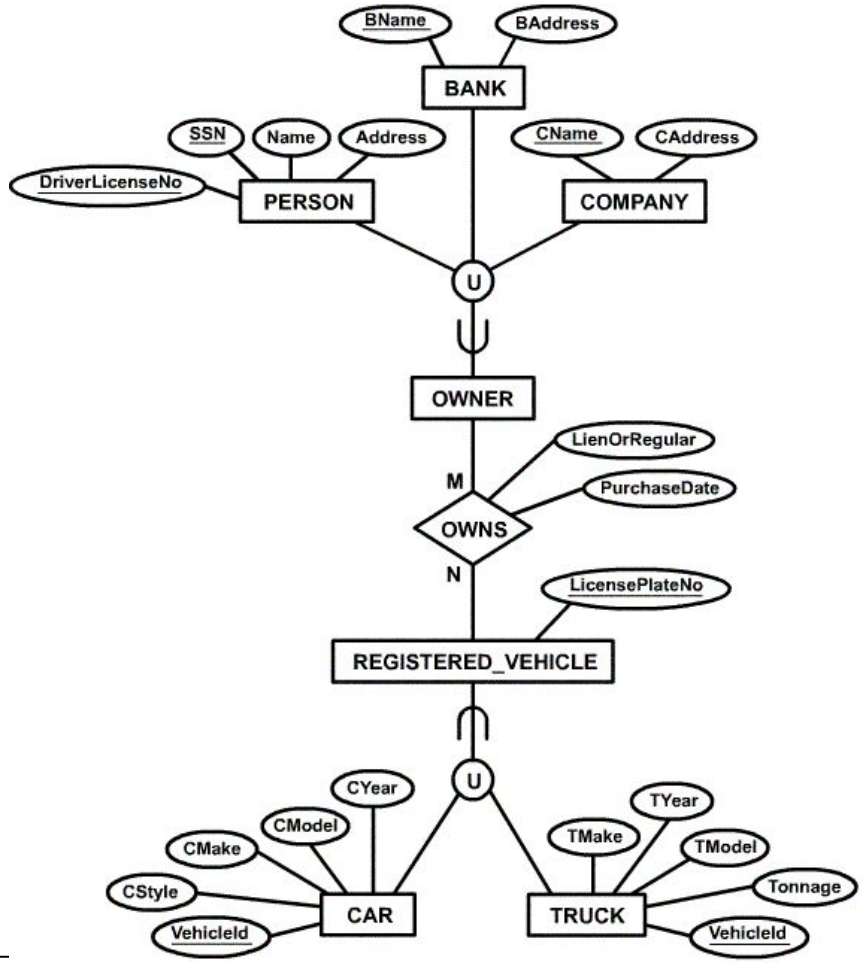
Specialization / Generalization Lattice Example (UNIVERSITY)



Categories (UNION TYPES)

- All of the superclass/subclass relationships we have seen thus far have a single superclass
- A shared subclass is subclass in more than one distinct superclass/subclass relationships, where each relationships has a single superclass (multiple inheritance)
- In some cases, need to model a single superclass/subclass relationship with more than one superclass
- Superclasses represent different entity types
- Such a subclass is called a category or UNION TYPE
- Example: Database for vehicle registration, vehicle owner can be a person, a bank (holding a lien on a vehicle) or a company.
  - Category (subclass) OWNER is 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
- Note: The difference from shared subclass, which is subset of the intersection of its superclasses (shared subclass member must exist in all of its superclasses).

Example of categories (UNION TYPES)



Formal Definitions of EER Model (1)

- Class C: A set of entities; could be entity type, subclass, superclass, category.
- Subclass S: A class whose entities must always be subset of the entities in another class, called the superclass C of the superclass/subclass (or IS-A) relationship S/C:

  $S \subseteq C$
- Specialization Z: Z = {S1, S2,…, Sn} a set of subclasses with same superclass G; hence, G/Si 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:

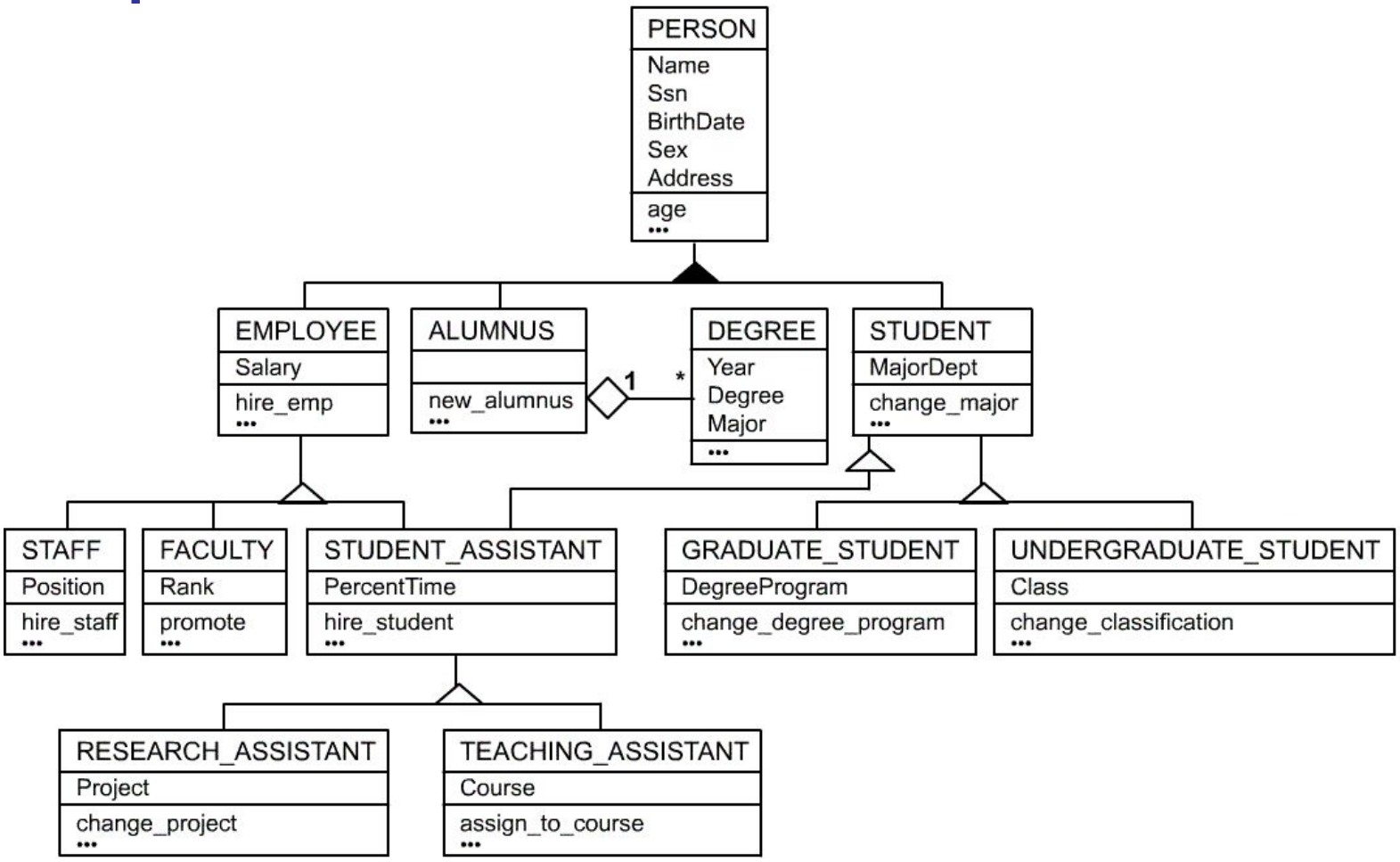
    $Si \cap S2$ empty-set for $i \neq j$;

    Otherwise, Z is overlapping.

Formal Definitions of EER Model (2)

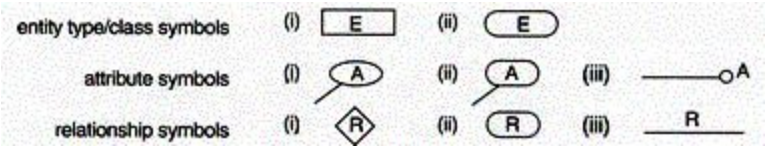
- Subclass S of C is predicate defined if predicate p on attributes of C is used to specify membership in S; that is, S = C[p], where C[p] is the set of entities in C that satisfy p
- A subclass not defined by a predicate is called user-defined
- Attribute-defined specialization: if a predicate A = ci (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.
- Category or UNION type T
  - A class that is a subset of the union of n defining superclasses D1, D2,…Dn, n>1:
    $T \subseteq (D1 \cup D2 \cup \ldots \cup Dn)$
    A predicate pi on the attributes of T.
  - If a predicate pi on the attributes of Di can specify entities of Di that are members of T.
  - If a predicate is specified on every Di: $T = (D1[p1] \cup D2[p2] \cup \ldots \cup Dn[pn]$
  - Note: The definition of relationship type should have 'entity type' replaced with 'class'.

UML Example for Displaying Specialization / Generalization

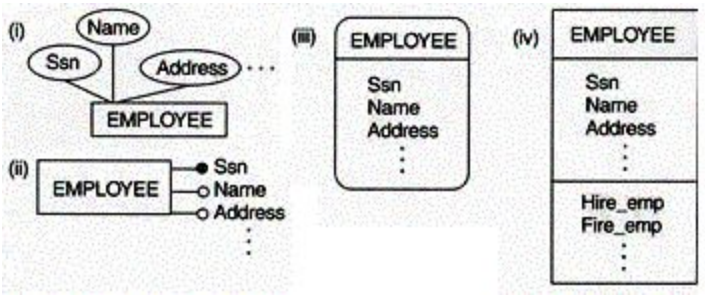


Alternative Diagrammatic Notations

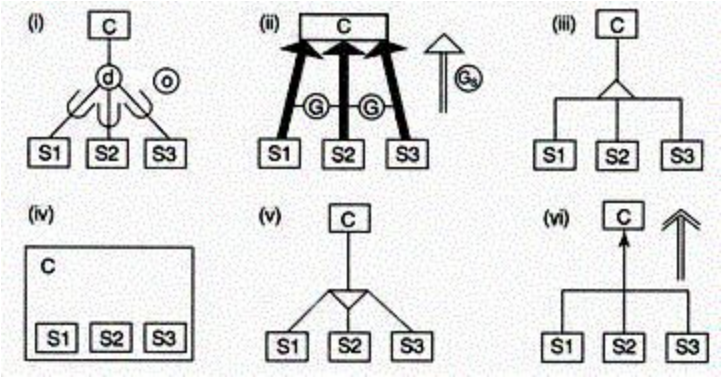
Symbols for entity type / class, attribute and relationship



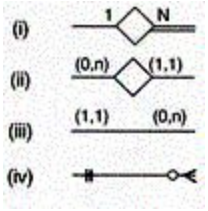
Displaying attributes



Notations for displaying specialization / generalization



Various (min, max) notations



Displaying cardinalitv ratios