Database Design I:
The Entity-Relationship Model

Chapter 5

Database Design

- Goal: specification of database schema
- Methodology:
  - Use *E-R model* to get a high-level graphical view of essential components of enterprise and how they are related
  - Convert E-R diagram to DDL
- *E-R Model*: enterprise viewed as set of
  - *Entities*
  - *Relationships* among entities

Entities

- *Entity*: an object that is involved in the enterprise
  - Ex: John, CSE305
- *Entity Type*: set of similar objects
  - Ex: students, courses
- *Attribute*: describes one aspect of an entity type
  - Ex: name, maximum enrollment

Entity Type

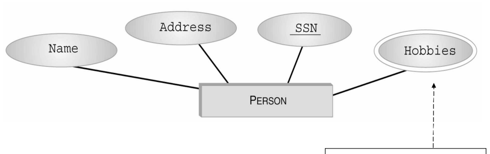
- Entity type described by set of attributes
  - Student: *Id*, *Name*, *Address*, *Hobbies*
- *Domain*: possible values of an attribute
  - Value can be a set (in contrast to relational model)
    - (111111, John, 123 Main St, (stamps, coins))
- *Key*: minimum set of attributes that uniquely identifies an entity (candidate key)
- *Entity Schema*: entity type name, attributes (and associated domain), key constraints

Representation in Relational Model

- Entity type corresponds to a relation
- Relation's attributes = entity type's attributes
  - *Problem*: entity type can have set valued attributes.
  - *Solution*: Use several rows to represent a single entity
    - (111111, John, 123 Main St, stamps)
    - (111111, John, 123 Main St, coins)
  - Problems with solution:
    - Redundancy
    - Key of entity type not key of relation
    - => resulting relation must be further transformed

Entity Type (con't)

- Graphical Representation in E-R diagram:



Set-valued attribute

Relationship

- Relationship: relates two or more entities
  - John *majors in* Computer Science
- Relationship Type: set of similar relationships
  - Student (entity type) related to Department (entity type) by MajorsIn (relationship type).
- Distinction:
  - *relation* (relational model) - set of tuples
  - *relationship* (E-R Model) – describes relationship between entities of an enterprise
  - Both entity types and relationship types (E-R model) can be represented as relations (relational model)

Attributes and Roles

- *Attribute* of a relationship type describes the relationship
  - e.g., John majors in CS *since* 2000
    - John and CS are related
    - 2000 describes relationship - value of SINCE attribute of MajorsIn relationship type
- *Role* of a relationship type names one of the related entities
  - e.g., John is value of *Student* role, CS value of *Department* role of MajorsIn relationship type
  - (John, CS, 2000) describes a relationship

Relationship Type

- Described by set of attributes and roles
  - e.g., MajorsIn: *Student*, *Department*, *Since*
  - Here we have used as the role name (*Student*) the name of the entity type (Student) of the participant in the relationship, but ...

Roles

- *Problem*: relationship can relate elements of same entity type
  - e.g., *ReportsTo* relationship type relates two elements of Employee entity type:
    - Bob reports to Mary since 2000
  - We do not have distinct names for the roles
  - It is not clear who reports to whom

Roles (con't)

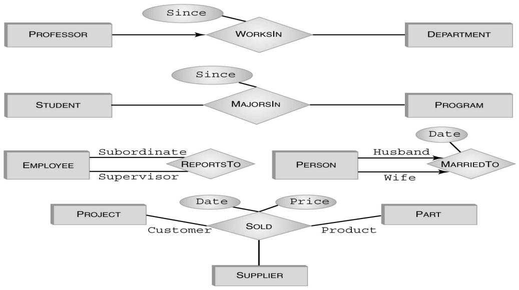
- *Solution*: role name of relationship type need not be same as name of entity type from which participants are drawn
  - ReportsTo has roles *Subordinate* and *Supervisor* and attribute *Since*
  - Values of *Subordinate* and *Supervisor* both drawn from entity type Employee

Schema of a Relationship Type

- *Role names*, R_i, and their corresponding entity sets. Roles must be single valued (number of roles = degree)
- *Attribute names*, A_j, and their corresponding domains. Attributes may be set valued
- *Key*: Minimum set of roles and attributes that uniquely identify a relationship
- *Relationship*: $<e_1, \ldots e_n; a_1, \ldots a_k>$
  - e_i is an entity, a value from R_i's entity set
  - a_j is a set of attribute values with elements from domain of A_j

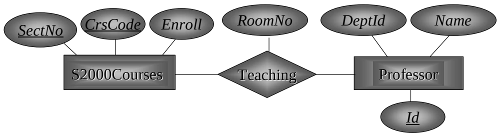
Graphical Representation

- Roles are edges labeled with role names (omitted if role name = name of entity set). Most attributes have been omitted.



Representation of Relationship Type in Relational Model

- Attributes of corresponding relation are
  - Attributes of relationship type
  - For each role, the primary key of the entity type associated with that role
- *Example*:



- S2000Courses (<u>*CrsCode*</u>, <u>*SectNo*</u>, *Enroll*)
- Professor (<u>*Id*,</u> *DeptId*, *Name*)
- Teaching (<u>*CrsCode*</u>, <u>*SecNo*</u>, *Id*, *RoomNo*)

Representation in Relational Model

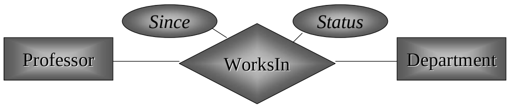
- Candidate key of corresponding table = candidate key of relation
  - Except when there are set valued attributes
  - Example: Teaching (*CrsCode*, *SectNo*, *Id*, *RoomNo*, *TA*)
    - Key of relationship type = (*CrsCode*, *SectNo*)
    - Key of relation = (*CrsCode*, *SectNo*, *TA*)

CrsCode	*SectNo*	*Id*	*RoomNo*	*TA*
CSE305	1 22	1234	Hum	Joe
CSE305	1 22	1234	Hum	Mary

Representation in SQL

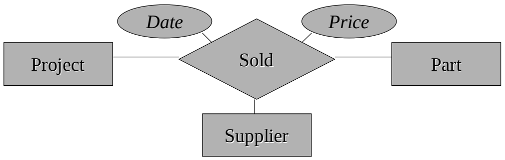
- Each role of relationship type produces a foreign key in corresponding relation
  - Foreign key references table corresponding to entity type from which role values are drawn

Example 1



```
CREATE TABLE WorksIn  (
   Since DATE,                -- attribute
   Status  CHAR (10),        -- attribute
   ProfId  INTEGER,          -- role (key of  Professor)
   DeptId  CHAR (4),          -- role (key of  Department)
   PRIMARY KEY (ProfId),  -- since a professor works in at most one department
   FOREIGN KEY (ProfId) REFERENCES Professor (Id),
   FOREIGN KEY (DeptId) REFERENCES Department )
```

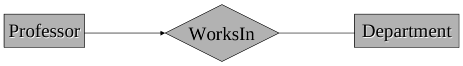
Example 2



```
CREATE TABLE  Sold  (
   Price  INTEGER,               -- attribute
   Date  DATE,                   -- attribute
   ProjId  INTEGER,              -- role
   SupplierId  INTEGER,         -- role
   PartNumber  INTEGER,        -- role
   PRIMARY KEY (ProjId, SupplierId, PartNumber, Date),
   FOREIGN KEY (ProjId) REFERENCES Project,
   FOREIGN KEY (SupplierId) REFERENCES Supplier (Id),
   FOREIGN KEY (PartNumber) REFERENCES Part (Number)  )
```

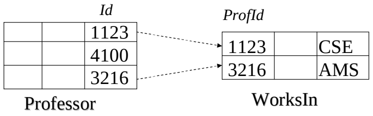
Key Constraint (special case)

- If, for a particular participant entity type, each entity participates in *at most* one relationship, corresponding role is a key of relationship type
  - E.g., *Professor* role is unique in WorksIn
- Representation in E-R diagram: arrow



Key Constraint (special case)

- *Relational model representation*: key of relation corresponding to entity type is key of relation corresponding to relationship type
  - *Id* is primary key of Professor; *ProfId* is key of WorksIn. Professor 4100 does not participate.
  - Cannot use foreign key in Professor since some professors do not participate



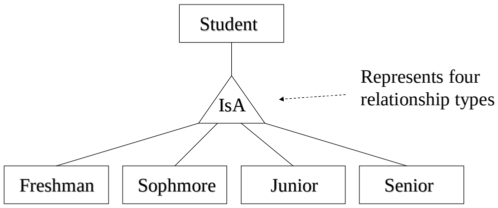
		Id
		1123
		4100
		3216

ProfId		
1123		CSE
3216		AMS

Entity Type Hierarchies

- One entity type might be subtype of another
  - Freshman is a subtype of Student
- A relationship exists between a Freshman entity and the corresponding Student entity
  - e.g., Freshman John is related to Student John
- This relationship is called *IsA*
  - Freshman IsA Student
  - The two entities related by IsA are always descriptions of the same real-world object

IsA



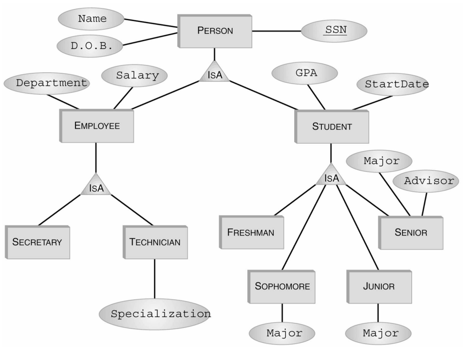
Properties of IsA

- *Inheritance* - Attributes of supertype apply to subtype.
  - E.g., *GPA* attribute of Student applies to Freshman
  - Subtype *inherits* all attributes of supertype.
  - Key of supertype is key of subtype
- *Transitivity* - Hierarchy of IsA
  - Student is subtype of Person, Freshman is subtype of Student, so Freshman is also a subtype of Student

IsA

- *Advantage*: Used to create a more concise and readable E-R diagram
  - Attributes common to different entity sets need not be repeated
  - They can be grouped in one place as attributes of supertype
  - Attributes of (sibling) subtypes can be different

IsA Hierarchy - Example



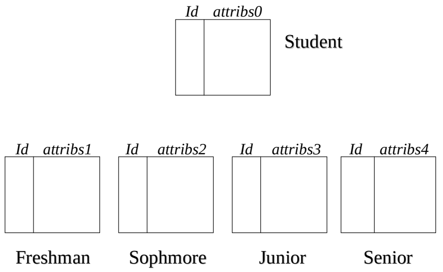
Type Hierarchy

- Might have associated constraints:
  - *Covering constraint*: Union of subtype entities is equal to set of supertype entities
    - Employee is either a secretary or a technician (or both)
  - *Disjointness constraint*: Sets of subtype entities are disjoint from one another
    - Freshman, Sophomore, Junior, Senior are disjoint sets
- Might be related to fragmentation of data

Type Hierarchies and Relational Model

- Supertypes and subtypes can be realized as separate relations
  - Need a way of identifying subtype entity with its (unique) related supertype entity
    - *Choose a candidate key and make it an attribute of all entity types in hierarchy*

Type Hierarchies and Relational Model



Id attribs0

Student

Id attribs1 *Id attribs2* *Id attribs3* *Id attribs4*

Freshman Sophmore Junior Senior

Type Hierarchies and Relational Model

- Redundancy eliminated if IsA is not disjoint
  - For individuals who are both employees and students, Name and DOB are stored once

Person

SSN	*Name*	*DOB*
1234	Mary	1950

Employee

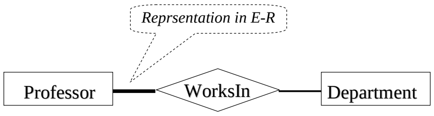
SSN	*Department*	*Salary*
1234	Accounting	35000

Student

SSN	*GPA*	*StartDate*
1234	3.5	1997

Participation Constraint

- If every entity participates in *at least* one relationship, a *participation constraint* holds:
  - A participation constraint of entity type E having role ρ in relationship type R states that for *e* in E there is an *r* in R such that ρ(*r*) = *e*.
  - e.g., every professor works in *at least* one department



Reprsentation in E-R

Professor WorksIn Department

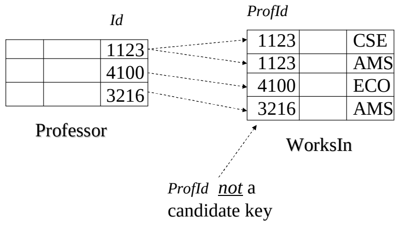
Representing Participation Constraints

- *Inclusion dependency*: Every professor works in *at least* one dep't.
  - in relational model: (easy)
    - Professor (*Id*) references WorksIn (*ProfId*)
  - in SQL:
    - Special case: Every professor works in *exactly one* dep't. (easy)
      - FOREIGN KEY *Id* REFERENCES WorksIn (*ProfId*)
    - General case (not so easy):

```
CREATE ASSERTION  ProfsInDepts
   CHECK ( NOT EXISTS (
     SELECT  *  FROM  Professor P
     WHERE NOT EXISTS (
        SELECT  *  FROM  WorksIn W
        WHERE   P.Id = W.ProfId ) ) )
```

Participation Constraint in Relational Model

- Example (can't use foreign key in Professor)



		Id
		1123
		4100
		3216

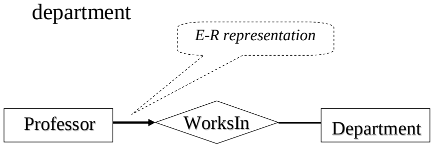
Professor

ProfId		
1123		CSE
1123		AMS
4100		ECO
3216		AMS

WorksIn

Participation *and* Key Constraint

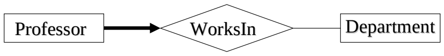
- If every entity participates in *exactly* one relationship, both a participation and a key constraint hold:
  - e.g., every professor works in *exactly one* department



Participation *and* Key Constraint in SQL

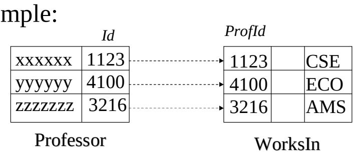
- If both participation and key constraints apply, use foreign key constraint in entity table (but beware: if candidate key in entity table is not primary, presence of nulls violates participation constraint).

```
CREATE TABLE Professor  (
   Id   INTEGER,
      ……
   PRIMARY KEY (Id),      -- Id can't be null
   FOREIGN KEY (Id) REFERENCES WorksIn  (ProfId)
                                  --all professors participate
)
```



Participation *and* Key Constraint in Relational Model

- Example:



	Id
xxxxxx	1123
yyyyyy	4100
zzzzzzz	3216

Professor

ProfId		
1123		CSE
4100		ECO
3216		AMS

WorksIn

Participation *and* Key Constraint in Relational Model (again)

- Alternate solution if both key and participation constraints apply: merge the tables representing the entity and relationship sets
  - Since there is a 1-1 and onto relationship between the rows of the entity set and the relationship sets, might as well put all the attributes in one table

Participation *and* Key Constraint in Relational Model

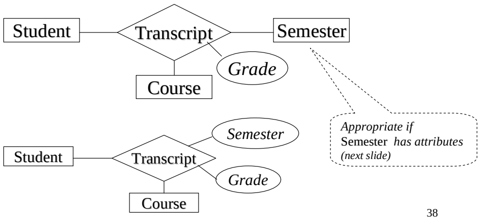
- Example

xxxxxxx	1123		CSE
yyyyyyy	4100		ECO
zzzzzzzz	3216		AMS

Prof_WorksIn

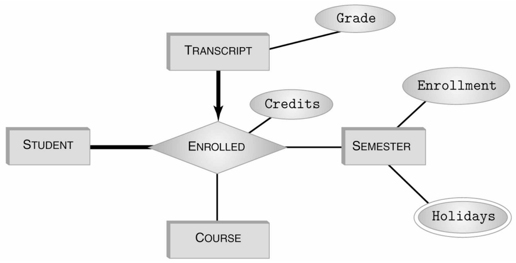
Entity or Attribute?

- Sometimes information can be represented as either an entity or an attribute.



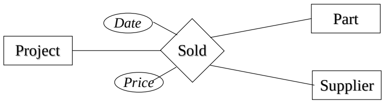
Appropriate if Semester *has attributes (next slide)*

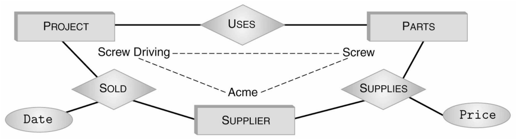
Entity or Relationship?



(Non-) Equivalence of Diagrams

- Transformations between binary and ternary relationships.





E-R and Object Databases

- Object databases allow set-valued: translation from E-R diagram into ODB is easier.
- IsA relationship can be directly represented in ODB.