The Relational Model 2

Week 3

We have seen how to create a database schema, how do we create an actual database on our computers?

professor(<u>*PID*</u> : string, *name* : string)
course(<u>*PID*</u> : string, *number* : string, <u>*name*</u> : string)
teaches(<u>*PID*</u> : string, *days* : string)

…how do we create an actual database on our computers?

We use SQL, a language that allows us to build, modify and query databases.

professor(<u>*PID*</u> : string, *name* : string)

```
SQL> CREATE TABLE Professor
  2    (pid CHAR(9),
  3     name CHAR(50),
  4     PRIMARY KEY(pid));

Table created.
```

SQL (Structured Query Language)

- SQL is a language that allows us to build, modify and query databases.
- SQL is an ANSI standard language. American National Standards Institute
- SQL is the "engine" behind Oracle, Microsoft SQL Server, etc.
- Most of these systems have built GUIs on top of the command line interface, so you don't normally write statements directly in SQL (although you can).

Creating Relations in SQL

- Creates a Students relation. Observe that the type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.

```
CREATE TABLE Students
        (sid CHAR(20),
         name CHAR(20),
         login CHAR(10),
         age INTEGER,
         gpa REAL);
```

- As another example, the Enrolled table holds information about courses that students take.

```
CREATE TABLE Enrolled
        (sid CHAR(20),
         cid CHAR(20),
         grade CHAR(2));
```

Creating Domains

- Say you want to restrict the values of GPA (0 < GPA <= 4.0)

- Approach 1: Specify constraint when defining the table

```
CREATE TABLE Students
        (sid CHAR(20),
         name CHAR(20),
         login CHAR(10),
         age INTEGER,
         gpa REAL check(gpa <= 4.0 AND gpa > 0) );
```

Creating Domains

- Approach 2: After CREATING TABLE, use ALTER TABLE

```
CREATE TABLE Students
        (sid CHAR(20),
         name CHAR(20),
         login CHAR(10),
         age INTEGER,
         gpa REAL);

ALTER TABLE Students
ADD CONSTRAINT check_gpa CHECK(gpa > 0 AND gpa <= 4.0);
```

To specify a set of allowed values, do something like this (using either approach):

… CHECK(gender='M' OR gender='F')

Getting Info About Existing Tables

To get the list of existing tables in your database:

```
SELECT table_name
FROM user_tables;
```

or

```
SELECT table_name
FROM all_tables
WHERE owner='YOUR_ACCOUNT_NAME_IN_UPPER_CASE';
```

To get more about an existing table, say, Students:

```
Describe Students;
```

Adding and Deleting Tuples

- Can insert a single tuple using:

```
INSERT INTO Students (sid, name, login, age, gpa)
VALUES (53688, ‘Smith’, ‘smith@ee’, 18, 3.2);
```

- Can delete all tuples satisfying some condition (e.g., name = Smith):

```
DELETE
FROM Students
WHERE name = ‘Smith’;
```

The SQL Query Language

- To find all 18 year old students, we can write:

```
SELECT *
FROM Students S
WHERE S.age=18;
```

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

- To show just names and logins columns, replace the first line with:

```
SELECT S.name, S.login
```

Querying Multiple Relations

- What does this query compute?

```
SELECT  S.name, E.cid
FROM  Students S, Enrolled E
WHERE  S.sid=E.sid AND E.grade='A';
```

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

Enrolled

sid	cid	grade
53831	Carnatic101	C
53831	Reggae203	B
53650	Topology112	A
53666	History105	B

we get:

S.name	E.cid
Smith	Topology112

Destroying and Altering Relations

- Destroys the relation Students. The schema information *and* the tuples are deleted.

```
DROP TABLE  Students;
```

- The schema of Students is altered by adding a new field; every tuple in the current instance is extended with a *null* value in the new field.

```
ALTER TABLE  Students
ADD COLUMN firstYear integer;
```

Integrity Constraints (ICs)

- IC: condition that must be true for *any* instance of the database; e.g., *domain constraints.*
  - ICs are specified when schema is defined.
  - ICs are checked when relations are modified.
- A *legal* instance of a relation is one that satisfies all specified ICs.
  - DBMS should not allow illegal instances.
- If the DBMS checks ICs, stored data is more faithful to real-world meaning.
  - Avoids data entry errors, too!

Primary Key Constraints Revisited

- A set of fields is a *key* for a relation if :
  1. No two distinct tuples can have same values in all key fields, and
  2. no subset of the key is also a key.
  - Otherwise, it's a *superkey*.
  - If there is >1 key for a relation, one of the keys is chosen (by DBA) to be the *primary key*.
- e.g., *sid* is a key for Students. (What about *name*?) The set {*sid, gpa*} is a superkey.

Primary and Candidate Keys in SQL

- Possibly many *candidate keys* (specified using UNIQUE), one of which is chosen as the *primary key*.
- What's the difference between the two statements below?

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid  CHAR(20),
   grade CHAR(2),
   PRIMARY KEY  (sid,cid) );
```

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid  CHAR(20),
   grade CHAR(2),
   PRIMARY KEY  (sid),
   UNIQUE (cid, grade) );
```

Used carelessly, an IC can prevent the storage of database instances that arise in practice!

Foreign Keys, Referential Integrity

- *Foreign key* : Set of fields in one relation that is used to `refer' to a tuple in another relation. (Must correspond to primary key of the second relation.) Like a `logical pointer'.
- e.g. *sid* is a foreign key referring to Students:
  - Enrolled(*sid*: string, *cid*: string, *grade*: string)
  - If all foreign key constraints are enforced, *referential integrity* is achieved, i.e., no dangling references.
  - Can you name a data model w/o referential integrity?
    - Links in HTML!

artist_id	artist_name
1	Bono
2	Cher
3	Nuno Bettencourt

Link Broken

artist_id	album_id	album_name
3	1	Schizophonic
4	2	Eat the rich
3	3	Crave (single)

Foreign Keys in SQL

- Only students listed in the Students relation should be allowed to enroll for courses.

```
CREATE TABLE Enrolled
  (sid CHAR(20),  cid CHAR(20),  grade CHAR(2),
   PRIMARY KEY  (sid,cid),
   FOREIGN KEY (sid) REFERENCES Students);
```

Enrolled

sid	cid	grade
53666	Carnatic101	C
53666	Reggae203	B
53650	Topology112	A
53666	History105	B

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

Enforcing Referential Integrity

- Consider Students and Enrolled; *sid* in Enrolled is a foreign key that references Students.
- What should be done if an Enrolled tuple with a non-existent student id is inserted? (*Reject it!*)
- What should be done if a Students tuple is deleted?
  - Also delete all Enrolled tuples that refer to it.
  - Disallow deletion of a Students tuple that is referred to.
  - Set sid in Enrolled tuples that refer to it to a *default sid*.
  - (In SQL, also: Set sid in Enrolled tuples that refer to it to a special value *null*, denoting `*unknown*' or `*inapplicable*'.)
- Similar if primary key of Students tuple is updated.

Referential Integrity in SQL

- SQL/92 and SQL:1999 support all 4 options on deletes and updates.
  - Default is NO ACTION (*delete/update is rejected*)
  - CASCADE (also delete all tuples that refer to deleted tuple)
  - SET NULL / SET DEFAULT (sets foreign key value of referencing tuple)

```
CREATE TABLE Enrolled
  (sid CHAR(20),
   cid CHAR(20),
   grade CHAR(2),
   PRIMARY KEY (sid,cid),
   FOREIGN KEY (sid)
     REFERENCES Students
        ON DELETE CASCADE
        ON UPDATE SET DEFAULT )
```

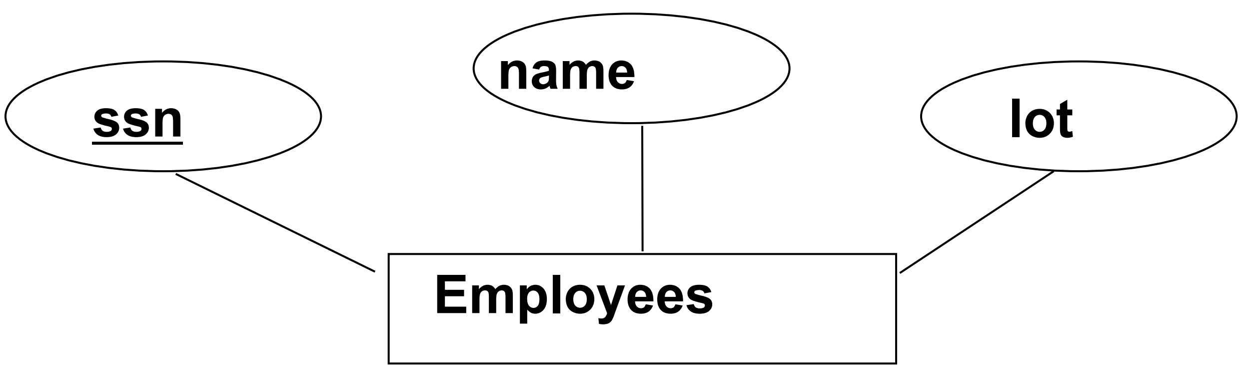
Where do ICs Come From?

- ICs are based upon the semantics of the real-world enterprise that is being described in the database relations.
- We can check a database instance to see if an IC is violated, but we can NEVER infer that an IC is true by looking at an instance.
  - An IC is a statement about *all possible* instances!
  - From example, we know *name* is not a key, but the assertion that *sid* is a key is given to us.
- Key and foreign key ICs are the most common; more general ICs supported too.

Logical DB Design: ER to Relational

- Entity sets to tables:

```
CREATE TABLE Employees
    (ssn CHAR(11),
    name CHAR(20),
    lot  INTEGER,
    PRIMARY KEY  (ssn));
```



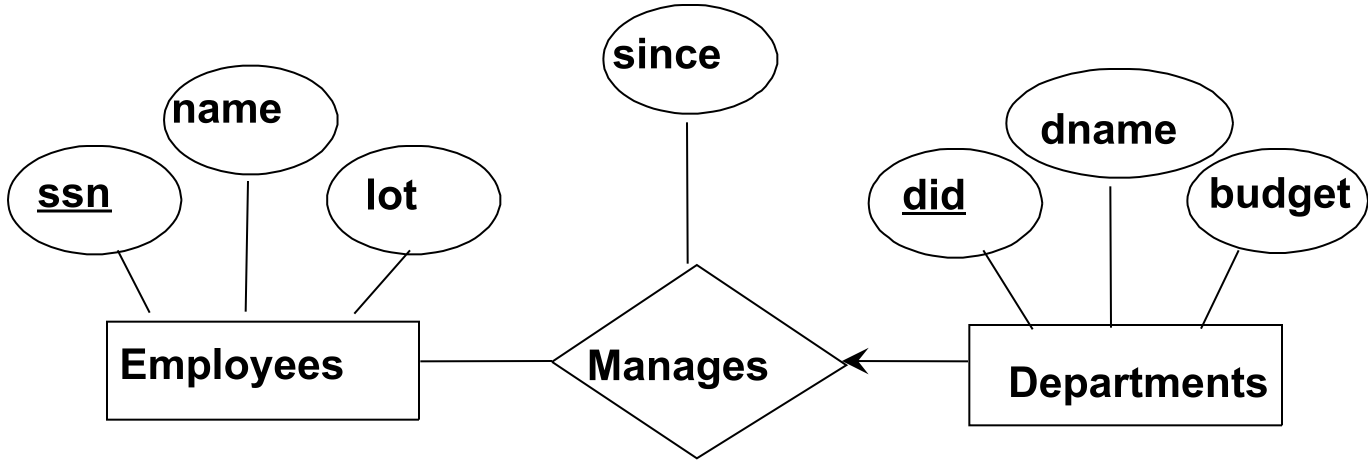
Relationship Sets to Tables

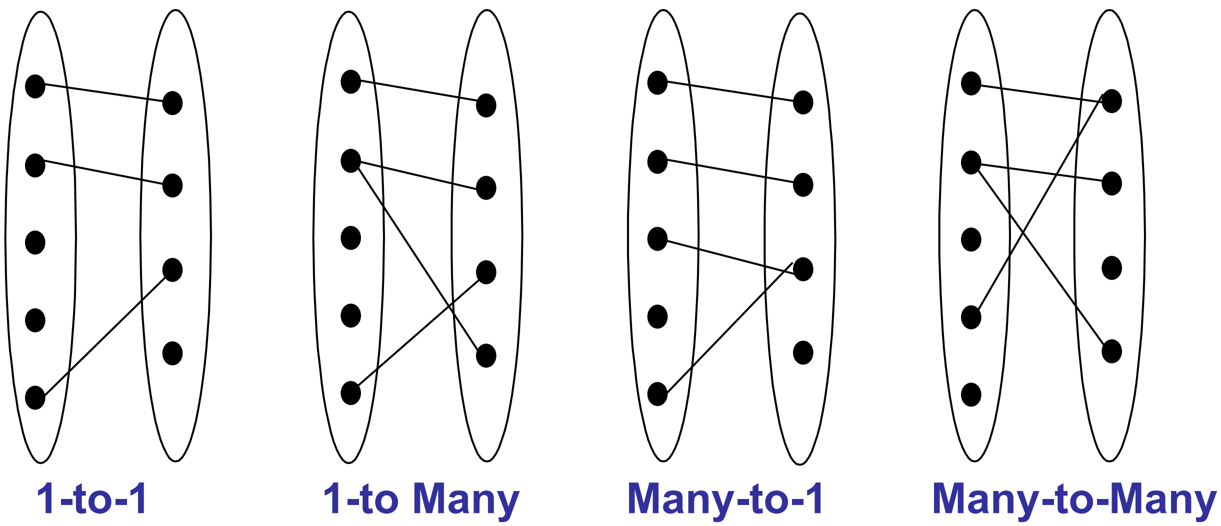
- In translating a relationship set to a relation, attributes of the relation must include:
  - Keys for the participating entity set(s) as foreign keys
    - This set of attributes forms a *superkey* for the relation.
  - All descriptive attributes.

```
CREATE TABLE Works_In(
  ssn  CHAR(11),
  did  INTEGER,
  since  DATE,
  PRIMARY KEY (ssn, did),
  FOREIGN KEY (ssn)
     REFERENCES Employees,
  FOREIGN KEY (did)
     REFERENCES Departments)
```

Review: Key Constraints

- Each dept has at most one manager, according to the *key constraint* on Manages.



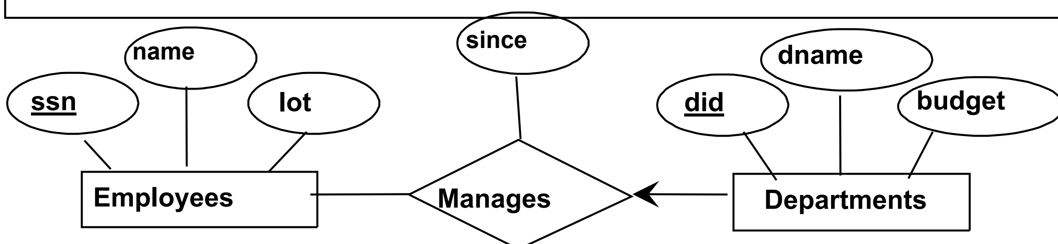


Translation to relational model?

Translating ER Diagrams with Key Constraints

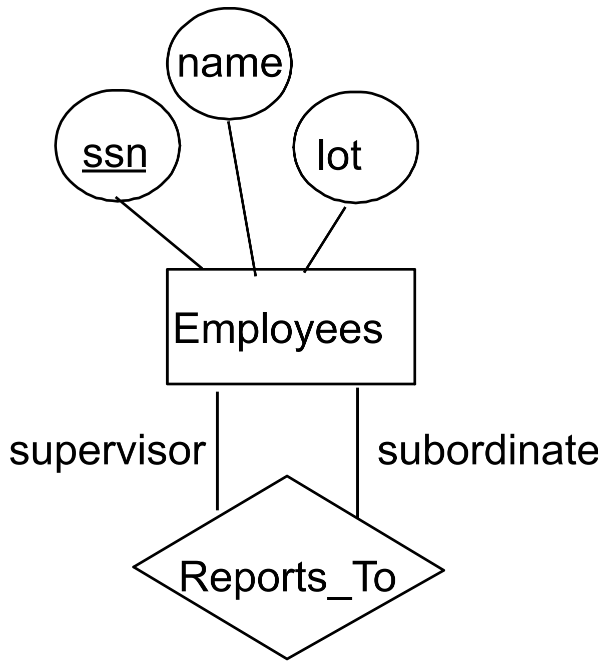
- Option 1: Map relationship to a table:
  - Note that *did* is the key now!
  - Separate tables for Employees and Departments.
- Option 2: Since each department has a unique manager, we could instead combine Manages and Departments.

```
CREATE TABLE  Manages(
  ssn  CHAR(11),
  did  INTEGER,
  since  DATE,
  PRIMARY KEY  (did),
  FOREIGN KEY (ssn) REFERENCES Employees,
  FOREIGN KEY (did) REFERENCES Departments);
```




```
CREATE TABLE  Dept_Mgr(
  did  INTEGER,
  dname  CHAR(20),
  budget  REAL,
  ssn  CHAR(11),
  since  DATE,
  PRIMARY KEY  (did),
  FOREIGN KEY (ssn) REFERENCES Employees);
```

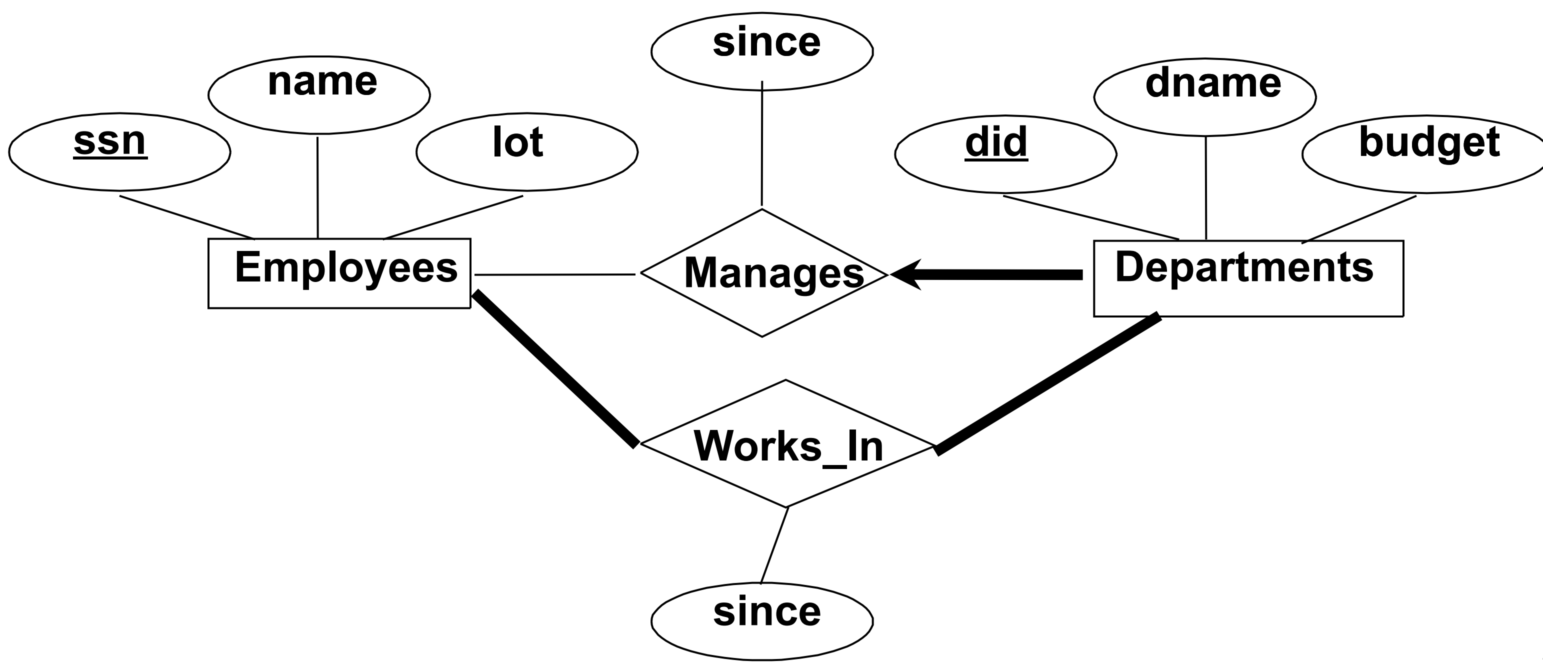
Relationship with Roles




```
CREATE TABLE  Reports_To(
    supervisor_ssn  CHAR(11),
    subordinate_ssn  CHAR(11),
    PRIMARY KEY  (supervisor_ssn, subordinate_ssn),
    FOREIGN KEY (supervisor_ssn) REFERENCES Employees(ssn),
    FOREIGN KEY (subordinate_ssn) REFERENCES Employees(ssn));
```

Review: Participation Constraints

- Does every department have a manager?
  - If so, this is a *participation constraint*: the participation of Departments in Manages is said to be *total* (vs. *partial*).
    - Every *did* value in Departments table must appear in a row of the Manages table (with a non-null *ssn* value!)



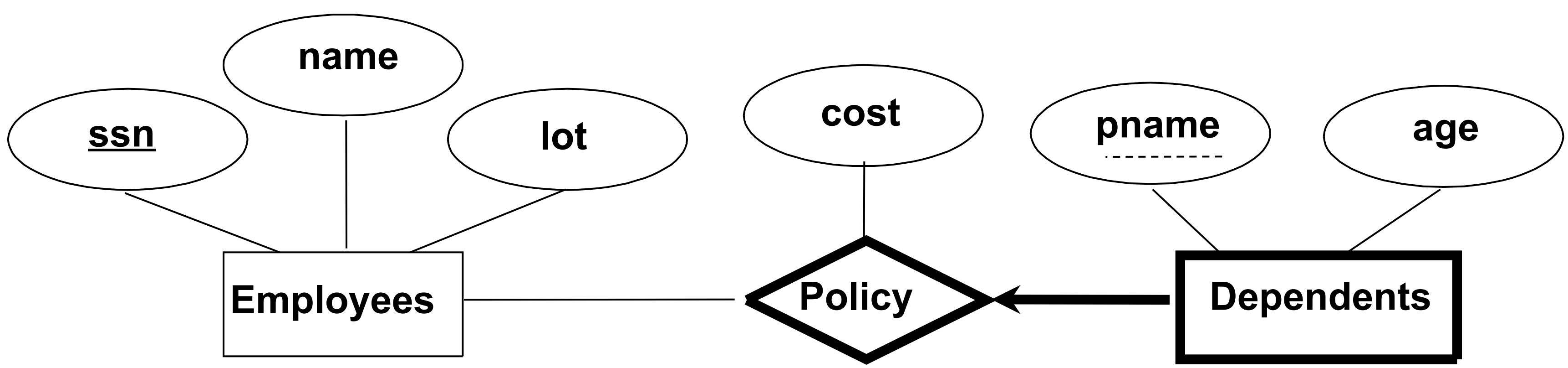
Participation Constraints in SQL

- We can capture participation constraints involving one entity set in a binary relationship, but little else (without resorting to CHECK constraints).

```
CREATE TABLE Dept_Mgr(
  did INTEGER,
  dname CHAR(20),
  budget REAL,
  ssn CHAR(11) NOT NULL,
  since DATE,
  PRIMARY KEY (did),
  FOREIGN KEY (ssn) REFERENCES Employees,
    ON DELETE NO ACTION);
```

Review: Weak Entities

- A *weak entity* can be identified uniquely only by considering the primary key of another (*owner*) entity.
  - Owner entity set and weak entity set must participate in a one-to-many relationship set (1 owner, many weak entities).
  - Weak entity set must have total participation in this *identifying* relationship set.

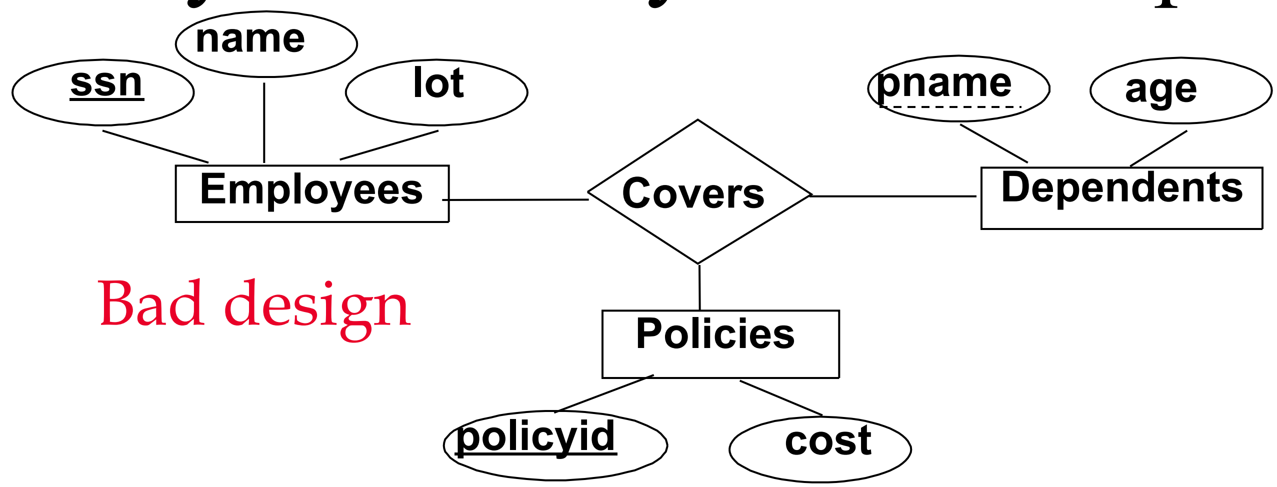


Translating Weak Entity Sets

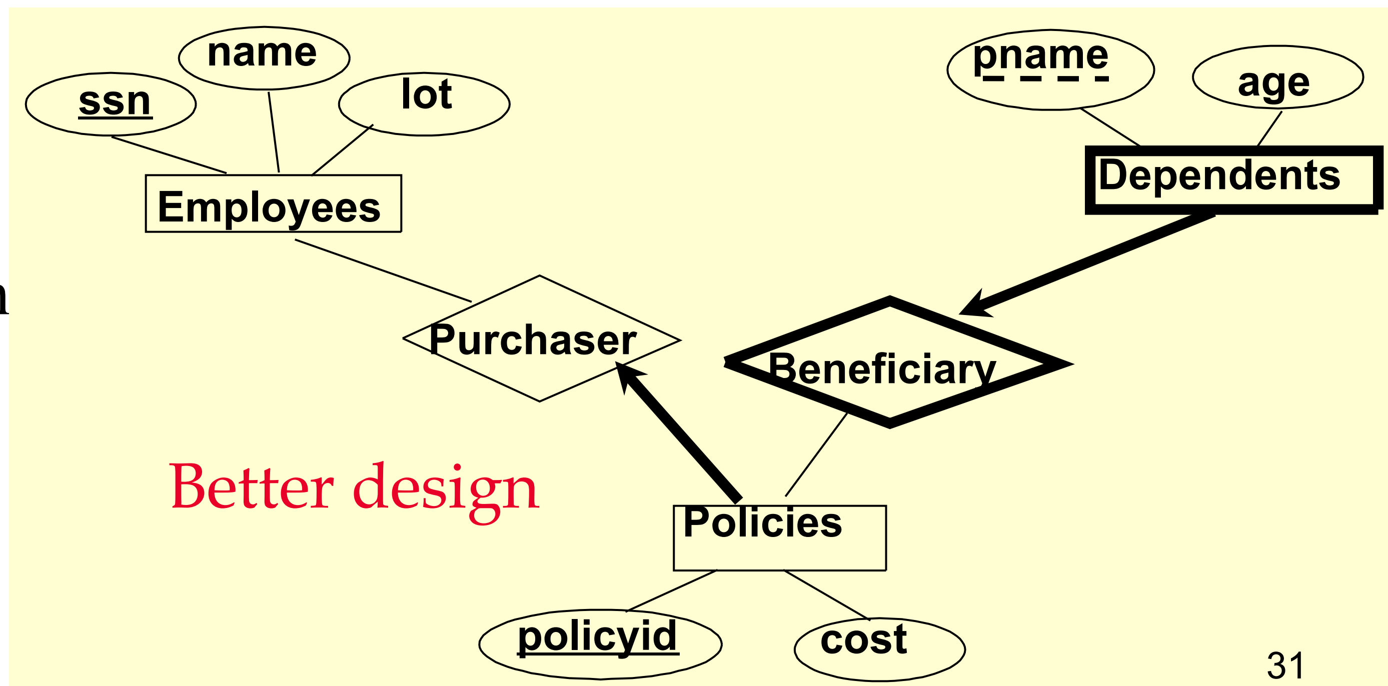
- Weak entity set and identifying relationship set are translated into a single table.
  - When the owner entity is deleted, all owned weak entities must also be deleted.

```
CREATE TABLE Dep_Policy (
  pname CHAR(20),
  age INTEGER,
  cost REAL,
  ssn CHAR(11) NOT NULL,
  PRIMARY KEY (pname, ssn),
  FOREIGN KEY (ssn) REFERENCES Employees,
    ON DELETE CASCADE)
```

Review: Binary vs. Ternary Relationships



- What are the additional constraints in the 2nd diagram?



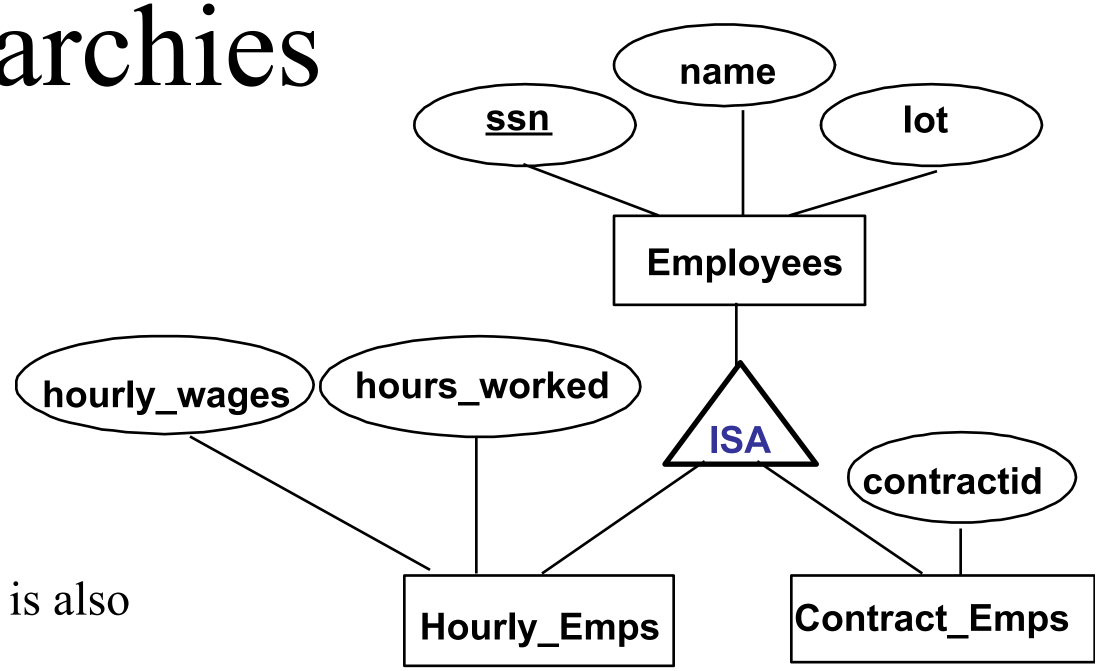
Binary vs. Ternary Relationships (Cont.)

- The key constraints allow us to combine Purchaser with Policies and Beneficiary with Dependents.
- Participation constraints lead to NOT NULL constraints.

```
CREATE TABLE Policies (
   policyid INTEGER,
   cost REAL,
   ssn CHAR(11) NOT NULL,
   PRIMARY KEY (policyid),
   FOREIGN KEY (ssn) REFERENCES Employees,
     ON DELETE CASCADE);
```

```
CREATE TABLE Dependents (
   pname CHAR(20),
   age INTEGER,
   policyid INTEGER,
   PRIMARY KEY (pname, policyid),
   FOREIGN KEY (policyid) REFERENCES Policies,
     ON DELETE CASCADE);
```

ISA ('is a') Hierarchies



- As in C++, or other PLs, attributes are inherited.
- If we declare A **ISA** B, every A entity is also considered to be a B entity.

- *Overlap constraints*: Can Joe be an Hourly_Emps as well as a Contract_Emps entity? (*Allowed/disallowed*)
- *Covering constraints*: Does every Employees entity also have to be an Hourly_Emps or a Contract_Emps entity? *(Yes/no)*
- Reasons for using ISA:
  - To add descriptive attributes specific to a subclass.
  - To identify entities that participate in a relationship.

Translating ISA Hierarchies to Relations

- General approach:
  - 3 relations: Employees, Hourly_Emps and Contract_Emps.
    - *Hourly_Emps*: Every employee is recorded in Employees. For hourly emps, extra info recorded in Hourly_Emps (*hourly_wages*, *hours_worked*, *ssn)*; must delete Hourly_Emps tuple if referenced Employees tuple is deleted.
    - Contract_Emps: Every employee is recorded in Employees. Extra info recorded in Contract_Emps (contract_id); must delete Contract_Emps tuple if referenced Employees tuple is deleted.
    - Queries involving all employees easy, those involving just Hourly_Emps require a join to get some attributes.
- Alternative: Just Hourly_Emps and Contract_Emps.
  - *Hourly_Emps*: *ssn, name, lot, hourly_wages, hours_worked.*
  - Similar for Contract_Emps
  - Each employee must be in one of these two subclasses.

Views

- A *view* is just a relation, but we store a *definition*, rather than a set of tuples.

```
CREATE VIEW YoungStudents (name, grade)
    AS SELECT S.name, E.grade
    FROM Students S, Enrolled E
    WHERE S.sid = E.sid and S.age<21;
```

- Views can be dropped using the DROP VIEW command.

Views and Security

- Views can be used to present necessary information (or a summary), while hiding details in underlying relation(s).
  - Given YoungStudents, but not Students or Enrolled, we can find young students who are enrolled, but not the *cids* of the courses they are enrolled in.

Relational Model: Summary

- A tabular representation of data.
- Simple and intuitive, currently the most widely used.
- Integrity constraints can be specified by the DBA, based on application semantics. DBMS checks for violations.
  - Two important ICs: primary and foreign keys
  - In addition, we *always* have domain constraints.
- Powerful and natural query languages exist.
- Rules to translate ER to relational model