Institute of Information and Communication and Technology
Bangladesh University of Engineering and Technology

ICT 5103: Database Design and Management

Lecture 3

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The Relational Model

The slides were taken from the following book

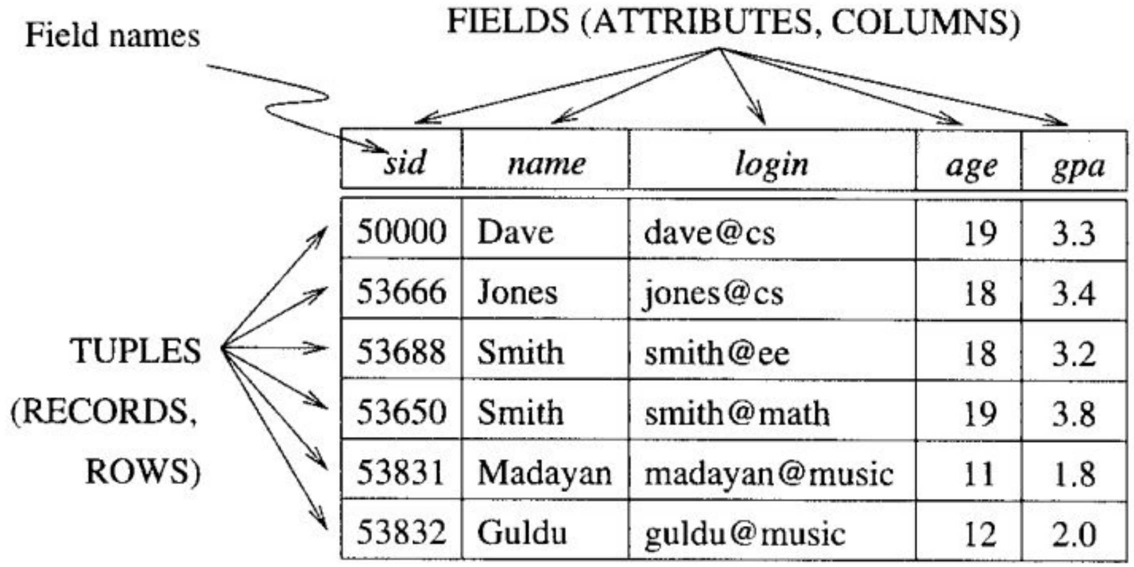
Why Study the Relational Model?

- Most widely used model.
  - Vendors: IBM, Informix, Microsoft, Oracle, Sybase, etc.
- “Legacy systems” in older models
  - E.G., IBM’s IMS
- Recent competitor: object-oriented model
  - ObjectStore, Versant, Ontos
  - A synthesis emerging: object-relational model
    - Informix Universal Server, UniSQL, O2, Oracle, DB2

Relational Database: Definitions

- **Relational database**: a set of relations
- **Relation**: made up of 2 parts:
  - **Instance**: a table, with rows and columns.
    - #Rows = cardinality, #fields = degree / arity.
  - **Schema**: specifies name of relation, plus name and type of each column.
    - E.G. Students(*sid*: string, *name*: string, *login*: string, *age*: integer, *gpa*: real).
- Can think of a relation as a *set* of rows or *tuples* (i.e., all rows are distinct).

Example Instance of Students Relation



sid	*name*	*login*	*age*	*gpa*
50000	Dave	dave@cs	19	3.3
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2
53650	Smith	smith@math	19	3.8
53831	Madayan	madayan@music	11	1.8
53832	Guldu	guldu@music	12	2.0

- Cardinality = 6, degree = 5, all rows distinct

Relational Query Language

- A major strength of the relational model: supports simple, powerful querying of data.
- Queries can be written intuitively, and the DBMS is responsible for efficient evaluation.
  - The key: precise semantics for relational queries.
  - Allows the optimizer to extensively re-order operations, and still ensure that the answer does not change.

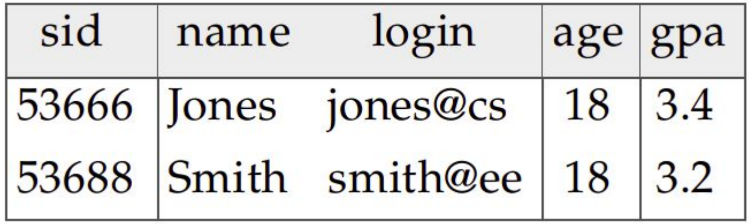
The SQL Query Language

- Developed by IBM (system R) in the 1970s
- Need for a standard since it is used by many vendors
- Standards:
  - SQL-86
  - SQL-89 (minor revision)
  - SQL-92 (major revision)
  - SQL-99 (major extensions)
  - SQL:2003
  - SQL:2006
  - SQL:2008
  - SQL:2011
  - SQL:2016
  - SQL:2019
  - SQL:2023 (current standard)

The SQL Query Language

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

```
SELECT  *
FROMStudents 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 find just names and logins, replace the first line:

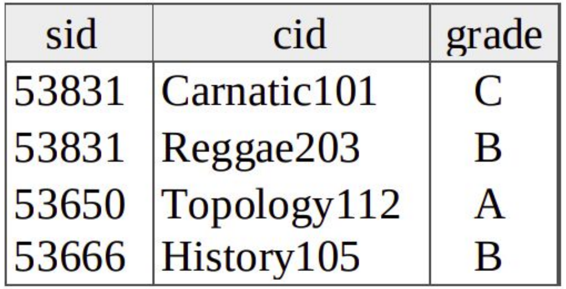
```
SELECT S.name, S.login
```

Querying Multiple Relations

- What does the following query compute?

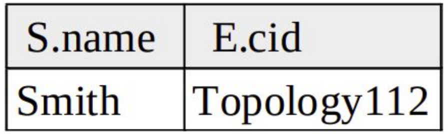
```
SELECT  S.name, E.cid
FROMStudents S, Enrolled E
WHERE   S.sid=E.sid AND E.grade=“A”
```

- Given the following instance of Enrolled (is this possible if the DBMS ensures referential integrity?):



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

- we get:



S.name	E.cid
Smith	Topology112

Creating Relations in SQL

- Creates the Students relation. Observe that the type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.
- As another example, the Enrolled table holds information about courses that students take.

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

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

Destroying and Altering Relations

```
DROP TABLE Student
```

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

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

- 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.

Adding and Deleting Tuple

- 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 S
WHERE S.name = ‘Smith’
```

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 error, too!

Primary Key Constraints

- A set of fields is a key for a relation if:
  a. No two distinct tuples can have same values in all key fields, and
  b. This is not true for any subset of the key.
  - Part 2 false? A superkey.
  - If there’s >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.
- “For a given student and course, there is a single grade.” vs. “Students can take only one course, and receive a single grade for that course; further, no two students in a course receive the same grade.”
- Used carelessly, an IC can prevent the storage of database instances that arise in practice!

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

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

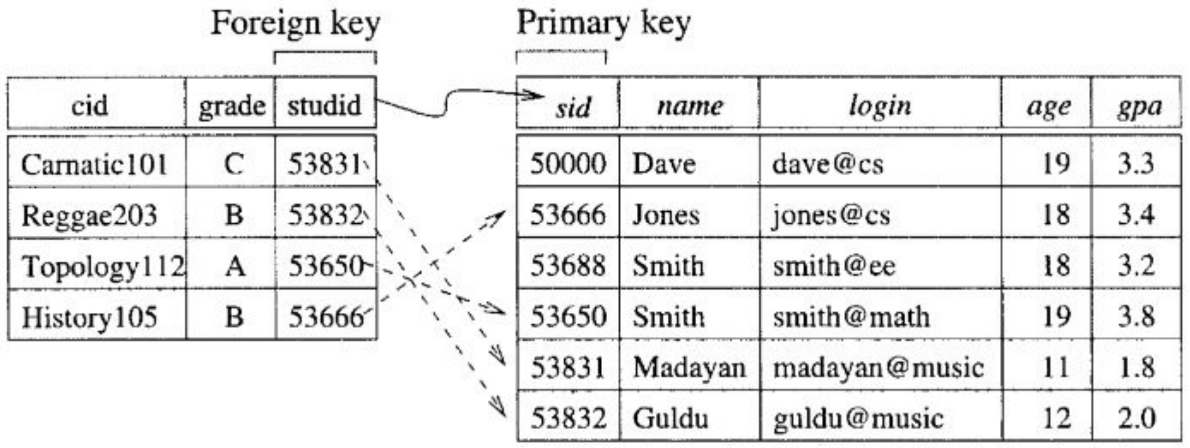
Foreign Keys, Referential Integrity

- 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!

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)
```



cid	grade	studid
Carnatic101	C	53831
Reggae203	B	53832
Topology112	A	53650
History105	B	53666

Enrolled **(Referencing relation)**

sid	*name*	*login*	*age*	*gpa*
50000	Dave	dave@cs	19	3.3
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2
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Students **(Referenced relation)**

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 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)

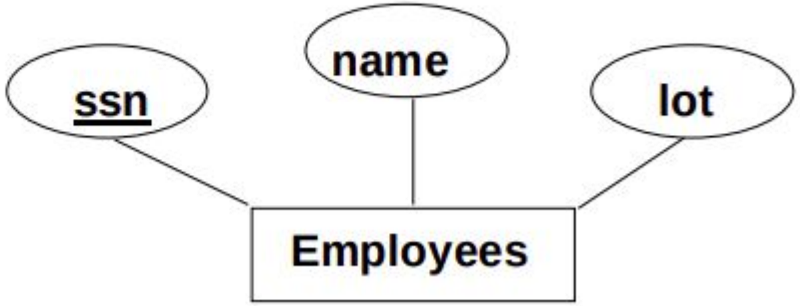
```
CREATE TABLE Enrolled
    (sid CHAR(20),
    cid CHAR(20),
    grade CHAR(2),
    PRIMARY KEY (sid, sid)
    FOREIGN KEY (sid)
        REFERENCES Students
            ON DELETE CASCADE
            ON UPDATE SET DEFAULT)
```

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))
```

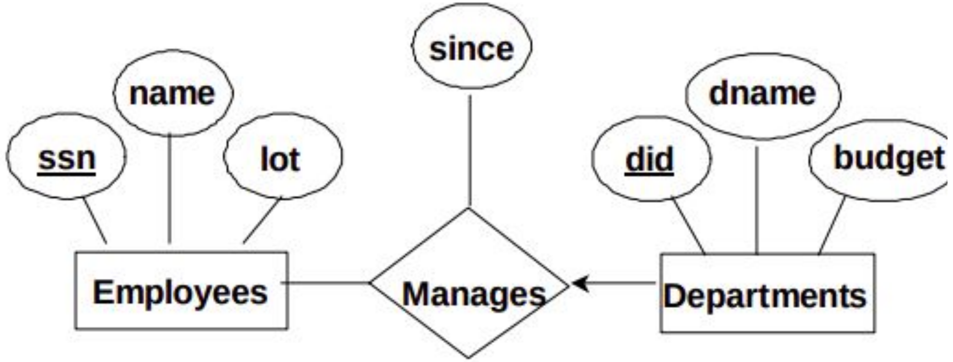
Relationship Sets to Tables

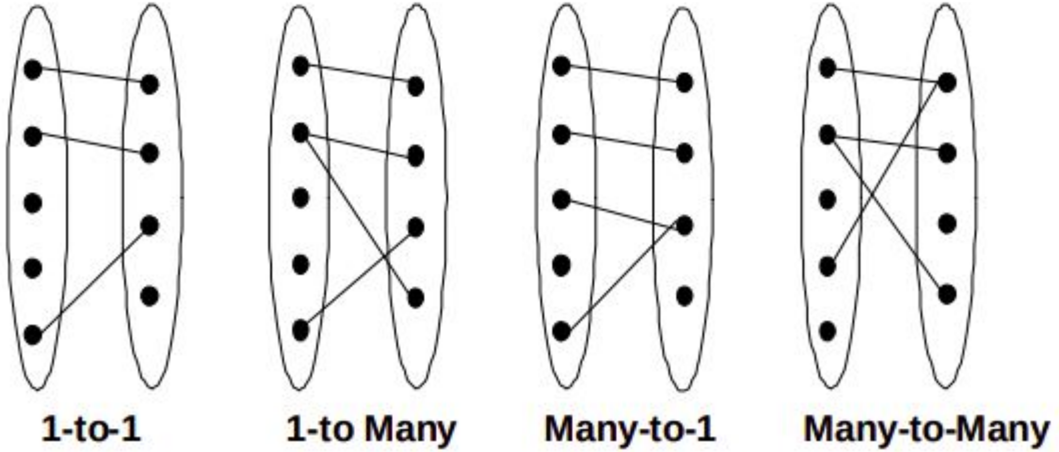
- In translating a relationship set to a relation, attributes of the relation must include:
  - Keys for each participating entity set (as foreign keys).
    - This set of attributes forms a superkey for the relation.
  - All descriptive attributes.

```
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 Constraint

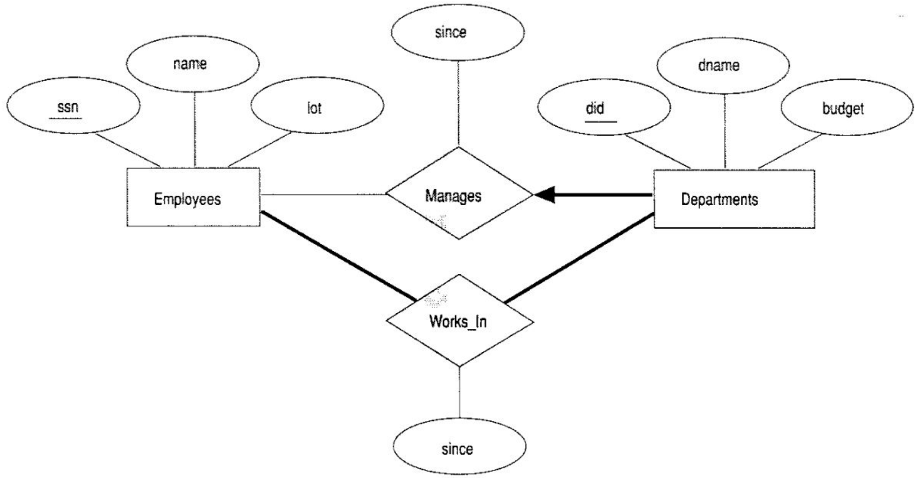
- Map relationship to a table:
  - Note that did is the key now!
  - Separate tables for Employees and Departments.
- Since each department has a unique manager, we could instead combine Manages and Departments

```
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),
    PRIMARY KEY (did),
    FOREIGN KEY (ssn) REFERENCES Employees)
```

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!)



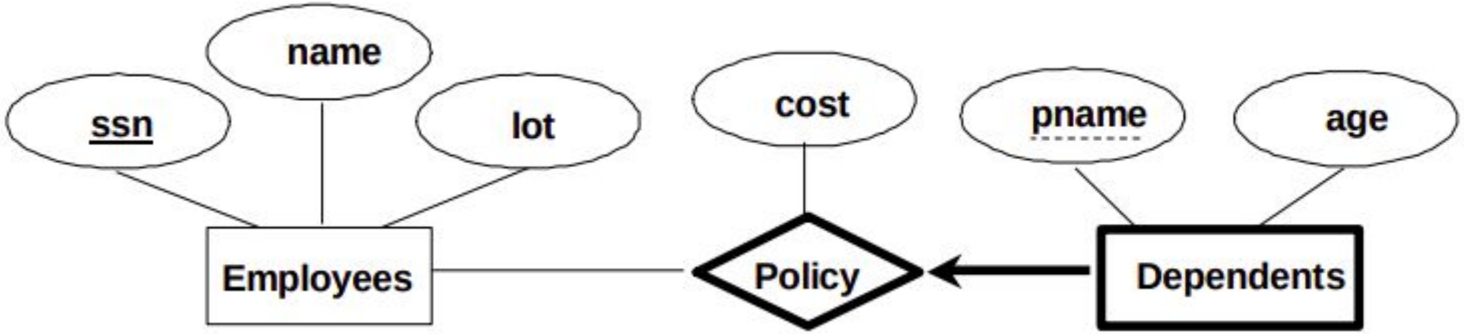
Participation Constraints in SQL

- 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.



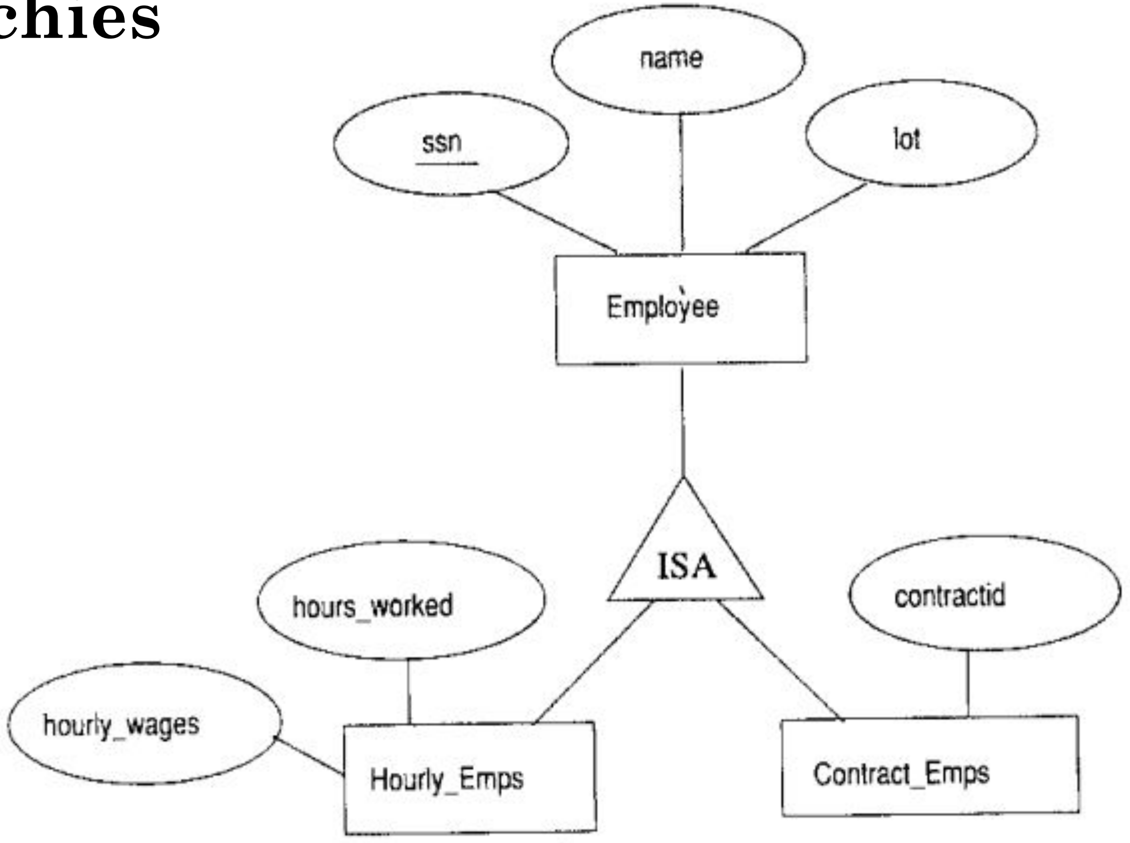
Translating Weak Entity Sets

- 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: ISA 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)

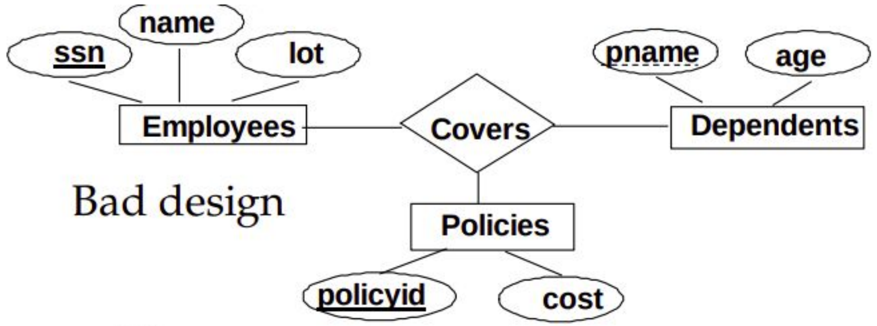


Translating ISA Hierarchies to Relations

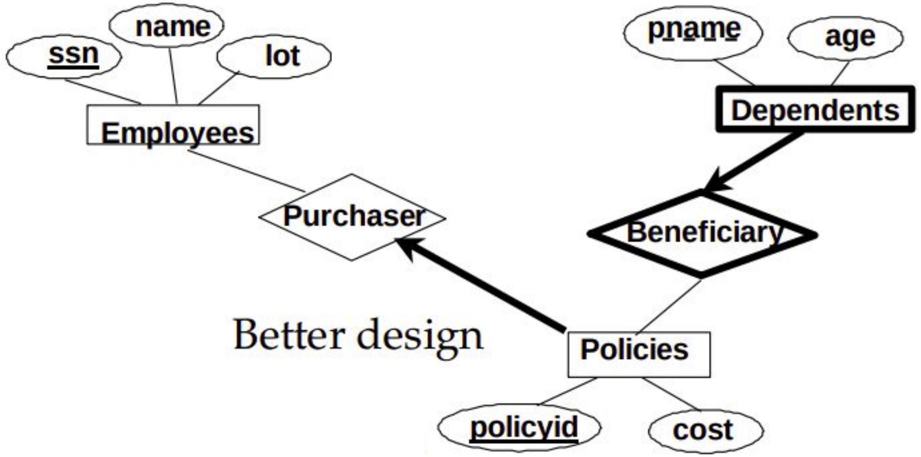
- General approach:
  - 3 relations: Employees, Hourly_Emps and Contract_Emps.
    - Hourly_Emps: Every employee is recorded in Employees. For hourly emps, extra info recorded in Hourly_Emps (hourly_wages, hours_worked, ssn); must delete Hourly_Emps tuple if referenced Employees tuple is deleted).
    - 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. Each employee must be in one of these two subclasses.

Review: Binary vs. Ternary Relationships

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



Bad design



Better design

Binary vs. Ternary Relationships (Contd.)

- The key constraints allow us to combine Purchaser with Policies and Beneficiary with Dependents.
- Participation constraints lead to NOT NULL constraints.
- What if Policies is a weak entity set?

```
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 Dependants (
    pname CHAR(20),
    age INTEGER,
    policyid INTEGER,
    PRIMARY KEY (pname, policyid),
    FOREIGN KEY (policyid) REFERENCES Policies,
        ON DELETE CASCADE)
```

Views

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

```
CREATE VIEW YoungActiveStudents (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.
  - How to handle DROP TABLE if there's a view on the table?
    - DROP TABLE command has options to let the user specify

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 students s who have are enrolled, but not the cid's 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