The Relational Model

Why Study the Relational Model?

- Most widely used model.
  - Vendors: IBM, Microsoft, Oracle, Sybase, etc.
- "Legacy systems" in older models
  - E.G., IBM's IMS
- Competitor in the early 90s: object-oriented model
  - A synthesis: *object-relational model*
    - Oracle, DB2
- XML

Relational Database: Definitions

- *Relational database:* a set of *relations*
- *Relation:* made up of two parts:
  - *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).
  - *Instance* : a *table*, with rows and columns. #Rows = *cardinality*, #fields = *degree / arity.*
- Can think of a relation as a *set* of rows or *tuples* (i.e., all rows are distinct).

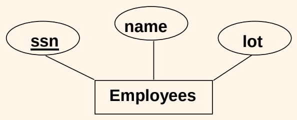
Example Instance of Students Relation

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

- Cardinality = 3, degree = 5, all rows distinct
- Do all columns in a relation instance have to be distinct?

Logical DB Design: ER to Relational

- Entity sets to tables.

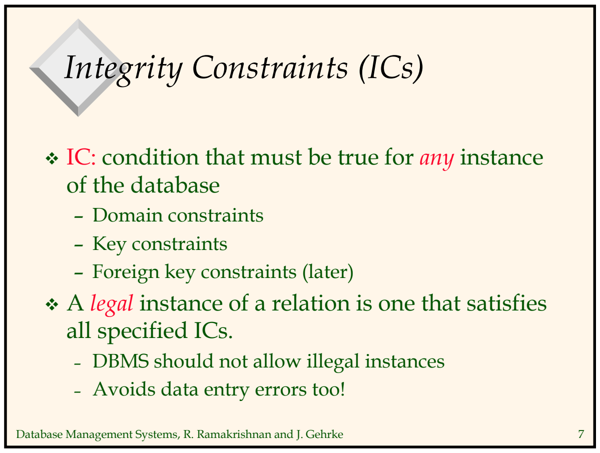


```
CREATE TABLE Employees
     (ssn CHAR(11),
     name CHAR(20),
     lot  INTEGER,
     PRIMARY KEY  (ssn))
```

Example Instance

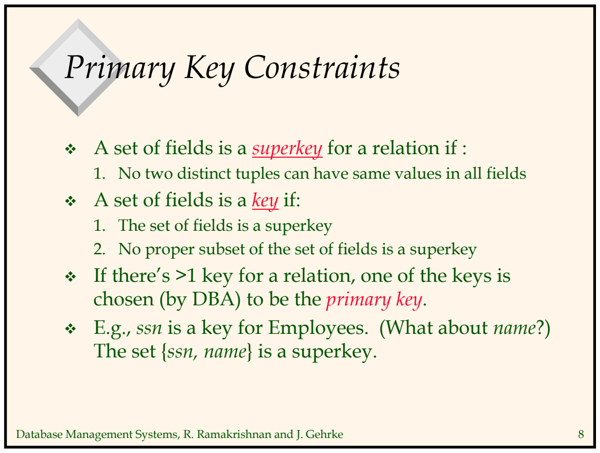
Employees

ssn	name	lot
0983763423	John	10
9384392483	Jane	10
3743923483	Jill	20



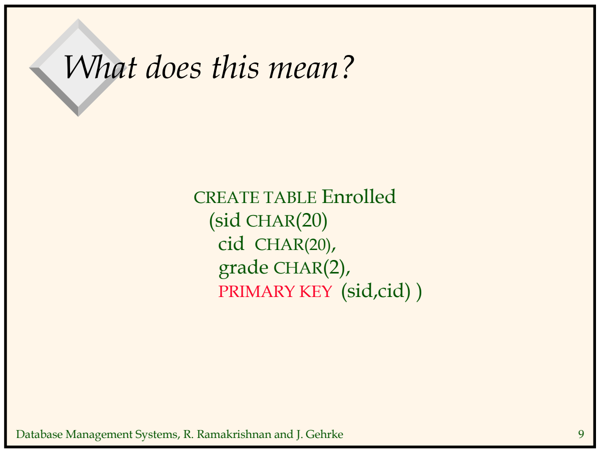
Integrity Constraints (ICs)

- IC: condition that must be true for *any* instance of the database
  - Domain constraints
  - Key constraints
  - Foreign key constraints (later)
- A *legal* instance of a relation is one that satisfies all specified ICs.
  - DBMS should not allow illegal instances
  - Avoids data entry errors too!



Primary Key Constraints

- A set of fields is a *superkey* for a relation if :
  1. No two distinct tuples can have same values in all fields
- A set of fields is a *key* if:
  1. The set of fields is a superkey
  2. No proper subset of the set of fields is 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., *ssn* is a key for Employees. (What about *name*?) The set {*ssn, name*} is a superkey.



What does this mean?

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

Candidate Keys

- Possibly many *candidate keys* (specified using UNIQUE), one of which is chosen as the *primary key*.

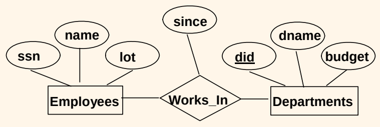
```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   grade CHAR(2),
   PRIMARY KEY  (sid),
   UNIQUE (cid, grade) )
```

- Each student is enrolled in at most one course
- No two students in a course get the same grade

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.

ER to Relational (contd.)



Relationship Sets to Tables

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

```
CREATE TABLE Departments
         (did INTEGER,
          dname CHAR(20),
          budget FLOAT,
          PRIMARY KEY  (did))
```

```
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)
```

Example Instance

Employees

ssn	name	lot
0983763423	John	10
9384392483	Jane	10
3743923483	Jill	20

Departments

did	dname	budget
101	Sales	10K
105	Purchasing	20K
108	Databases	1000K

Works_In

ssn	did	since
0983763423	101	1 Jan 2003
0983763423	108	2 Jan 2003
9384392483	108	1 Jun 2002

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'.
- If all foreign key constraints enforced, *referential integrity* is achieved, i.e., no dangling references.
  - Not like HTML links!

Enforcing Referential Integrity

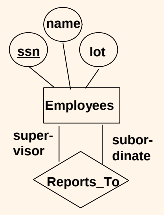
- What if a new "Works_In" tuple is added that references a non-existent employee?
  - Reject it!
- What if an Employee tuple is deleted?
  - Also delete all Works_In tuples that refer to it.
  - Disallow deletion of Employee tuple that is referred to.
  - Set *ssn* to some default value
  - Set *ssn* in Works_In to *null*, denoting *`unknown'*
- Similar if primary key of Employee tuple is updated

Referential Integrity in SQL/92

- SQL/92 supports all 4 options on deletes and updates.
  - Default is NO ACTION (*delete/update is rejected*)
  - CASCADE (delete all tuples that refer to deleted tuple)
  - SET NULL / SET DEFAULT

```
CREATE TABLE Works_In(
      ssn  CHAR(11),
      did  INTEGER,
      since  DATE,
      PRIMARY KEY (ssn, did),
      FOREIGN KEY (ssn) REFERENCES Employees
          ON DELETE CASCADE ON UPDATE SET DEFAULT,
      FOREIGN KEY (did) REFERENCES Departments
          ON DELETE SET NULL ON UPDATE CASCADE)
```

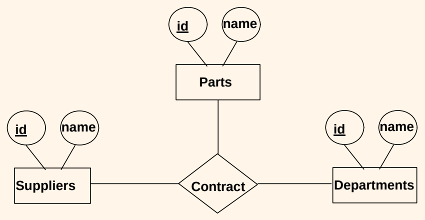
ER to Relational (contd.)



Relationship Sets to Tables

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

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

ER to Relational (contd.)

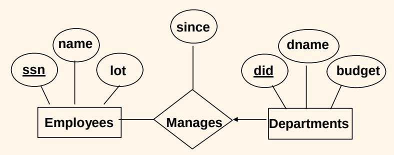


Relationship Sets to Tables

```
CREATE TABLE Contracts (
     supplier_id  INTEGER,
     part_id  INTEGER,
     department_id  INTEGER,
     PRIMARY KEY (supplier_id, part_id, department_id),
     FOREIGN KEY (supplier_id) REFERENCES Suppliers,
     FOREIGN KEY (part_id) REFERENCES Parts,
     FOREIGN KEY (department_id) REFERENCES Departments)
```

ER to Relational (contd.)

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

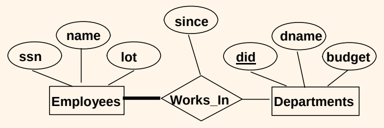


Relationship Sets to Tables

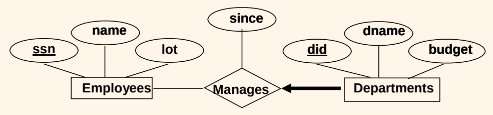
```
CREATE TABLE Employees
         (ssn CHAR(11),
          name CHAR(20),
          lot  INTEGER,
          PRIMARY KEY  (ssn))

CREATE TABLE Departments
         (did INTEGER,
          dname CHAR(20),
          budget FLOAT,
          mgr_ssn CHAR(11),
          PRIMARY KEY  (did)
          FOREIGN KEY (mgr_ssn) REFERENCES Employees)
```

ER to Relational (contd.)

- Each employee works in at least one department according to the *participation constraint* on Works_In



ER to Relational (contd.)

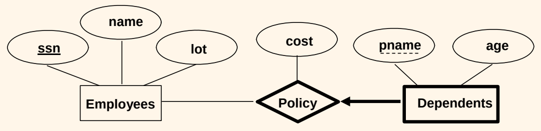


Relationship Sets to Tables

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

ER to Relational (contd.)

- A *weak entity* can be identified uniquely only by considering the primary key of another (*owner*) entity.

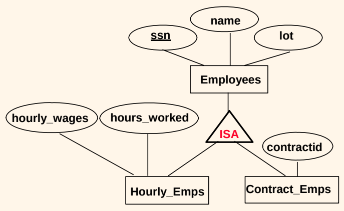


Translating Weak Entity Sets

- 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)
```

ER to Relational (Contd.)



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.

Destroying and Altering Relations

```
DROP TABLE Students
```

- 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 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 S
WHERE S.name = 'Smith'
```

🖂 *Powerful variants of these commands are available; more later!*

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.
- Rules to translate ER to relational model