Querying Relational Data, SQL

CMPSCI 445

Fall 2008

Today

- Review of Joins
- Conclude relational algebra
- Begin SQL

Review of Joins

- Joins are the most common way to combine information from two tables.
- Theta Join:

$$R_1 \bowtie_\theta R_2 = \sigma_\theta (R_1 \times R_2)$$

- Equijoin:

$$R_1 \bowtie_{A=B} R_2 = \sigma_{A=B} (R_1 \times R_2))$$

- Natural Join

$$R_1 \bowtie R_2 = \Pi_A(\sigma_C(R_1 \times R_2))$$

Example Database

STUDENT

sid	name
1	Jill
2	Bo
3	Maya

Takes

sid	cid
1	445
1	483
3	435

COURSE

cid	title	sem
445	DB	F08
483	AI	S08
435	Arch	F08

PROFESSOR

fid	name
1	Diao
2	Saul
8	Weems

Teaches

fid	cid
1	445
2	483
8	435

Natural join questions

- Given the schemas R(A, B, C, D), S(A, C, E), what is the schema of R ⋈ S ?
  - **R(A,B,C,D,E)**
- Given R(A, B, C), S(D, E), what is R ⋈ S ?
  - **Cartesian Product**
- Given R(A, B), S(A, B), what is R ⋈ S ?
  - **Intersection**

Algebraic Equivalences

- Relational algebra has laws of commutativity, associativity, etc. that imply certain expressions are **equivalent**.

$$\sigma_{c \wedge d}(R) \equiv \sigma_c(\sigma_d(R)) \qquad \text{cascading selection}$$

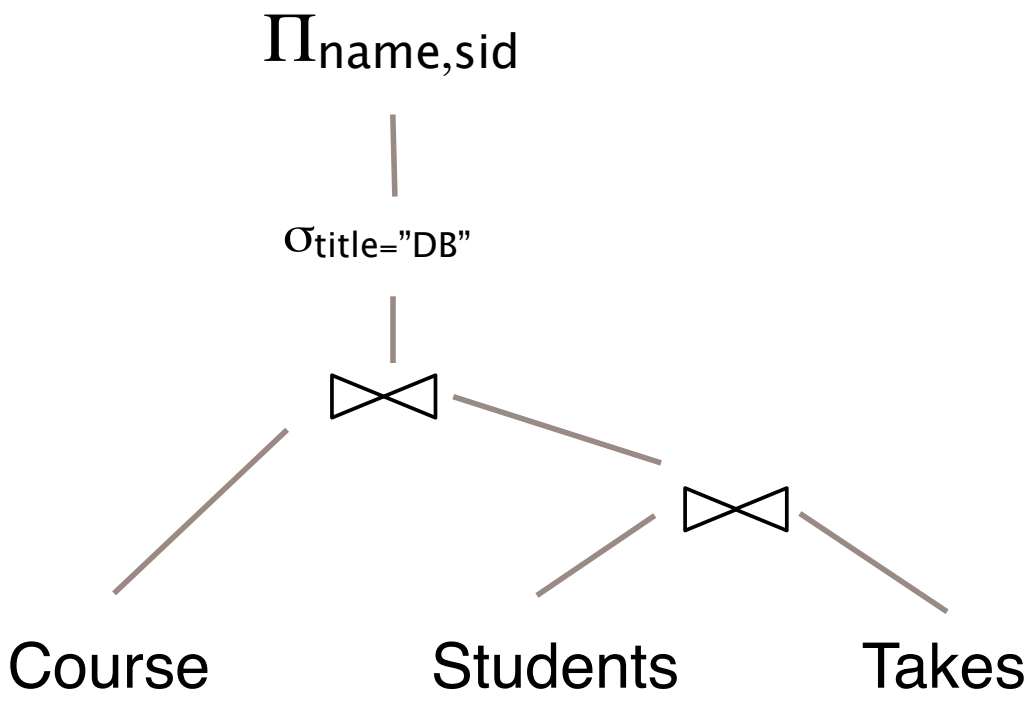
$$R \bowtie (S \bowtie T) \equiv (R \bowtie S) \bowtie T \qquad \text{join associativity}$$

$$\sigma_c(R \bowtie S) \equiv \sigma_c(R) \bowtie S \qquad \text{pushing selections}$$

- We can use these equivalences to generate equivalent operator trees

Expression tree

$\Pi_{name,sid}\ (\sigma_{title="DB"}\ (Course \bowtie (\ Students \bowtie Takes\ )))$



Algebra v. Calculus

- *Relational Algebra*: More operational; very useful for representing execution plans.
- *Relational Calculus*: More declarative, basis of SQL

- The calculus and algebra have equivalent expressive power (Codd)

A language that can express this core class of queries is called **Relationally Complete**

Relational Algebra & Calculus can't express all queries

- Tuples in FLIGHTS represent direct flights from departure city to arrival city.
- What about connecting flights?
- A **self-join** is a join of a table with itself
- RA, RC can't express repeated joins

FLIGHTS

depart	arrive
NYC	Reno
NYC	Oakland
Boston	Tampa
Oakland	Boston
Tampa	NYC

Next: SQL

SQL Overview

- SQL Preliminaries
- Integrity constraints
- Query capabilities
  - SELECT-FROM-WHERE blocks,
  - Basic features, ordering, duplicates
  - Set ops (union, intersect, except)
  - Aggregation & Grouping
  - Nested queries (correlation)
  - Null values
- Modifying the database
- Views

Review in the textbook, Ch 5

The SQL Query Language

Structured **Q**uery **L**anguage

- Developed by IBM (system R) in the 1970s
- Need for a standard since it is used by many vendors
- Evolving standard
  - SQL-86
  - SQL-89 (minor revision)
  - SQL-92 (major revision)
  - SQL-99 (major extensions)
  - SQL-2003 (minor revisions) ...

Two parts of SQL

- Data Definition Language (DDL)
  - Create/alter/delete tables and their attributes
  - establish and modify schema
- Data Manipulation Language (DML)
  - Query and modify database instance

Creating Relations in SQL

- Creates the **Student** 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 **Takes** table holds information about courses that students take.

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

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

Data Types in SQL

- Characters:
  - CHAR(20) -- fixed length
  - VARCHAR(40) -- variable length
- Numbers:
  - BIGINT, INT, SMALLINT, TINYINT
  - REAL, FLOAT -- differ in precision
  - MONEY
- Times and dates:
  - DATE
  - DATETIME
- Others...

Destroying and Altering Relations

DROP TABLE **Student**

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

ALTER TABLE **Student**
ADD COLUMN firstYear integer

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

Integrity Constraints (ICs)

- IC: condition that must be true for *any* instance of the database.
  - 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 only allow legal instances.
- If the DBMS checks ICs, stored data is more faithful to real-world meaning.
  - Avoids data entry errors, too!

Key Constraints

- 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. This is not true for any subset of the key.
  - If part 2 false: then fields are a *superkey*.
  - If there's more than one 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.

Student table

STUDENT

sid	name	login	age	gpa
50000	Dave	dave@cs	19	3.2
53666	Jones	jones@cs	18	3.3
53688	Smith	smith@ee	18	3.2
53650	Smith	smith@math	19	3.7
53831	Madayan	madayan@music	11	1.8
53832	Guldu	guldu@music	12	2.0

Specifying Key Constraints in SQL

```
CREATE TABLE Student
       (sid CHAR(20),
        name CHAR(20),
        login CHAR(10),
        age INTEGER,
        gpa REAL,
      UNIQUE (name, age),
      PRIMARY KEY (sid) )
```

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

Primary and Candidate Keys in SQL

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

"For a given student and course, there is a single grade."

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

"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!

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:
  - **Takes**(*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!

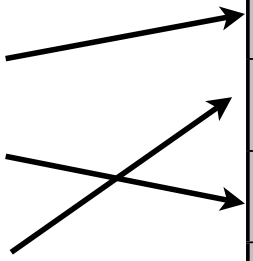
Foreign Keys in SQL

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

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

Takes

sid	cid	grade
50000	445	A
53688	483	C
53666	435	B



STUDENT

sid	name	login
50000	Dave	dave@cs
53666	Jones	jones@cs
53688	Smith	smith@ee
53650	Smith	smith@math

Enforcing Referential Integrity

- Consider **Student** and **Takes**; *sid* in **Takes** is a foreign key that references **Student**.
- What should be done if a **Takes** tuple with a non-existent student id is inserted? (*Reject it!*)
- What should be done if a **Student** tuple is deleted?
  - Also delete all Takes tuples that refer to it.
  - Disallow deletion of a Students tuple that is referred to.
  - Set sid in Takes tuples that refer to it to a *default sid*.
  - (In SQL, also: Set sid in Takes 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 Takes
  (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.