

SQL: Part II

Introduction to Databases

CompSci 316 Fall 2019



DUKE
COMPUTER SCIENCE

Announcements (Mon., Sep. 16)

- Homework 1 due tonight!
 - Sample solution to be posted on Sakai later this week
- Gradiance
 - FD exercise due today; MVD due Wed.
 - Gradiance SQL Querying assigned; due next Wed.
- Homework 2 due in 2 weeks
- Get started on your project!
 - For ideas, check out project handout and examples from previous years (in intro lecture slides), and talk to us
- Project mixer this Wed.
 - Send me your elevator pitch slides by Tue. midnight
 - See email for details

Project resources

- Working web dev examples in PHP, Flask, and Play/Java for course VM
 - See “Help” on course website for more details

- Duke Co-Lab offerings
 - Many interesting “Roots” courses



INNOVATION
CO-LAB

- Create Your First Android App, Create a Web App with Django, Embrace Web Interactivity With JavaScript, First Steps Into Programming: The Bash Shell And Linux, etc.
 - Advance registration required
- Office hours on full-stack web/app development
- **Danai Adkisson** will be here on Wed.

Incomplete information

- Example: *User* (*uid*, *name*, *age*, *pop*)
- Value **unknown**
 - We do not know Nelson's age
- Value **not applicable**
 - Suppose *pop* is based on interactions with others on our social networking site
 - Nelson is new to our site; what is his *pop*?

Solution 1

- Dedicate a value from each domain (type)
 - *pop* cannot be -1 , so use -1 as a special value to indicate a missing or invalid *pop*
 - Leads to incorrect answers if not careful
 - `SELECT AVG(pop) FROM User;`
 - Complicates applications
 - `SELECT AVG(pop) FROM User
WHERE pop <> -1;`
- Perhaps the value is not as special as you think!
 - Ever heard of the Y2K bug?
“00” was used as a missing or invalid year value



Miel THE STRAITS TIMES 010898

<http://www.90s411.com/images/y2k-cartoon.jpg>

Solution 2

- A valid-bit for every column
 - *User* (*uid*,
 name, *name_is_valid*,
 age, *age_is_valid*,
 pop, *pop_is_valid*)
 - Complicates schema and queries
 - `SELECT AVG(pop) FROM User
WHERE pop_is_valid;`

Solution 3

- Decompose the table; missing row = missing value
 - *UserName* (*uid*, *name*)
 - *UserAge* (*uid*, *age*)
 - *UserPop* (*uid*, *pop*)
 - *UserID* (*uid*)
 - Conceptually the cleanest solution
 - Still complicates schema and queries
 - How to get all information about users in a table?
 - Natural join doesn't work!

SQL's solution

- A special value **NULL**
 - For every domain
 - Special rules for dealing with NULL's
- Example: *User* (*uid*, *name*, *age*, *pop*)
 - $\langle 789, \text{"Nelson"}, \text{NULL}, \text{NULL} \rangle$

Computing with NULL's

- When we operate on a NULL and another value (including another NULL) using +, −, etc., the result is NULL
- Aggregate functions ignore NULL, except COUNT (*) (since it counts rows)

Three-valued logic

- TRUE = 1, FALSE = 0, UNKNOWN = 0.5
- $x \text{ AND } y = \min(x, y)$
- $x \text{ OR } y = \max(x, y)$
- $\text{NOT } x = 1 - x$
- When we compare a NULL with another value (including another NULL) using =, >, etc., the result is UNKNOWN
- WHERE and HAVING clauses only select rows for output if the condition evaluates to TRUE
 - UNKNOWN is not enough

Unfortunate consequences

- `SELECT AVG(pop) FROM User;`
`SELECT SUM(pop) / COUNT(*) FROM User;`
 - Not equivalent
 - Although $AVG(pop) = SUM(pop) / COUNT(pop)$ still
 - `SELECT * FROM User;`
`SELECT * FROM User WHERE pop = pop;`
 - Not equivalent
- ☞ Be careful: NULL breaks many equivalences

Another problem

- Example: Who has NULL *pop* values?
 - `SELECT * FROM User WHERE pop = NULL;`
 - Does not work; never returns anything
 - `(SELECT * FROM User)`
`EXCEPT ALL`
`(SELECT * FROM User WHERE pop = pop);`
 - Works, but ugly
 - SQL introduced special, built-in predicates
IS NULL and **IS NOT NULL**
 - `SELECT * FROM User WHERE pop IS NULL;`

Outerjoin motivation

- Example: a master group membership list
 - ```
SELECT g.gid, g.name AS gname,
 u.uid, u.name AS uname
FROM Group g, Member m, User u
WHERE g.gid = m.gid AND m.uid = u.uid;
```
  - What if a group is empty?
  - It may be reasonable for the master list to include empty groups as well
    - For these groups, *uid* and *uname* columns would be NULL

# Outerjoin flavors and definitions

- A **full outerjoin** between  $R$  and  $S$  (denoted  $R \bowtie S$ ) includes all rows in the result of  $R \Join S$ , plus
  - “Dangling”  $R$  rows (those that do not join with any  $S$  rows) padded with NULL’s for  $S$ ’s columns
  - “Dangling”  $S$  rows (those that do not join with any  $R$  rows) padded with NULL’s for  $R$ ’s columns
- A **left outerjoin** ( $R \Join S$ ) includes rows in  $R \Join S$  plus dangling  $R$  rows padded with NULL’s
- A **right outerjoin** ( $R \Join S$ ) includes rows in  $R \Join S$  plus dangling  $S$  rows padded with NULL’s

# Outerjoin examples

Group ⋈ Member

Group

| <i>gid</i> | <i>name</i>            |
|------------|------------------------|
| abc        | Book Club              |
| gov        | Student Government     |
| dps        | Dead Putting Society   |
| nuk        | United Nuclear Workers |

Member

| <i>uid</i> | <i>gid</i> |
|------------|------------|
| 142        | dps        |
| 123        | gov        |
| 857        | abc        |
| 857        | gov        |
| 789        | foo        |

Group ⋈ Member

Group ⋈ Member

| <i>gid</i> | <i>name</i>            | <i>uid</i> |
|------------|------------------------|------------|
| abc        | Book Club              | 857        |
| gov        | Student Government     | 123        |
| gov        | Student Government     | 857        |
| dps        | Dead Putting Society   | 142        |
| nuk        | United Nuclear Workers | NULL       |

| <i>gid</i> | <i>name</i>          | <i>uid</i> |
|------------|----------------------|------------|
| abc        | Book Club            | 857        |
| gov        | Student Government   | 123        |
| gov        | Student Government   | 857        |
| dps        | Dead Putting Society | 142        |
| foo        | NULL                 | 789        |

| <i>gid</i> | <i>name</i>            | <i>uid</i> |
|------------|------------------------|------------|
| abc        | Book Club              | 857        |
| gov        | Student Government     | 123        |
| gov        | Student Government     | 857        |
| dps        | Dead Putting Society   | 142        |
| nuk        | United Nuclear Workers | NULL       |
| foo        | NULL                   | 789        |

# Outerjoin syntax

- `SELECT * FROM Group LEFT OUTER JOIN Member  
ON Group.gid = Member.gid;`  
 $\approx \text{Group} \bowtie_{\text{Group.gid}=\text{Member.gid}} \text{Member}$
- `SELECT * FROM Group RIGHT OUTER JOIN Member  
ON Group.gid = Member.gid;`  
 $\approx \text{Group} \bowtie_{\text{Group.gid}=\text{Member.gid}} \text{Member}$
- `SELECT * FROM Group FULL OUTER JOIN Member  
ON Group.gid = Member.gid;`  
 $\approx \text{Group} \bowtie_{\text{Group.gid}=\text{Member.gid}} \text{Member}$

☞ A similar construct exists for regular (“inner”) joins:

- `SELECT * FROM Group JOIN Member  
ON Group.gid = Member.gid;`

☞ These are **theta joins** rather than **natural joins**

- Return all columns in *Group* and *Member*

☞ For natural joins, add keyword **NATURAL**; don’t use ON



# SQL features covered so far

- SELECT-FROM-WHERE statements
- Set and bag operations
- Table expressions, subqueries
- Aggregation and grouping
- Ordering
- NULL 's and outerjoins

☞ Next: data modification statements, constraints

# INSERT

- Insert one row

- `INSERT INTO Member VALUES (789, 'dps');`

- User 789 joins Dead Putting Society

- Insert the result of a query

- `INSERT INTO Member`

- `(SELECT uid, 'dps' FROM User`

- `WHERE uid NOT IN (SELECT uid`

- `FROM Member`

- `WHERE gid = 'dps')));`

- Everybody joins Dead Putting Society!

# DELETE

- Delete everything from a table
  - `DELETE FROM Member;`
- Delete according to a WHERE condition

Example: User 789 leaves Dead Putting Society

- `DELETE FROM Member  
WHERE uid = 789 AND gid = 'dps';`

Example: Users under age 18 must be removed from United Nuclear Workers

- `DELETE FROM Member  
WHERE uid IN (SELECT uid FROM User  
WHERE age < 18)  
AND gid = 'nuk';`

# UPDATE

- Example: User 142 changes name to “Barney”
  - `UPDATE User`  
`SET name = 'Barney'`  
`WHERE uid = 142;`
- Example: We are all popular!
  - `UPDATE User`  
`SET pop = (SELECT AVG(pop) FROM User);`
    - But won't update of every row causes average *pop* to change?  
☞ Subquery is always computed over the old table

# Constraints

- Restrictions on allowable data in a database
  - In addition to the simple structure and type restrictions imposed by the table definitions
  - Declared as **part of the schema**
  - Enforced by the DBMS
- Why use constraints?
  - Protect data integrity (catch errors)
  - Tell the DBMS about the data (so it can optimize better)

# Types of SQL constraints

- NOT NULL
- Key
- Referential integrity (foreign key)
- General assertion
- Tuple- and attribute-based CHECK's

# NOT NULL constraint examples

- CREATE TABLE User  
(uid INTEGER NOT NULL,  
name VARCHAR(30) NOT NULL,  
twitterid VARCHAR(15) NOT NULL,  
age INTEGER,  
pop FLOAT);
- CREATE TABLE Group  
(gid CHAR(10) NOT NULL,  
name VARCHAR(100) NOT NULL);
- CREATE TABLE Member  
(uid INTEGER NOT NULL,  
gid CHAR(10) NOT NULL);

# Key declaration

- At most one **PRIMARY KEY** per table
  - Typically implies a **primary index**
  - Rows are stored inside the index, typically sorted by the primary key value  $\Rightarrow$  best speedup for queries
- Any number of **UNIQUE** keys per table
  - Typically implies a **secondary index**
  - Pointers to rows are stored inside the index  $\Rightarrow$  less speedup for queries



# Key declaration examples

- CREATE TABLE User  
(uid INTEGER NOT NULL PRIMARY KEY,  
name VARCHAR(30) NOT NULL,  
twitterid VARCHAR(15) NOT NULL UNIQUE,  
age INTEGER,  
pop FLOAT);
- CREATE TABLE Group  
(gid CHAR(10) NOT NULL PRIMARY KEY,  
name VARCHAR(100) NOT NULL);
- CREATE TABLE Member  
(uid INTEGER NOT NULL,  
gid CHAR(10) NOT NULL,  
PRIMARY KEY(uid, gid));

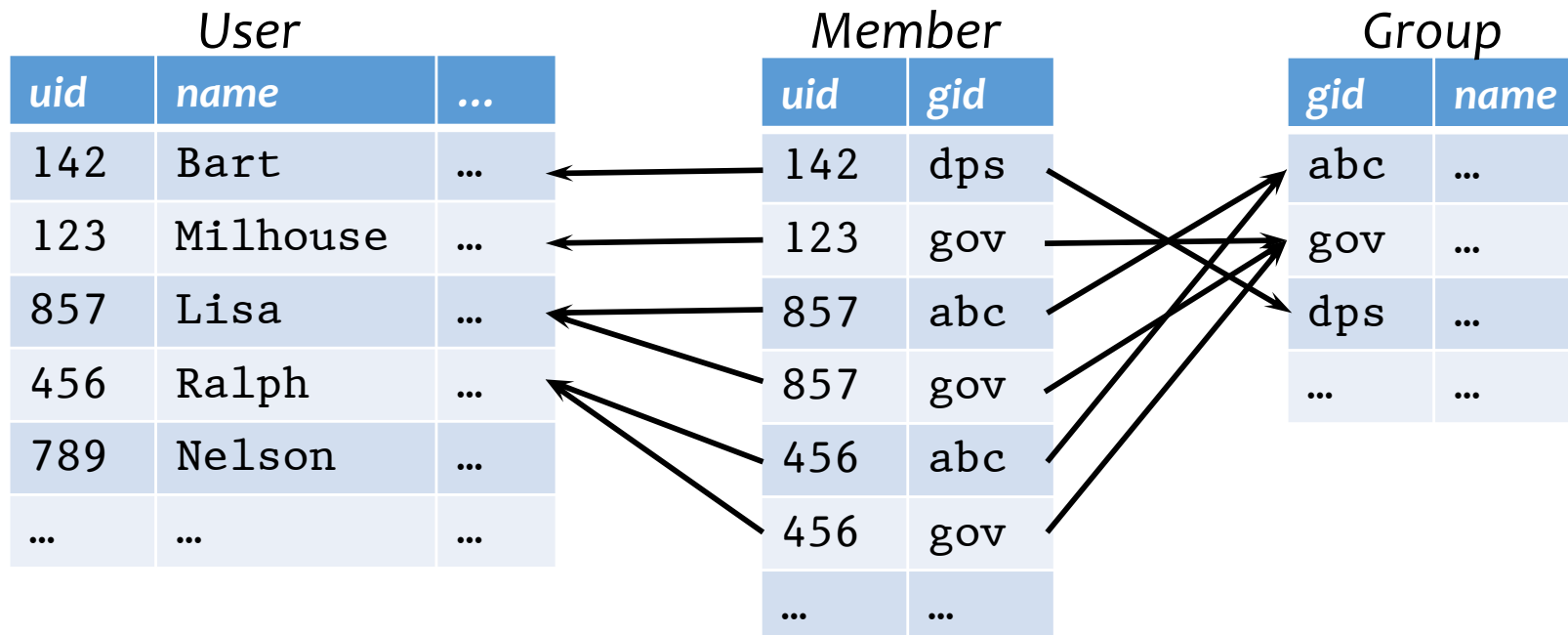


This form is required for multi-attribute keys

# Referential integrity example

- *Member.uid* references *User.uid*
  - If an *uid* appears in *Member*, it must appear in *User*
- *Member.gid* references *Group.gid*
  - If a *gid* appears in *Member*, it must appear in *Group*

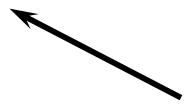
☞ That is, no “dangling pointers”



# Referential integrity in SQL

- Referenced column(s) must be PRIMARY KEY
- Referencing column(s) form a FOREIGN KEY
- Example

- ```
CREATE TABLE Member
(uid INTEGER NOT NULL
 REFERENCES User(uid),
gid CHAR(10) NOT NULL,
PRIMARY KEY(uid, gid),
FOREIGN KEY (gid) REFERENCES Group(gid));
```



This form is useful for multi-attribute foreign keys

Enforcing referential integrity

Example: *Member.uid* references *User.uid*

- Insert or update a *Member* row so it refers to a non-existent *uid*
 - **Reject**
- Delete or update a *User* row whose *uid* is referenced by some *Member* row
 - **Reject**
 - **Cascade**: ripple changes to all referring rows
 - **Set NULL**: set all references to NULL
 - All three options can be specified in SQL

Deferred constraint checking

- No-chicken-no-egg problem
 - `CREATE TABLE Dept`
 (`name` CHAR(20) NOT NULL PRIMARY KEY,
 `chair` CHAR(30) NOT NULL
 REFERENCES Prof(`name`));
 - `CREATE TABLE Prof`
 (`name` CHAR(30) NOT NULL PRIMARY KEY,
 `dept` CHAR(20) NOT NULL
 REFERENCES Dept(`name`));
 - The first INSERT will always violate a constraint!
- Deferred constraint checking is necessary
 - Check only at the end of a transaction
 - Allowed in SQL as an option
- Curious how the schema was created in the first place?
 - ALTER TABLE ADD CONSTRAINT (read the manual!)

General assertion

- `CREATE ASSERTION assertion_name
CHECK assertion_condition;`
 - *assertion_condition* is checked for each modification that could potentially violate it
 - Example: *Member.uid* references *User.uid*
 - `CREATE ASSERTION MemberUserRefIntegrity
CHECK (NOT EXISTS
 (SELECT * FROM Member
 WHERE uid NOT IN
 (SELECT uid FROM User)));`
- ☞ In SQL3, but not all (perhaps no) DBMS supports it

Tuple- and attribute-based CHECK's

- Associated with a single table
- Only checked when a tuple/attribute is inserted/updated
 - Reject if condition evaluates to FALSE
 - TRUE and UNKNOWN are fine
- Examples:
 - ```
CREATE TABLE User(...
 age INTEGER CHECK(age IS NULL OR age > 0),
 ...);
```
  - ```
CREATE TABLE Member  
(uid INTEGER NOT NULL,  
  CHECK(uid IN (SELECT uid FROM User)),  
  ...);
```

 - Is it a referential integrity constraint?
 - Not quite; not checked when *User* is modified

SQL features covered so far

- Query
 - SELECT-FROM-WHERE statements
 - Set and bag operations
 - Table expressions, subqueries
 - Aggregation and grouping
 - Ordering
 - Outerjoins
 - Modification
 - INSERT / DELETE / UPDATE
 - Constraints
- 👉 Next: triggers, views, indexes