SQL: Part II

Introduction to Databases

CompSci 316 Spring 2019

DUKE
COMPUTER SCIENCE

Announcements (Thu., Jan. 31)

- Homework #1 due next Tuesday (Feb 5) 11:59pm
    - Extra credit problems due on Feb 8 (Friday) 11:59 pm
    - Some bug in RATEST-problem f – same set of beers (to be fixed soon)

- Project mixer next Tuesday in class (first half, 2nd half regular lecture)
    - Presentation by Elliott Bolzan (your UTA) about their project in the last semester – do not miss it!
        - You will get an idea how much work and what output is expected
    - Please let me know by next Monday if you want to make a pitch in front of the class (to recruit teammates)!

- Sudeepa's office hours Wednesdays 1:30-2:30 pm, LSRC D325.

Project resources

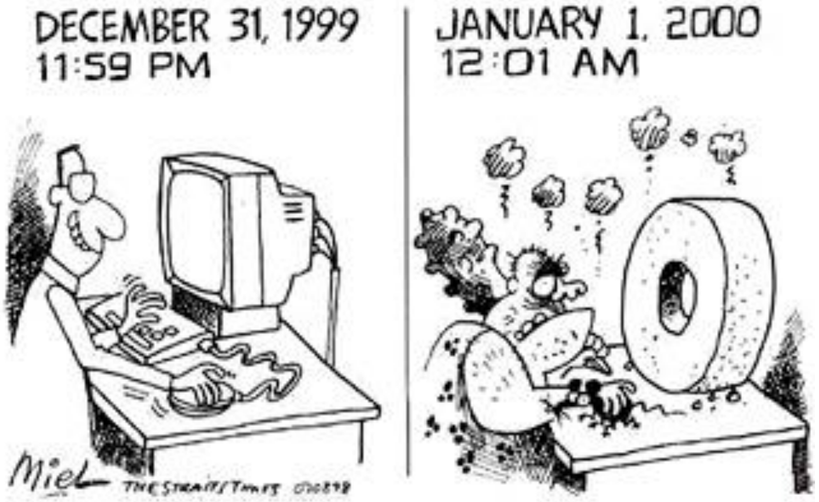
- Working web dev examples in PHP, Flask, and Play/Java for course VM
  - See "Help" on course website for more details
- Duke Co-Lab offerings
  - Many interesting "Roots" courses
    - Build Your First iPhone or iPad App, Making Your Website Interactive, Intro to React.js, Introduction to Linux, etc.
    - Advance registration required
  - Office hours on full-stack web/app development

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



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! Why?

SQL’s solution

- A special value NULL
    - For every domain
    - Special rules for dealing with NULL’s

- Example: *User* (*uid*, *name*, *age*, *pop*)
    - ⟨789, “Nelson”, NULL, NULL⟩

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)

Sum

A
5
10
null
6
null

= 21

count(*) = 5

count(A) = 3

Three-valued logic

where $(A \vee B) \wedge C = \text{true}$

$\vee$

1 0.5

A = True

B = null

C = null

$1 \wedge 0.5$

$= 0.5$

$\neq$ true

- TRUE = 1, FALSE = 0, UNKNOWN = 0.5
- x AND y = $\min(x, y)$
- x OR y = $\max(x, y)$
- 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

$x = 1$ · $x \wedge y = 0$

$y = 0$

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

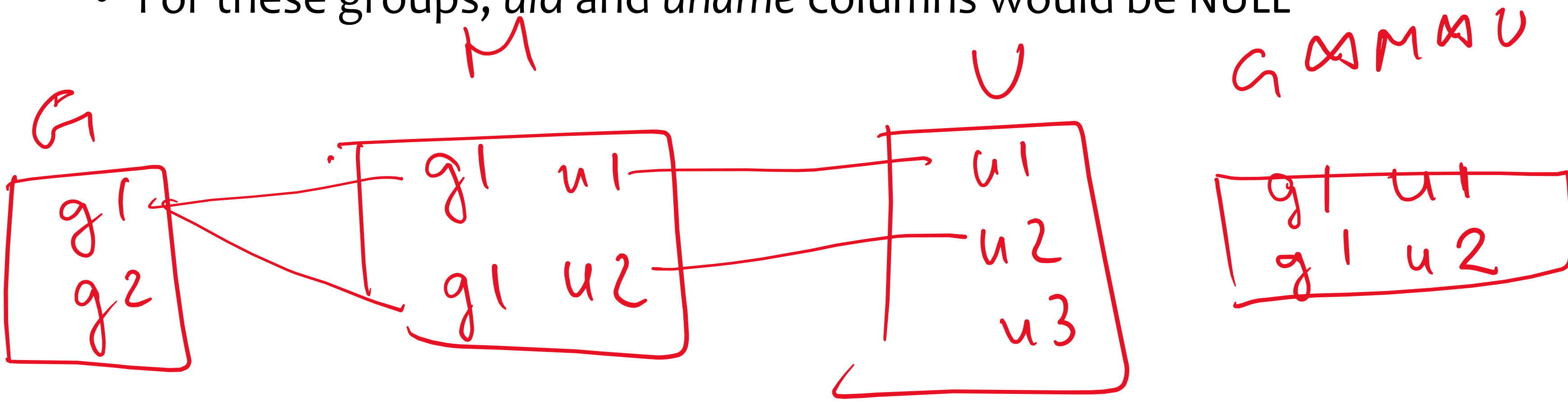
☞Be careful: NULL breaks many equivalences

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 $R ⟗ S$) includes all rows in the result of $R \bowtie S$, 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 ($R ⟕ S$) includes rows in $R \bowtie S$ plus dangling R rows padded with NULL's
- A right outerjoin ($R ⟖ S$) includes rows in $R \bowtie S$ plus dangling S rows padded with NULL's

Outerjoin examples

Group

gid	*name*
abc	Book Club
gov	Student Government
dps	Dead Putting Society
nuk	United Nuclear Workers

Member

uid	*gid*
142	dps
123	gov
857	abc
857	gov
789	foo

Group ⟕ *Member*

gid	*name*	*uid*
abc	Book Club	857
gov	Student Government	123
gov	Student Government	857
dps	Dead Putting Society	142
nuk	United Nuclear Workers	NULL

Group ⟖ *Member*

gid	*name*	*uid*
abc	Book Club	857
gov	Student Government	123
gov	Student Government	857
dps	Dead Putting Society	142
foo	NULL	789

Group ⟗ *Member*

gid	*name*	*uid*
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;

  $\approx Group \mathbin{⟕}_{Group.gid=Member.gid} Member$
- SELECT * FROM Group RIGHT OUTER JOIN Member
  ON Group.gid = Member.gid;

  $\approx Group \mathbin{⟖}_{Group.gid=Member.gid} Member$
- SELECT * FROM Group FULL OUTER JOIN Member
  ON Group.gid = Member.gid;

  $\approx Group \mathbin{⟗}_{Group.gid=Member.gid} Member$

☞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

key
superkey
primary key

- 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 ⇒ best speedup for queries
- Any number of UNIQUE keys per table
  - Typically implies a secondary index
  - Pointers to rows are stored inside the index ⇒ 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);
  ```

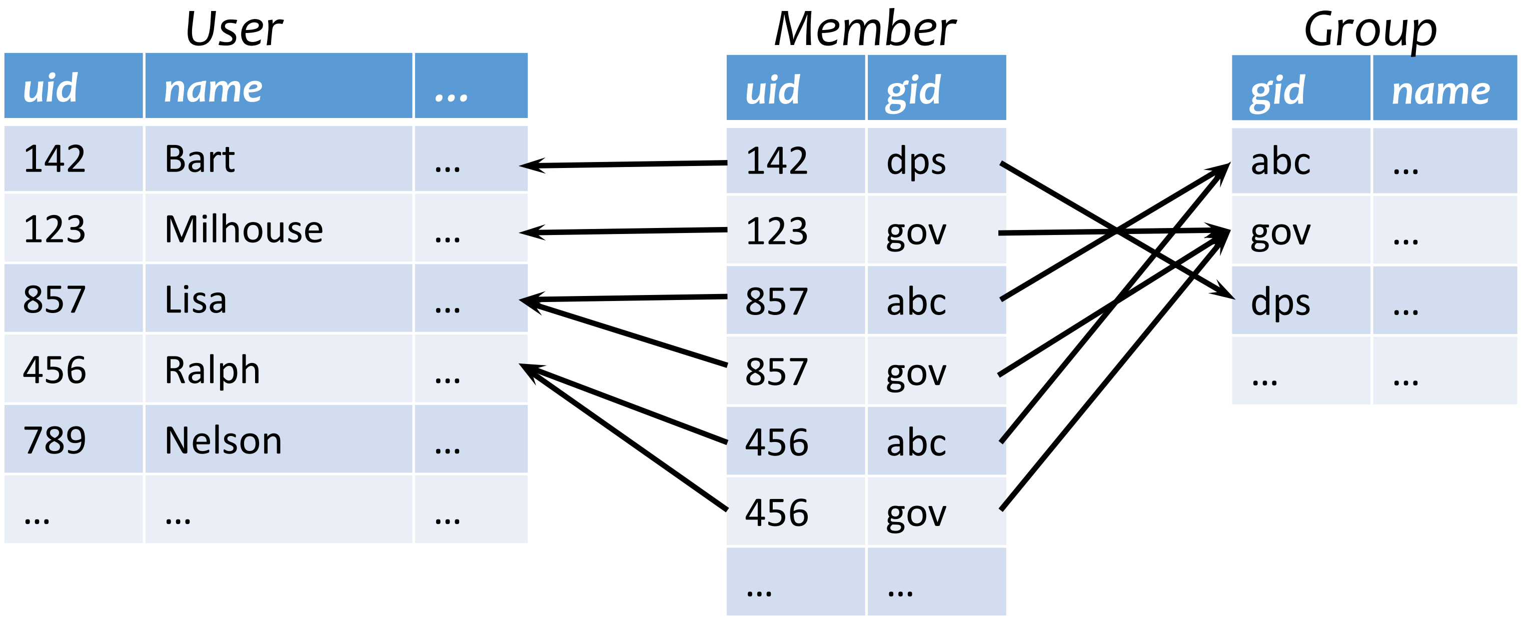
-
  ```
  CREATE TABLE Member
  (uid INTEGER NOT NULL,
   gid CHAR(10) NOT NULL,
   PRIMARY KEY(uid, gid));
  ```

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"



User

uid	*name*	…
142	Bart	…
123	Milhouse	…
857	Lisa	…
456	Ralph	…
789	Nelson	…
…	…	…

Member

uid	*gid*
142	dps
123	gov
857	abc
857	gov
456	abc
456	gov
…	…

Group

gid	*name*
abc	…
gov	…
dps	…
…	…

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