SQL: Part II

Introduction to Databases

CompSci 316 Fall 2017

DUKE
COMPUTER SCIENCE

Announcements (Thu., Sep. 21)

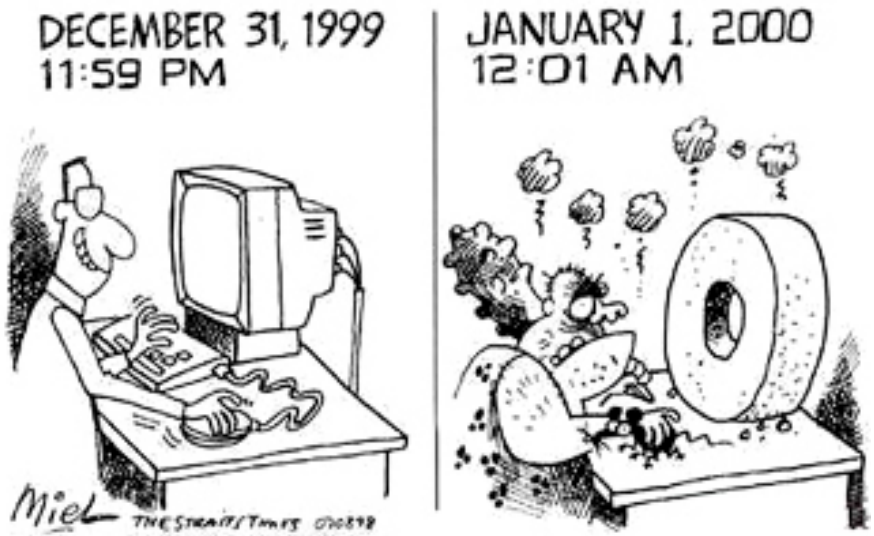
- Homework #1 sample solution to be posted on Sakai by this weekend
- Homework #2 due in 1½ weeks
- Get started on your project!
  - For ideas, check out project handout and examples from previous years (in intro lecture slides), and talk to us
  - Again, 5 is the expected team size
- Project mixer next Tuesday
  - Send me your elevator pitch slides by Monday midnight
  - See email for details

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?

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)

Three-valued logic

- 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

Unfortunate consequences

- `SELECT AVG(pop) FROM User;`
  `SELECT SUM(pop)/COUNT(*) FROM User;`

- `SELECT * FROM User;`
  `SELECT * FROM User WHERE pop = pop;`

☞ Be careful: `NULL` breaks many equivalences

Another problem

- Example: Who has NULL *pop* values?
  - `SELECT * FROM User WHERE pop = NULL;`
  - `(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;`
  - $\approx Group \overset{}{\underset{Group.gid=Member.gid}{\bowtie}} Member$
- `SELECT * FROM Group RIGHT OUTER JOIN Member ON Group.gid = Member.gid;`
  - $\approx Group \overset{}{\underset{Group.gid=Member.gid}{\bowtie}} Member$
- `SELECT * FROM Group FULL OUTER JOIN Member ON Group.gid = Member.gid;`
  - $\approx Group \overset{}{\underset{Group.gid=Member.gid}{\bowtie}} Member$

☞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

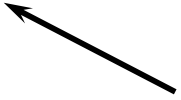
- ```
  CREATE TABLE User
  (uid INTEGER NOT NULL,
   name VARCHAR(30) NOT NULL,
   twitterid VARCHAR(15) NOT NULL,
   age INTEGER,
   pop FLOAT);
  ```
- ```
  CREATE TABLE Group
  (gid CHAR(10) NOT NULL,
   name VARCHAR(100) NOT NULL);
  ```
- ```
  CREATE TABLE Member
  (uid INTEGER NOT NULL,
   gid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

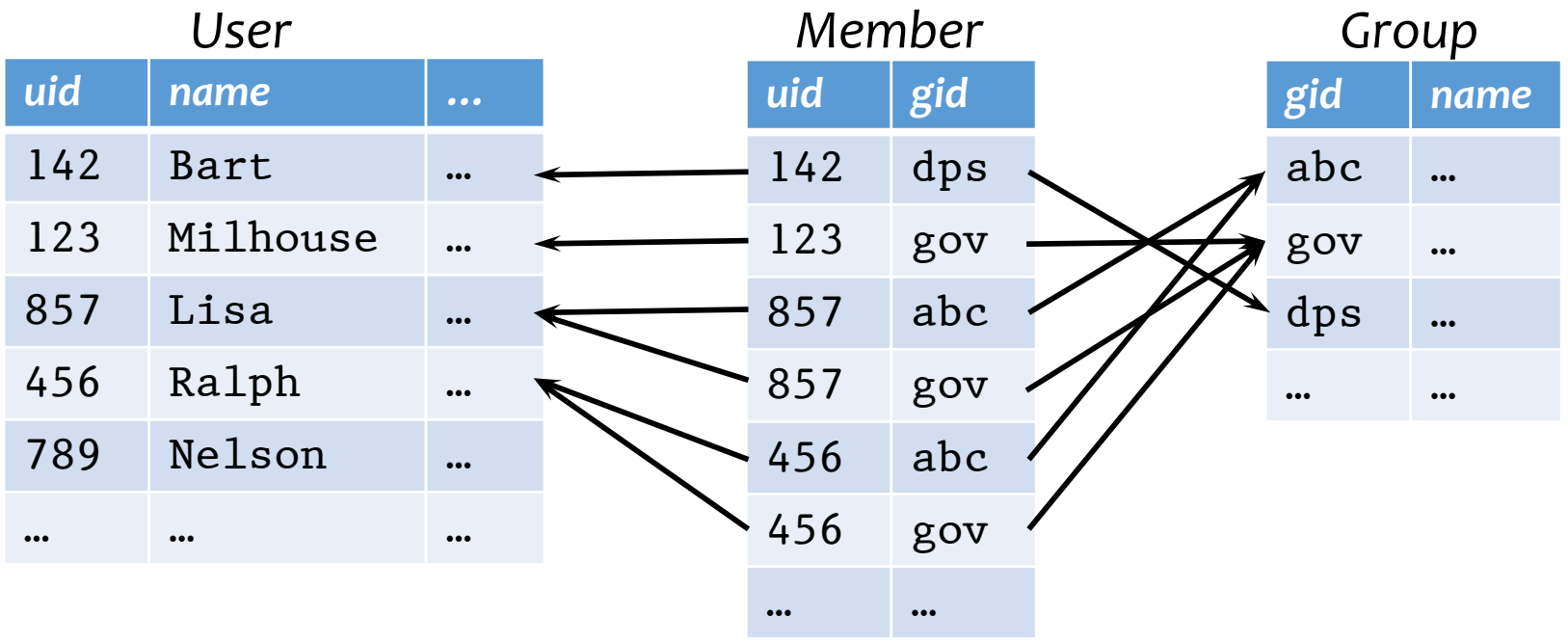


This form is required for multi-attribute keys
  ```

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"



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));
    ```
    ```

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));
    ```
- 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