# SQL: Part II

Introduction to Databases

CompSci 316 Fall 2014

DUKE
COMPUTER SCIENCE

# Announcements (Thu., Sep. 18)

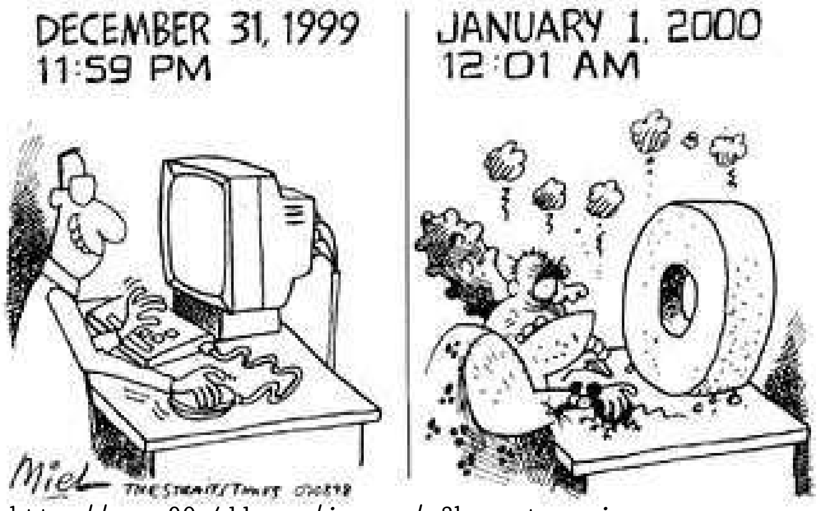
- Homework #1 sample solution to be posted on Sakai by tomorrow
- We are working on resolving the `websumbit` issue
  - Use Chrome and IE for now
- Homework #2 due in two weeks

# 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`<br>`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*,<br>*age*, *age_is_valid*,<br>*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*)
  - ⟨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;`
  - 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
    - 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 classes, *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;
```

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

☞These are theta joins rather than natural joins

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

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

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

# 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);
  ```

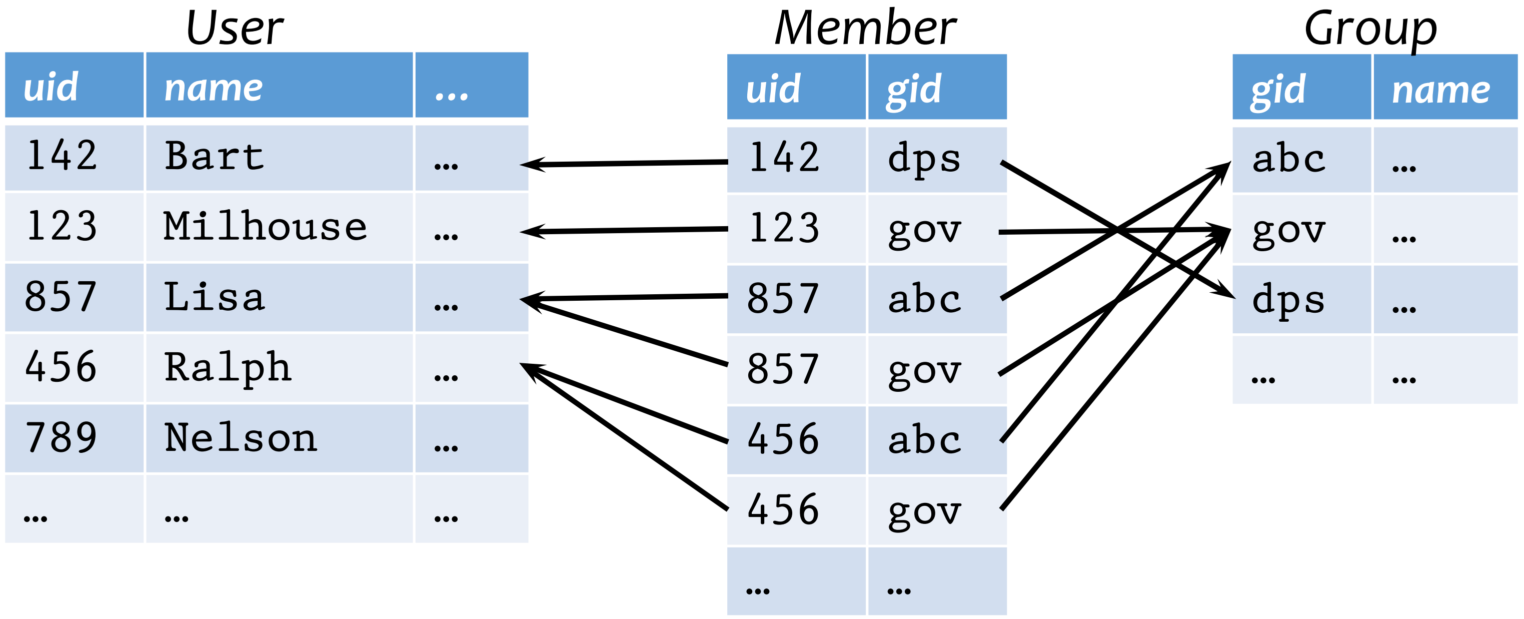
-
  ```
  CREATE TABLE Member
  (uid INTEGER NOT NULL,
   gid CHAR(10) NOT NULL,
   PRIMARY KEY(uid, gid));
  ```

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"



*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));
    ```

# 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 or an attribute is inserted or updated
- 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