SQL: Part II

CompSci 316

Introduction to Database Systems

Announcements (Tue. Sep. 18)

- Homework #2 assigned today
  - Due on Thu. Oct. 4 (in a little more than 2 weeks)
  - Again, a long homework—start early!
- Project idea session next Tue.
  - Send me 1-2 slides by this weekend if you want to pitch your idea to the class
- Midterm (Thu. Oct. 11) right before fall break
- Project milestone 1 due right after fall break

Incomplete information

- Example: *Student* (*SID*, *name*, *age*, *GPA*)
- Value unknown
  - We do not know Nelson's age
- Value not applicable
  - Nelson has not taken any classes yet; what is his GPA?

Solution 1

- Dedicate a value from each domain (type)
  - GPA cannot be −1, so use −1 as a special value to indicate a missing or invalid GPA
  - Leads to incorrect answers if not careful
    - `SELECT AVG(GPA) FROM Student;`
  - Complicates applications
    - `SELECT AVG(GPA) FROM Student WHERE GPA <> -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

Solution 2

- A valid-bit for every column
  - *Student* (*SID*, *name*, *name_is_valid*, *age*, *age_is_valid*, *GPA*, *GPA_is_valid*)
  - Complicates schema and queries
    - `SELECT AVG(GPA) FROM Student WHERE GPA_is_valid;`

Solution 3?

- Decompose the table; missing row = missing value
  - *StudentName* (*SID*, *name*)
    StudentAge (*SID*, *age*)
    StudentGPA (*SID*, *GPA*)
  - *StudentID* (*SID*)
  - Conceptually the cleanest solution
  - Still complicates schema and queries
    - How to get all information about a student in a table?
    - Natural join doesn't work!

SQL's solution

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- A special value NULL
  - For every domain
  - Special rules for dealing with NULL's
- Example: *Student* (*SID*, *name*, *age*, *GPA*)
  - ⟨789, "Nelson", NULL, NULL⟩

Computing with NULL's

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- 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

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- 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

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- ```
  SELECT AVG(GPA) FROM Student;
  SELECT SUM(GPA)/COUNT(*) FROM Student;
  ```
  - Not equivalent
  - Although AVG(GPA) = SUM(GPA)/COUNT(GPA) still
- ```
  SELECT * FROM Student;
  SELECT * FROM Student WHERE GPA = GPA;
  ```
  - Not equivalent

☞ Be careful: NULL breaks many equivalences

Another problem

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

Outerjoin motivation

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- Example: a master class list
  - ```
    SELECT c.CID, c.title, s.SID, s.name
    FROM Course c, Enroll e, Student s
    WHERE c.CID = e.CID AND e.SID = s.SID;
    ```
  - What if a class is empty?
  - It may be reasonable for the master class list to include empty classes as well
    - For these classes, *SID* and *name* columns would be NULL

Outerjoin flavors and definitions

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- A full outerjoin between R and S (denoted $R \bowtie\!\!\!\!\!\!\bowtie S$) 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 ($R \bowtie\!\!\!\!\!\!\bowtie S$) includes rows in $R \bowtie S$ plus dangling R rows padded with NULL's
- A right outerjoin ($R \bowtie\!\!\!\!\!\!\bowtie S$) includes rows in $R \bowtie S$ plus dangling S rows padded with NULL's

Outerjoin examples

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Course ⟗ *Enroll*

CID	title	SID
CPS391	Independent Study	NULL
CPS330	Analysis of Algorithms	857
CPS316	Intro. to Database Systems	142
CPS316	Intro. to Database Systems	857
CPS316	Intro. to Database Systems	456

Course

CID	title
CPS391	Independent Study
CPS330	Analysis of Algorithms
CPS316	Intro. to Database Systems

Enroll

SID	CID
142	CPS316
142	CPS310
123	CPS310
857	CPS316
857	CPS330
456	CPS316

Course ⟕ *Enroll*

CID	title	SID
CPS316	Intro. to Database Systems	142
CPS310	NULL	142
CPS310	NULL	123
CPS316	Intro. to Database Systems	857
CPS330	Analysis of Algorithms	857
CPS316	Intro. to Database Systems	456

Course ⟖ *Enroll*

CID	title	SID
CPS391	Independent Study	NULL
CPS316	Intro. to Database Systems	142
CPS310	NULL	142
CPS310	NULL	123
CPS316	Intro. to Database Systems	857
CPS330	Analysis of Algorithms	857
CPS316	Intro. to Database Systems	456

Outerjoin syntax

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- `SELECT * FROM Course LEFT OUTER JOIN Enroll ON Course.CID = Enroll.CID;`
- `SELECT * FROM Course RIGHT OUTER JOIN Enroll ON Course.CID = Enroll.CID;`
- `SELECT * FROM Course FULL OUTER JOIN Enroll ON Course.CID = Enroll.CID;`

☞ These are theta joins rather than natural joins

- Return all columns in *Course* and *Enroll*
- Equivalent to $Course \bowtie_{Course.CID=Enroll.CID} Enroll$, $Course \bowtie\!\!\!\!\!\!\bowtie_{Course.CID=Enroll.CID} Enroll$, and $Course \bowtie\!\!\!\!\!\!\bowtie_{Course.CID=Enroll.CID} Enroll$

☞ You can write regular ("inner") joins using this syntax too:
`SELECT * FROM Course JOIN Enroll ON Course.CID = Enroll.CID;`

Summary of SQL features covered so far

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- 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

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- Insert one row
  - `INSERT INTO Enroll VALUES (456, 'CPS316');`
    - Student 456 takes CPS316
- Insert the result of a query
  - ```
    INSERT INTO Enroll
    (SELECT SID, 'CPS316' FROM Student
     WHERE SID NOT IN (SELECT SID FROM Enroll
                       WHERE CID = 'CPS316'));
    ```
    - Force everybody to take CPS316

DELETE

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- Delete everything
  - `DELETE FROM Enroll;`
- Delete according to a WHERE condition

  Example: Student 456 drops CPS316
  - ```
    DELETE FROM Enroll
    WHERE SID = 456 AND CID = 'CPS316';
    ```

  Example: Drop students from all CPS classes with GPA lower than 1.0
  - ```
    DELETE FROM Enroll
    WHERE SID IN (SELECT SID FROM Student
                  WHERE GPA < 1.0)
    AND CID LIKE 'CPS%';
    ```
    ```

UPDATE

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- Example: Student 142 changes name to "Barney"
  - `UPDATE Student`
    `SET name = 'Barney'`
    `WHERE SID = 142;`
- Example: Let's be "fair"?
  - `UPDATE Student`
    `SET GPA = (SELECT AVG(GPA) FROM Student);`
    - But won't update of every row causes average GPA to change?
    - ☞Subquery is always computed over the old table

Constraints

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- 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

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

NOT NULL constraint examples

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```
CREATE TABLE Student
  (SID INTEGER NOT NULL,
   name VARCHAR(30) NOT NULL,
   email VARCHAR(30),
   age INTEGER,
   GPA FLOAT);
CREATE TABLE Course
  (CID CHAR(10) NOT NULL,
   title VARCHAR(100) NOT NULL);
CREATE TABLE Enroll
  (SID INTEGER NOT NULL,
   CID CHAR(10) NOT NULL);
```

Key declaration

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- 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

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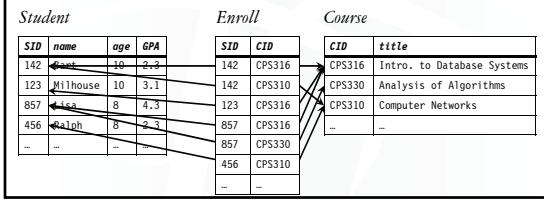
```
CREATE TABLE Student
  (SID INTEGER NOT NULL PRIMARY KEY,
   name VARCHAR(30) NOT NULL,
   email VARCHAR(30) UNIQUE,
   age INTEGER,
   GPA FLOAT);
CREATE TABLE Course
  (CID CHAR(10) NOT NULL PRIMARY KEY,
   title VARCHAR(100) NOT NULL);
CREATE TABLE Enroll
  (SID INTEGER NOT NULL,
   CID CHAR(10) NOT NULL,
   PRIMARY KEY(SID, CID));
```

↑ This form is required for multi-attribute keys

Referential integrity example

- *Enroll.SID* references *Student.SID*
  - If an SID appears in *Enroll*, it must appear in *Student*
- *Enroll.CID* references *Course.CID*
  - If a CID appears in *Enroll*, it must appear in *Course*
- ☞ 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 Enroll
  (SID INTEGER NOT NULL
    REFERENCES Student(SID),
   CID CHAR(10) NOT NULL,
   PRIMARY KEY(SID, CID),
   FOREIGN KEY CID REFERENCES Course(CID));
```

Enforcing referential integrity

Example: *Enroll.SID* references *Student.SID*

- Insert or update an *Enroll* row so it refers to a non-existent SID
  - Reject
- Delete or update a *Student* row whose SID is referenced by some *Enroll* 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: *Enroll.SID* references *Student.SID*

```
CREATE ASSERTION EnrollStudentRefIntegrity
CHECK (NOT EXISTS
        (SELECT * FROM Enroll
         WHERE SID NOT IN
         (SELECT SID FROM Student)));
```

- ☞ 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
- Example:

```
CREATE TABLE Enroll
(SID INTEGER NOT NULL
     CHECK (SID IN (SELECT SID FROM Student)),
 CID ...);
```

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

Summary of 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: recursion