SQL: Part II

CPS 116

Introduction to Database Systems

Announcements (September 19)

- Homework #1 due today (11:50pm)
  - Submit in class, or slide it underneath my office door
  - Sample solution available Thursday
- Homework #2 assigned today
  - Due next Thursday
- Project milestone #1 due in 23 days
- Tomcat/DB2 combo is working on `rack040`; see *Programming Notes* on Web for how to use it for your course project

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

- A dedicated special value for 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;`
  - Remember 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?

SQL's solution

- 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

- 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(GPA) FROM Student;`
  `SELECT SUM(GPA)/COUNT(*) FROM Student;`

- `SELECT * FROM Student;`
  `SELECT * FROM Student WHERE GPA = GPA;`

☞ Be careful: NULL breaks many equivalences

Another problem

- Example: Who has NULL GPA values?
  - `SELECT * FROM Student WHERE GPA = NULL;`
  -
  - Introduced built-in predicates IS NULL and IS NOT NULL
    - `SELECT * FROM Student WHERE GPA IS NULL;`

Outerjoin motivation

- 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

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

Outerjoin examples

Course

CID	*title*
CPS199	Independent Study
CPS130	Analysis of Algorithms
CPS114	Computer Networks

Enroll

SID	*CID*
142	CPS196
142	CPS114
123	CPS196
857	CPS196
857	CPS130
456	CPS114

Course $\leftrightarrow\!\!\bowtie\!\!\leftrightarrow$ *Enroll*

CID	*title*	*SID*
CPS199	Independent Study	NULL
CPS130	Analysis of Algorithms	857
CPS114	Computer Networks	142
CPS114	Computer Networks	456

Course $\bowtie\!\!\leftrightarrow$ *Enroll*

CID	*title*	*SID*
CPS196	NULL	142
CPS114	Computer Networks	142
CPS196	NULL	123
CPS196	NULL	857
CPS130	Analysis of Algorithms	857
CPS114	Computer Networks	456

Course $\bowtie$ *Enroll*

CID	*title*	*SID*
CPS199	Independent Study	NULL
CPS130	Analysis of Algorithms	857
CPS114	Computer Networks	142
CPS114	Computer Networks	456
CPS196	NULL	142
CPS196	NULL	123
CPS196	NULL	857

Outerjoin syntax

```
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 $Course \bowtie_{Course.CID = Enroll.CID} Enroll$, $Course \leftrightarrow\!\!\bowtie\!\!\leftrightarrow_{Course.CID = Enroll.CID} Enroll$, and $Course \leftrightarrow\!\!\bowtie_{Course.CID = Enroll.CID} Enroll$
- 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

- 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 Enroll VALUES (456, 'CPS116');`
    - Student 456 takes CPS116
- Insert the result of a query
  - ```
    INSERT INTO Enroll
    (SELECT SID, 'CPS116' FROM Student
     WHERE SID NOT IN (SELECT SID FROM Enroll
                       WHERE CID = 'CPS116'));
    ```
    - Force everybody to take CPS116

DELETE

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

  Example: Student 456 drops CPS116
  - ```
    DELETE FROM Enroll
    WHERE SID = 456 AND CID = 'CPS116';
    ```

  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

- 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 update of every row causes average GPA to change!
    - Average GPA is computed over the old `Student` 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 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

- 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

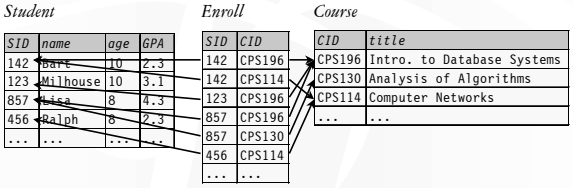
- CREATE TABLE Student
  (SID INTEGER NOT NULL PRIMARY KEY,
   name VARCHAR(30) NOT NULL,
   email VARCHAR(30) UNIQUE,
   age INTEGER,
   GPA FLOAT);
- CREATE TABLE Course
  (CID CHAR(10) NOT NULL PRIMARY KEY,
   title VARCHAR(100) NOT NULL);
- CREATE TABLE Enroll
  (SID INTEGER NOT NULL,
   CID CHAR(10)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

Doesn't work on DB2: DB2 requires UNIQUE key columns to be NOT NULL

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
- Delete or update a *Student* row whose SID is referenced by some *Enroll* row
  - 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: *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?
    ```

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: triggers, views, indexes