SQL: Part II

CPS 116

Introduction to Database Systems

Announcements (Thu. Sep. 22)

- Homework #2 assigned today
  - Due on Tue. Oct. 4 (in less than 2 weeks)
- Midterm in class in 2 weeks
- Project milestone 1 due in 3 weeks

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;`
  - 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?

SQL's solution

7

- 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

8

- 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

9

- 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

10

- `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

11

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

Outerjoin motivation

12

- 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

13

- 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

14

Course

CID	title
CPS199	Independent Study
CPS130	Analysis of Algorithms
CPS116	Intro. to Database Systems

Enroll

SID	CID
142	CPS116
142	CPS114
123	CPS114
857	CPS116
857	CPS130
456	CPS116

Course ⟗ *Enroll*

CID	title	SID
CPS199	Independent Study	NULL
CPS130	Analysis of Algorithms	857
CPS116	Intro. to Database Systems	142
CPS116	Intro. to Database Systems	857
CPS116	Intro. to Database Systems	456

Course ⟕ *Enroll*

CID	title	SID
CPS116	Intro. to Database Systems	142
CPS114	NULL	142
CPS114	NULL	123
CPS116	Intro. to Database Systems	857
CPS130	Analysis of Algorithms	857
CPS116	Intro. to Database Systems	456

Course ⟖ *Enroll*

CID	title	SID
CPS199	Independent Study	NULL
CPS116	Intro. to Database Systems	142
CPS114	NULL	142
CPS114	NULL	123
CPS116	Intro. to Database Systems	857
CPS130	Analysis of Algorithms	857
CPS116	Intro. to Database Systems	456

Outerjoin syntax

15

- `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

16

- 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

17

- 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

18

- 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

19

- 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

20

- 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

21

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

NOT NULL constraint examples

22

- 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

23

- 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

24

- 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));

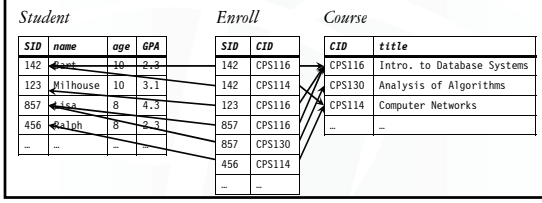
This form is required for multi-attribute keys

Referential integrity example

25

- *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

26

- 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

27

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
    ```

Deferred constraint checking

28

- 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

29

- `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

30

- 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

31

- Query
  - `SELECT-FROM-WHERE` statements
  - Set and bag operations
  - Table expressions, subqueries
  - Aggregation and grouping
  - Ordering
  - Outerjoins
- Modification
  - `INSERT/DELETE/UPDATE`
- Constraints
- Next: recursion
  - SQL programming & transactions will be covered after we take a detour with XML